LITTLE SCIENTISTS: IDENTITY, SELF-EFFICACY, AND ATTITUDES TOWARD SCIENCE IN A GIRLS' SCIENCE CAMP

by

BRANDY TODD

A DISSERTATION

Presented to the Department of Educational Methodology, Policy, and Leadership
and the Graduate School of the University of Oregon
in partial fulfillment of the requirements
for the degree of
Doctor of Philosophy

December 2015

DISSERTATION APPROVAL PAGE

Student: Brandy Todd

Title: Little Scientists: Identity, Self-Efficacy, and Attitudes Toward Science in a Girls' Science Camp

This dissertation has been accepted and approved in partial fulfillment of the requirements for the Doctor of Philosophy degree in the Department of Educational Methodology, Policy, and Leadership by:

Keith Zvoch	Chair
Charles Martinez	Core Member
Joanna Smith	Core Member
Joanna Goode	Institutional Representative

and

Scott L. Pratt	Dean of the Graduate School

Original approval signatures are on file with the University of Oregon Graduate School.

Degree awarded December 2015

DISSERTATION ABSTRACT

Brandy Todd

Doctor of Philosophy

Department of Educational Methodology, Policy, and Leadership

December 2015

Title: Little Scientists: Identity, Self-Efficacy, and Attitude Toward Science in a Girls' Science Camp

Underrepresentation of women and minorities in the science, technology, and engineering (STEM) fields is a perennial concern for researchers and policy-makers. Many causes of this problem have been identified. Less is known about what constitutes effective methods for increasing women's participation in STEM. This study examines the role that identity formation plays in encouraging girls to pursue STEM education and careers utilizing data from a cohort-based, informal science enrichment program that targets middle-school-aged girls. A Mixed-methods design was employed to examine girls' science interests, efficacy, attitudes, and identity—referred to as *affinities*. Quantitative data were collected before and after program participation using science affinity scales. Qualitative data included observations, focus groups, and individual interviews. This study builds on past research conducted on the same program. The study is presented in three components: fidelity of implementation, participant affinities, and science identity theory building. Quantitative and qualitative measures reveal that the program was implemented with high fidelity. Participants had high initial affinities for science as compared to a contrast group. Analysis of qualitative data of science affinities revealed several themes in girls' attitudes, experiences, and intentions toward science.

Emergent themes discussed include girls' preferences and interests in science, gender and science efficacy, attitudes toward science, and elements of science identities. Archetypes of emergent science identities developed in this study (*expert*, *experimenter*, and *inventor*) inform different ways in which girls engage with and envision science study and careers. Implications for best practice in fostering science engagement and identities in middle-school-aged girls include the importance of hands-on science activities, the need for enthusiastic relatable role models, and an emphasis on deep understanding of scientific principles.

CURRICULUM VITAE

NAME OF AUTHOR: Brandy Todd

GRADUATE AND UNDERGRADUATE SCHOOLS ATTENDED:

University or Oregon, Eugene

DEGREES AWARDED

Doctor of Philosophy, Educational Leadership, 2015, University of Oregon
Master of Public Administration, 2010, University of Oregon
Bachelor of Science, Sociology & Political Science, 2001, University of Oregon

AREAS OF SPECIAL INTEREST:

Informal Science Education
Science & Educational Policy

PROFESSIONAL EXPERIENCE

Assistant Director, Oregon Center for Optics, University of Oregon, Eugene, OR 2006–present
Director, SPICE Program, University of Oregon, 2008–present

GRANTS, AWARDS, AND HONORS

Center for the Study of Women in Society Research Grant, 2014–2015
David Bussman Scholarship, College of Education, 2014
Travel Grant, Department of Educational Methodology, Policy and Leadership, 2014
Evaluating the Science Program to Inspire Creativity and Excellence, College of Arts and Sciences, 2013–2014
Resources for the Science Program to Inspire Creativity and Excellence, International Society of Photonics, 2013
Supporting the Seasons of Science: Resources for the Science Program to Inspire Creativity & Excellence, Office of Institutional Equity and Diversity, 2012
Laserfest: SPICE and 50 Years of the Laser, American Physical Society, 2010
Pi Alpha Alpha Honor Society Member, 2010
Magna cum Laude, University of Oregon, 2001

ACKNOWLEDGMENTS

Thanks to Professor Zvoch and Lecturer Smith for their guidance in preparing this manuscript. Thanks also to Professors Martinez and Goode for their good advice. Thanks to Professor Deutsch for her continued encouragement. I also thank the Center for the Study of Women in Society for financial support of this research.

To my parents, for laughing at my jokes and not my dreams.
To my husband, for encouraging (or at least tolerating) all my harebrained schemes.
To my son, for being an irredeemable smart aleck.
To my Jen for always saying "YES!"

To every nine-year old girl who dreamed (or will dream) of scary mansions, Tesla coils, Bunsen burners, and electron microscopes . . . never stop practicing that evil mad scientist laugh.

TABLE OF CONTENTS

Chapter Page

LIST OF FIGURES

Figure Page

Figure Page

LIST OF TABLES

Table Page

Table Page

CHAPTER I

INTRODUCTION

The underrepresentation of women and minorities in the disciplines of science, technology, engineering, and mathematics (STEM) has been characterized as an intractable problem (Bayer Corporation, 2010; Corbett & Hill, 2015; Hill, Corbett, & St. Rose, 2010). Despite 30 years of attention, women have made little ground in the STEM disciplines (Corbett & Hill, 2015; Kelly, 1981; Saraga & Griffiths, 1981; Xu, 2008). The lack of progress is particularly problematic given that women now outnumber men in college enrollment (United States Census Bureau, 2011a) and in degrees earned (United States Census Bureau, 2011b). The overall increase of women in higher education, however, has not led to the equal inclusion of women in the STEM disciplines.

The Numbers: Where Women Stand in STEM Careers

The percentage of workers in select STEM occupations who identify as women is notably small (see figure 1). In all STEM occupations except biological sciences, women hold well under half of the jobs. The occupations presented represent a range of STEM disciplines and are indicative of the larger patterns in women's STEM employment. The majority of these positions require a bachelor's degree, and many require a master's degree or higher as the occupational standard (Burning Glass, 2014; Minnesota State Colleges and Universities, 2015; National Science Board, 2014a). Women are represented the most in sciences related to life processes such as biology and chemistry. Their participation drops well below half in the physical, mathematical, and computational sciences (see figure 1).

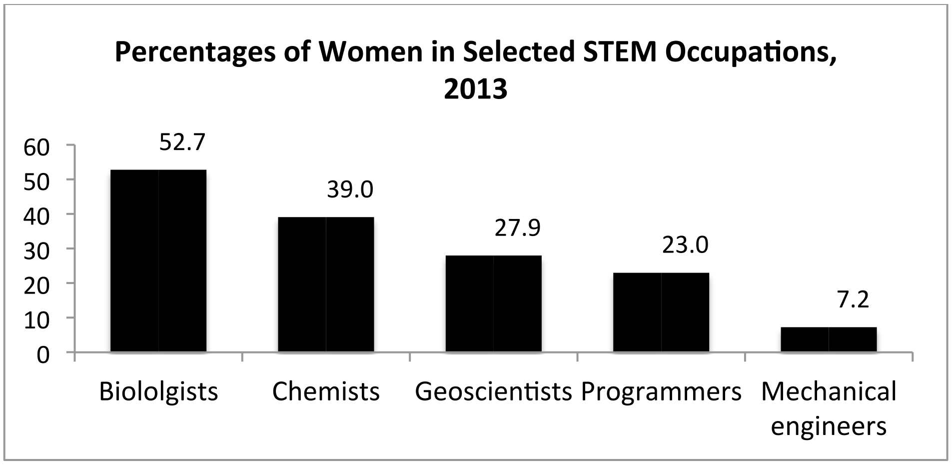


Figure 1. Women in a selection of representative STEM occupations as a percentage of all workers in that occupation (U.S. Depatment of Labor, Bureau of Labor Statistics, 2014).

Though low overall, the current number of women in STEM occupations represents a substantial increase from women's representation in STEM careers dating back to the 1960s (see figure 2). Generally, the trend is for the proportion of women in these careers to increase; however, some—physicists and astronomers—have begun to flatten out well before reaching parity and others—mathematical and computer scientists—have actually declined in recent years. Further, women remain vastly underrepresented in engineering.

Even in disciplines where the trend has been for the proportion of women to increase, these gains are not commensurate with the gains in educational achievement women have accomplished (Kulis, Sicotte, & Collins, 2002). In academia, women remain underrepresented among tenured faculty both in absolute numbers and in terms of the number of well-prepared women and girls available at each earlier stage of STEM education and careers (Kulis et al., 2002).

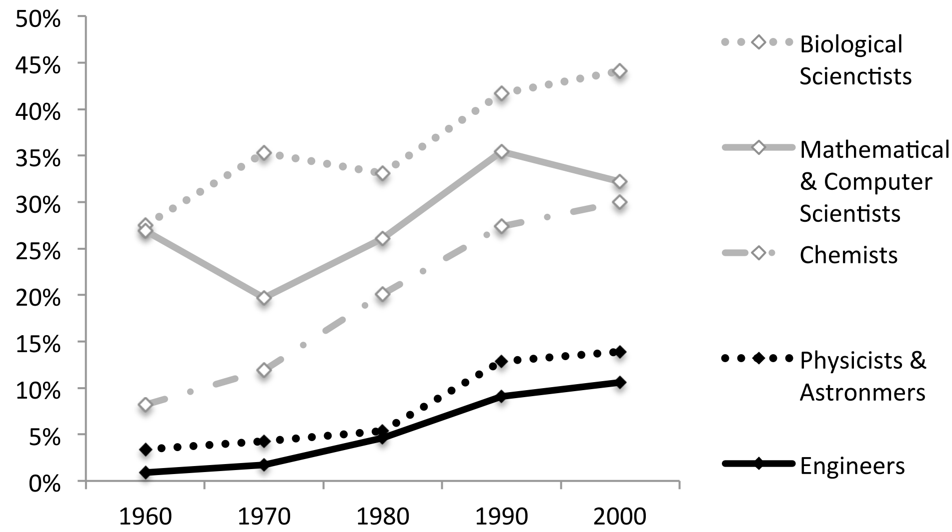


Figure 2. Women in select STEM occupations as a percentage of all workers (Hill et al., 2010). Trends from the 1960s to the 1990s were generally upward and steady. Since the 1990s increases have slowed, stalled, or reversed in most STEM fields.

In the corporate world women also experience greater rates of attrition from STEM careers than both their male counterparts and women pursuing careers in non-STEM disciplines (Hewlett et al., 2008; Simard, Henderson, Gilmartin, Scheibinger, & Whitney, 2008). Hewlett et al. (2008) found that women in science, engineering, and technological fields are fairly well represented at private firms, with women comprising 41% of early career professionals. However, they leave those jobs midcareer (after 10 years or less) at much higher rates than their male colleagues, 52% to 17%, respectively. The study of 6,000 engineers who earned degrees between 1985 and 2003 showed that 25% of the women, compared to 10% of the men, were not employed in engineering or a related field.

Differential attrition from STEM careers has been attributed to a number of social and cultural factors. The demanding nature of STEM careers and desires for family are perennial explanations supplied by and to individuals both inside and outside of STEM (Chen & Soldner, 2013; Ulriksen, Madsen, & Holmegaard, 2010; Xu, 2008). Recent research, however, suggests this explanation is far too simplistic, finding that compared to professional women in other disciplines, STEM career women are not leaving work for commonly cited reasons (working conditions, hours, flexibility) any more than non-STEM professional women. Rather, women are leaving STEM for undefined workplace dissatisfaction, likely related to climate, isolation, lack of peers and mentors, and the attitudes and expectations of more "traditional" colleagues (Glass, Sassler, Levitte, & Michelmore, 2013).

Attrition from STEM careers does not just happen postgraduation; it occurs throughout the STEM training pipeline. STEM careers involve a number of educational and professional milestones. For example, a career as a tenured academic STEM researcher, considered the gold standard in most STEM disciplines, involves multiple degrees and traineeships. Key milestones along this trajectory include a bachelor's degree, graduate degrees (typically Ph.D.), postdoctoral fellowships, and tenure-track assistant professor positions at research universities, prior to achieving status as a tenured professor.

As figure 3 illustrates, women now outnumber men in the attainment of undergraduate degrees in both the biological and psychological sciences. However, many of the women who earn degrees in these fields become nurses, physicians, and clinical psychologists (Hill et al., 2010). Women who are studying biological and psychological sciences as a precursor to careers in the medical and mental health professions are not part of the traditional STEM pipeline (National Science Board, 2010). Therefore, the numbers reported overrepresent women's participation in STEM education at the bachelor's and graduate degree levels and explain part of the precipitous drop in female participation in the biological and psychological disciplines between the graduate and postdoctoral levels. Though women have gained ground in the life sciences, they remain underrepresented at the top levels of the life science professions (Marschke, Laursen, McCarl Nielsen, & Rankin, 2007) and earn less than their male peers in these fields (Hill et al., 2010). In the physical sciences, representation of women at the graduate level, an important milestone in science careers, hovers around 20% (National Science Foundation, 2011b).

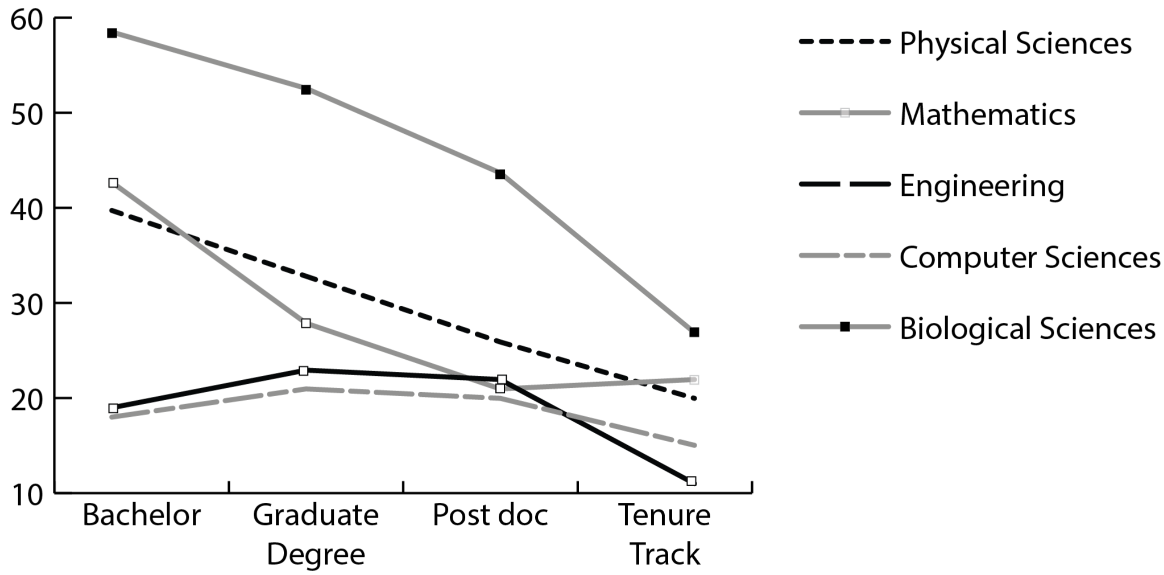


Figure 3. Women holding STEM degrees/positions as percentage of total (National Science Board, 2014b, 2014c, 2014d; National Science Foundation, 2011a).

Though the trend for women in STEM has been generally upward for the last 50 years (as noted above), some gains have actually been lost in the last few decades (see figure 1). Since the 1980s the proportion of women earning computer science degrees has dropped from 36% to 20% overall, and both the number and proportion of female physics postdoctoral fellows has been on the decline since 2000 (National Science Foundation & Division of Science Resources and Statistics, 2008). The disproportionate attrition of women from STEM education and careers is so ubiquitous among STEM practitioners and educators that it is often simply referred to as "the leaky pipeline." The leaky pipeline is nearly universally attributed as the major source of the underrepresentation of women in mature STEM careers. The origin of the term is unknown; however, addressing pipeline issues is a major identified priority for a variety of STEM groups and agencies including all the major STEM professional organizations, the National Science Board, the National Science Foundation, and the American Association for the Advancement of Science (American Association for the Advancement of Science, 2013; Hill et al., 2010; National Science Foundation, 2014). Attrition may also explain the decrease in gains women in STEM have achieved over the last 50 years. Disproportionate attrition signals that simply increasing the number of girls interested in STEM early in their education may not result in parity at the top levels of STEM.

Project Overview

This dissertation is presented in five chapters. The introduction, provides an overview of the problem the research addresses, gender disparities in STEM, and outlines the study. Chapter II reviews the literature on the sources of STEM disparities, presents the theoretical and conceptual framework underpinning the study. Chapter III details the methodologies employed, including data types and sources, as well as the analyses conducted. Chapter IV presents the results of the study, and chapter V discusses the implications of the results.

This study seeks to explore how a summer science outreach program can operationalize theories on how to retain girls in STEM in a practical setting. As discussed above, girls and women leave the STEM pipeline at disproportionately higher rates than boys and men (see figure 3). The study will examine how girls respond to the program and what can be learned from the participating girls' ideas, affinities, and intentions regarding science. The foundational theories employed in the outreach program are identity formation theory (Erikson, 1968), self-efficacy theory (Bandura, 1976), and research on mindsets (Dweck, 2007). Identity theory provides insight into how girls may incorporate enduring science identities into their self-concept, which is hypothesized to increase retention in STEM. Self-efficacy theory provides a map for understanding how individuals build confidence in their abilities through experiences, shared learning, and feedback. Mindset research provides additional insight into methods for fostering growth and resilience in approaching challenging tasks. In this dissertation, these foundational theories will be used both to provide the guidance for implementing an intervention designed to increase girls' participation in STEM, and as the lens through which the intervention will be assessed as well as data to build new theory. These theories will be discussed in depth in chapter II.

The SPICE intervention. The Science Program to Inspire Creativity and Excellence (SPICE) is a cohort-based, university-run science outreach program targeting middle-school girls. The goal of the program is to encourage more young girls to pursue STEM education and careers. The primary activity carried out by the program is a series of summer camps. Camp participants range in age from 11 to 14 and attend various schools in Lane County, Oregon. Girls are invited to join the camp in the summer following their 5th grade year and participate in three consecutive summers of themed science camps. Each cohort consists of 20 girls who go through the program together. Instructors are drawn from University of Oregon science undergraduate majors and are trained in the application of the foundational theories of identity, self-efficacy, and mindsets.

Middle school is a time of great change in children's identities (Archer et al., 2010; Archer et al., 2012, 2013; Dweck, 2006; Erikson, 1968). Up until the age of about 10, children are generally positively disposed toward science and confident in their science abilities (Archer et al., 2010; Archer et al., 2013). After that, children begin to narrow their identity options and most become disillusioned with formal science (Erickson, 1977; Archer et al., 2010). The reduction of interest in science in middle-school-aged children is attributed to a number of sources, not the least of which are negative stereotypes about scientists (Cundiff, Vescio, Loken, & Lo, 2013; Steinke et al., 2007). One of the key features of STEM interest attrition as opposed to other areas such as the arts and social sciences is that attrition from STEM is disproportionate by gender (Corbett & Hill, 2015; Hill et al., 2010; Ing, Aschbacher, & Tsai, 2014). Middle school is when girls begin to lose interest in STEM at higher rates than boys. The differential attrition then continues throughout the entire STEM pipeline (see figure 3).

Children are recruited to SPICE at the age of 11 just when the downturn in science attitudes and confidence begins (Dweck, 2006; Good, Aronson, & Harder, 2008; Halpern, Aronson, et al., 2007; Rabenberg, 2013; Stake, 2006). For this reason, a large jump in preference for science is not the goal of the program. Rather, SPICE is intended to produce a steady and continued interest in science in order to facilitate the formation of stable long-term science identities and strong science self-efficacy in participants. The theory of action for this program is that by supporting the formation of strong identities and self-efficacy participants will be more likely to pursue STEM education and careers.

The presence of a science identity is hypothesized to increase the likelihood that girls will take STEM opportunities that come their way, and be more likely to seek out additional opportunities. As they accumulate more experience and skill, they will begin to see science as core part of their lives and consider science a viable career. It is also hypothesized that participants will also be more resilient to attrition from STEM at later stages, having been connected to relatable role models early on and provided experience in the context of real scientific research (Bayer Corporation, 2010; Corbett & Hill, 2015; Glass et al., 2013).

Specific characteristics of the camps relevant to this research study will be discussed in chapter III. A detailed description of the program schedule (appendix A) and history (appendix B) can be found in the appendices.

Results from previous research. In the summer of 2013, the author conducted a pilot study of SPICE camper science attitudes and career preferences. Study subjects included 53 girls in 6th, 7th, and 8th grades attending the 2013 SPICE summer camps. The study included career preference surveys that asked students to use pairings to rank STEM and non-STEM careers, implicit association tests of gender bias toward science, parent surveys of camper engagement, and focus group interviews.

The findings of the pilot study are as follows:

- Girls in the SPICE program already enjoy and relate to science.
- Girls in the SPICE program have strong preferences for STEM careers over non-STEM careers.

- Girls in the SPICE program have different associations and identities with regard to science that emphasize different aspects of scientific inquiry (exploration, creativity, mastery).
- Girls in the SPICE program crave relatable role models as a means of boosting confidence and feeling welcomed into the culture of science.

Findings from the pilot project were used to inform the research questions, methods, and instruments used in this dissertation study. Results of the pilot study were largely descriptive while this dissertation project sought to assess changes in girls' science affinities before and after camp. A detailed description of the pilot study results can be found in appendix C.

Research project. The goal of the current project is to examine the extent to which the SPICE camp supports girls in developing strong science identities and to explore how SPICE girls conceive of, relate to, and develop interest in science studies and careers. The project employed a mixed-methods, pre-post design to explore SPICE campers' attitudes, identities, and career intentions. The data collected included surveys of camper science affinities, parent reports of camper science engagement, observations of camp activities, focus groups, and individual camper interviews.

The research questions for this project are as follows:

1. Was the SPICE program implemented with fidelity to the operationalized theories of identity, self-efficacy, and mindsets as embodied in the SPICE program model?
2. Do SPICE participants show increased interest in science following camp?

3. Do SPICE participants show an increase in science efficacy following camp?
4. Do SPICE participants show an increase in positive attitudes toward science following camp?
5. Do SPICE participants show an increase in science identities following camp?
6. How do SPICE girls' science affinities inform an understanding of how they form identities as scientists and what form those identities take?

Significance of the study. As will be discussed in chapter II, while a great deal of research has been conducted on gender disparities in STEM at a variety of levels, there is little extant research on informal general science interventions for middle-school-aged girls. Studies tend to focus on school-related activities (Haussler & Hoffman, 2002; Laursen, Liston, Thiry, & Graf, 2007; V. Parker, 2000), programs that target specific disciplines or careers (Colvin, Lyden, & Leon de la Barra, 2013; Haussler & Hoffman, 2002; Hyun, 2014), and precollege preparatory programs (Merolla & Serpe, 2013; Swail & Perna, 2002; Wigfield & Eccles, 2000). Much of the literature uses high-achieving or talented and gifted students as study subjects (Lubinksi & Benbow, 2006; Shoffner & Newson, 2001; Stake & Mares, 2001). Another large section of literature looks at race/ethnicity and STEM or the intersectionality of race/ethnicity and gender (Jayaratne, Thomas, & Trautmann, 2003; Riegle-Crumb & King, 2013).

This study examines a cross section of girls from varied socioeconomic status families participating in an informal science outreach program. Girls in the study also have a wide range of exposure to science learning both outside of and through the program. The results of this study will inform the program under investigation in the areas of fidelity, participants' science affinities, and participants' ideas about science and scientists. Broader implications of the study include examples of how to operationalize theory in identity formation, self-efficacy and mindsets into a learning environment, a more nuanced understanding of girls science affinities, and new theory in the types of science identities girls form. The results of this research may prove useful to other science outreach programs, schoolteachers and administrators, policy makers, parents and researchers.

Summary

Gender disparities in STEM disciplines persist despite decades of study and intervention. The dissertation presented here is informed by scholarly research, as well as best practice guidelines from national science education authorities. The study examines how science affinities in girls change after participation in an informal outreach program. The study also examines participants' interests and engagement with science, their science efficacy, their attitudes toward science, and their emerging science identities. A pre-post design employing mixed methods was used to obtain both quantitative and qualitative data to answer the research questions. This study is intended to describe how participants relate to science and to inform future study on the ways in which girls develop identities as scientists.

CHAPTER II

LITERATURE REVIEW

Literature from the fields of education, psychology, sociology, and women's and gender studies were reviewed to inform this study. Reports from national government and nonprofit agencies, literature from journals in the natural sciences, and educational journals for specific natural and health sciences were also included in the review of literature. Articles, reports, and books were found through searches using Google Scholar and the ERIC database using the following terms in various configurations: girls, women, STEM, gender disparity, science education, science identity, intervention, informal education, outreach, leaky pipeline, and feminist educational theory. References were also found by examining the bibliographies of relevant works. Libraries of online reports from relevant professional associations, government agencies, and nonprofit groups invested in science education were also consulted. Lastly, colleagues shared many references with the author. Given the wide range of disciplines and theories consulted, this literature review is not meant to be exhaustive; rather, the key salient works and their implications for this study are represented.

This review first covers literature that addresses the sources and nature of gender disparities in STEM education and careers. Next the review presents theories from psychology, sociology, and education that inform the theoretical underpinnings of the study. Lastly, a conceptual framework integrating the theoretical framework, key concepts, theory of action, and best practices from the world of informal science education is presented.

STEM Career Paths

Before embarking on the discussion of the sources of gender disparities in STEM disciplines, it is important to understand how individuals are prepared for STEM careers. Preparation for careers in the sciences is known as the STEM pipeline. Official STEM training begins with undergraduate study in colleges and universities. Preparation for STEM studies in college begins during high school. Students who wish to pursue STEM careers need to have completed advanced high school level chemistry, biology, and physics coursework in addition to precalculus (Bandura, 1976; Wimberly & Noeth, 2005). Students who have not met the expected requirements will require remediation, which increases time to degree and the likelihood of attrition from STEM studies (Chen & Soldner, 2013). Although preparation for STEM studies occurs during high school, the foundation for success in high school is laid in middle school or even as early as elementary school (Maltese & Tai, 2011; Wimberly & Noeth, 2005). Students who wish to complete at least some precalculus courses in high school—required for successful completion of many first-year science courses for STEM majors—must complete an algebra course in middle school.

The career arc of a tenured faculty researcher requires four years of undergraduate study, four to seven years of graduate training, postdoctoral research of one to four years, and seven years of junior faculty status before achieving tenure (DeNeef, 2002; Nyquist & Wulff, 2000). That is a minimum of 16 years of postsecondary training, approximately 8 to 11 of which are past completion of the Ph.D. degree. Career arcs in government research science, such as work for national laboratories, require a similar amount of training (Neal, Smith, & McCormick, 2001). Preparation for careers with private STEM companies varies. In applied disciplines, many individuals begin their careers following attainment of a master's or even bachelor's degree and work as interns and junior scientists. Other private STEM occupations require years of postgraduate study comparable to academic training (Turk-Bicakci, Berger, & Hazton, 2014). Regardless of the sector of employment (academia, government, private), traineeship, and the preparation that precedes it, is typically long and challenging.

The STEM pipeline metaphor is meant to conjure an image similar to a water distribution system in a city. The starting point is a large body of water, which is separated into smaller, but still large delivery pipes. These pipes step down into even smaller pipes, eventually delivering water to individual faucets where only a small flow of water emerges. Each schoolchild starts out as a potential scientist. Over time, however, as they make choices (or choices are made for them) about their interests and education, students are directed out of the pipes leading to STEM careers and into other occupational options. Individuals who leave the STEM pipeline at any stage rarely find their way back (Alper, 1993; Chesler, Barabino, Bhatia, & Richards-Kortum, 2010; Glass et al., 2013; Varma & Hahn, 2008). Students who lose interest early in science are unlikely to pursue the type of rigorous math and science education that will prepare them for STEM studies in college. Students who leave STEM majors in college are unlikely to find employment in STEM careers (Chen & Soldner, 2013).

Science and the Gender Filter

In his review and analysis of literature on women and science careers, Blickenstaff (2005) identified nine explanations presented in the literature for why women remain underrepresented in STEM. These frequently proposed explanations are:

- biological differences between men and women
- girls' lack of preparation for STEM careers
- girls' poor attitude toward or lack of positive experiences in science
- absence of female STEM role models
- STEM curriculum that is irrelevant to many girls
- pedagogy of STEM classes that favors boys
- the "chilly climate" of science
- cultural pressure to conform to gender roles
- an inherently masculine worldview of science culture

Blickenstaff (2005) presents an overview of research addressing each of these explanations and the relative merits of each argument. Brotman and Moore (2008) take this analysis further and construct four themes around women and STEM based on the research literature. These themes are: (a) equity and access, (b) pedagogy and curriculum, (c) nature and culture of science, and (d) identity formation (see figure 4). The four themes are organized chronologically based on their emergence in the literature. Brotman and Moore (2008) surveyed literature from 1995 to 2006. The time frame beginning in 1995 is the first period to contain literature from all four themes, though literature on equity and access has been in decline since the mid-1990s. No review of this nature conducted more recently was found. Subsequent reviews and meta-analyses tend to focus on the intersection of race/ethnicity and gender in STEM. Figure 4 presents these themes visually and chronologically.

Many of the explanations of gender disparity in STEM identified by Blickenstaff (2005) are closely linked with one another, as are the themes elucidated by Brotman and

Moore (2008). Many of the items listed under one theme can be listed under multiple themes, however in the interest of simplicity each explanation is situated under only one theme for the purpose of this review. The following section will outline issues related to these four themes and assess the explanations for gender disparities in STEM that relate to the theme. Table 1 shows how the two approaches align thematically.

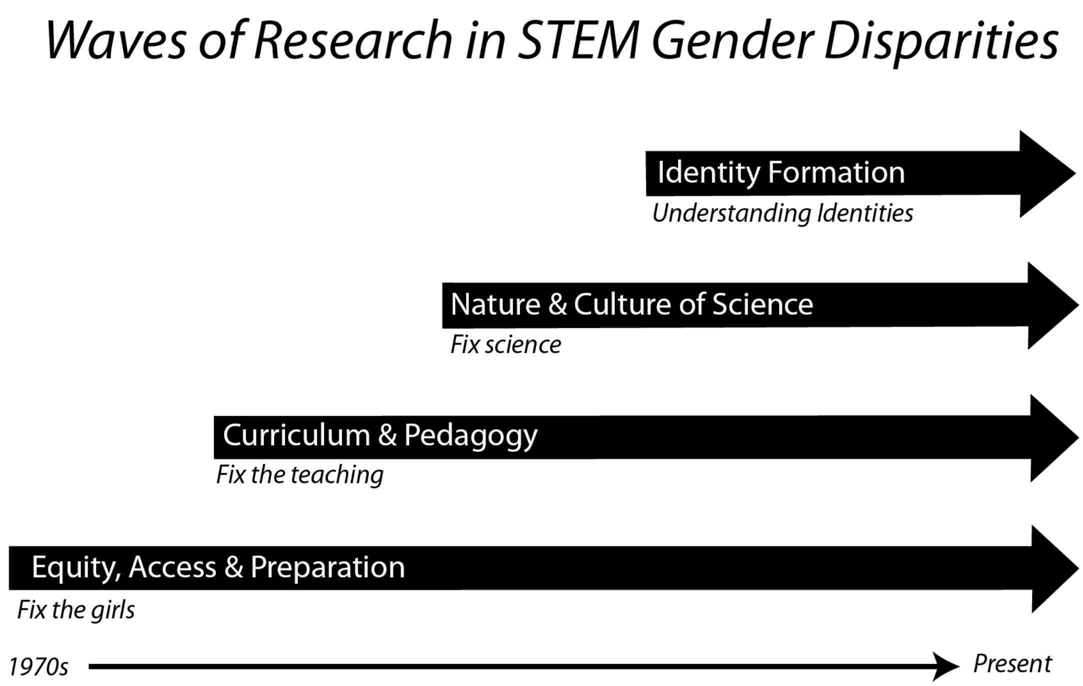


Figure 4. Timeline of waves of research in STEM gender disparities.

Equity and access. Blickenstaff presents and refutes two equity and access related explanations for STEM disparities between the genders. These are: fundamental biological differences between the sexes, and lack of adequate STEM preparation among women. The oldest and most persistent explanation for why women do not pursue STEM careers as often as men is that women are not as naturally adept in STEM studies as men. That is, women are at a biological disadvantage to men, particularly in mathematics and the physical sciences.

Table 1

Explanations for Gender Disparities in STEM Organized by Theme

Equity & Access	Curriculum and Pedagogy	Nature and Culture of Science	Identity
• Biological differences (perceived and real) contributing to achievement • Lack of adequate preparation	• STEM curriculum that is irrelevant to many girls ○ Sex bias in textbooks ○ Developing gender-inclusive curriculum • Pedagogy of STEM classes that favors boys ○ Feminist perspectives on education	• "Chilly" Climate • Inherently masculine worldview of science culture ○ Including discussion of the construct of science in the classroom ○ Gender binary excludes girls from science	• Poor attitude/lack of positive experience • Absence of female role models • Gender identities and stereotypes

(Blickenstaff, 2005; Brotman & Moore, 2008)

To clarify, the terms *equity* and *access* are used as employed by Brotman and Moore (2008), who presented more research than is discussed here. This theme in research about gender disparities in STEM addresses how *early* researchers sought to explain and address the issue of gender disparities in STEM. Some researchers looked to essentialist or biological arguments to explain the difference, while others sought to refute, clarify, and contextualize essentialist findings. Research in this theme also sought to highlight ways in which institutions and social expectations restricted women's access to science education. The arguments presented below address and refute common (older) explanations for why gender disparities in STEM exist. This discussion is not meant to reify out of date, unsupported ideas about gender and STEM. Furthermore, this theme does not address modern conceptions of equity in and access to education and careers.

Biological explanations. The biological explanation for STEM gender disparities is no longer given much credence among researchers (Buchmann, Diprete, & McDaniel, 2007), but there is some evidence of biological differences between the sexes. Hyde (1996) in a meta-analysis of 143 studies, found statistically significant differences between women and men in mathematics, spatial perception, and verbal ability. Differences in spatial perception between the genders have often been cited as an explanation for why men outnumber women in engineering fields. However, in other skill areas also employed in engineering such as tests of memory of spatial locations of objects, arithmetic calculation, and verbal fluency, women tend to exceed men (Spelke, 2005).

Hyde (1996) used the effect sizes derived from her meta-analysis to extrapolate the expected ratios of male to female engineers. Using the assumption that only individuals scoring in the top 95th percentile on spatial perception or mathematical skills tests would be suitable for a career in engineering, a ratio of 2:1 (males to females) would be expected. At the time of Hyde's study, the ratio of men to women in engineering was nearly 20:1. Currently, it ranges from 8 to 12:1 depending on engineering discipline (U.S. Depatment of Labor, Bureau of Labor Statistics, 2014). In fact, this closing of the gap from 5% of professional engineers being women to nearly 8% to 12% in only 20 years would seem to indicate that social factors, rather than biological ones, play a greater role in STEM gender disparities. Furthermore, the areas in which women achieved at higher (memory of spatial locations, calculation and verbal fluency), would be expected to balance out the areas in which men achieve at higher levels, leaving men and women on roughly equal footing biologically speaking. Halpern, Benbow, et al. (2007) and Buchmann et al. (2007) also reviewed the literature on biologically based explanations for gender disparities in STEM. Both teams agree that there is evidence of biological differences between men and women that might contribute to competitive advantages in some areas of STEM education and careers. Not all of these advantages are attributed to men, however. They also note the near impossibility of fully separating biological differences from socialized differences. Furthermore, as Hyde (1996) and Blickenstaff (2005) conclude, biological differences do not account for the vast gender disparities in STEM and more fruitful methods of addressing disparities lie outside of biological explanations.

In a longitudinal study of undergraduate STEM majors, Brainard and Carlin (1998), found that there was no difference in performance of women who stayed in STEM majors and those who left. That is, factors beyond achievement were the deciding ones in women's departure from STEM. The only statistically significant factor identified in women's departure from STEM was loss of academic self-confidence.

Inadequate preparation. The next most common explanation (historically) for women's underrepresentation in STEM disciplines is inadequate preparation of girls to study STEM disciplines.

In the late 19th and early 20th centuries women were excluded from work in the sciences both formally and informally. Particularly, women were prevented from obtaining membership in elite science societies and academies (R. Holmes, 2010). Genders were often segregated in education, and women were excluded from much of higher education (R. Holmes, 2010). As free public education in the United States became the norm boys and girls received different instruction, with girls tracked into home economics coursework and boys into industrial arts (Tolley, 2002). Females who did manage to secure STEM education and pursue important research were often subject to theft of their ideas by advisors and peers (Kaku, 2010).

History of science education. The assumption that STEM studies were for boys and home and liberal arts studies were for girls was not always the dominant operating paradigm. In her history of science education in colonial and postrevolutionary America, Tolley (2002) paints a rather different picture of the educational history of women. From the postrevolution era until the late 19th century, the study of geography and mathematics was extremely popular in girls' schools. Scans of educational literature of the time indicate that the study of geography (at the time a much broader and more holistic discipline encompassing geology, astronomy, botany, and mathematics) in particular was considered ideal for young women. Reviewing and comparing curriculum from gender-segregated schools of the antebellum period, Tolley found that girls' schools more often offered courses in mathematics and sciences than boys' schools, and were more likely to use the popular science text books of the time (Tolley, 2002).

Study of the classics and humanities, on the other hand, was largely reserved for men. In the 19th century, women were active members of the growing scientific community and made major contributions as educators, amateur scientists, and members of scientific societies. Their presence in the science community, at the time, seemed natural and gender appropriate (Tolley, 2002). Near the end of the 19th century and into the 20th, the assumption that science was a natural realm of women began to shift. Tolley (2002) finds that the change occurred partially because of a male backlash to growing political power that education and careers in science were bringing women, a renewed focus among women's social movements on elevating the traditional roles and duties of women, and women's breaking into the once elite realm of study of the classics.

The sciences increasingly became known as a rational, objective, masculine, and professional field throughout the early 20th century (DeBoer, 1991; Rudolph, 2002; Tolley, 2002). As the sciences became increasingly organized, women found themselves shut out of professional societies and access to science education. This education had once been widely available in "higher" schools (private and public secondary schools), but now was the domain of colleges and universities to which women had limited access. This quickly came to be seen as the "natural" or "normal" organization of education; home economics and humanities for women, science and mathematics for men (Tolley, 2002).

In the mid-20th century, women and minorities began to push back against educational barriers. The federal government played a major role in guaranteeing equal access to education through Title IX of the Civil Rights Act of 1964 (Blickenstaff, 2005). Boys and girls now take the same basic curriculum in public schools, students have redress through the courts to oppose unequal access (Blickenstaff, 2005), and women now outnumber men in college enrollments (National Center for Education Statistics, 2010). In the 1970s and 1980s scholars began to look closely at gender disparities in STEM, looking for ways to explain and increase women's participation (Kelly, 1981). Gender disparities in STEM have been a consistent area of concern through the 1990s and into the 21st century. Though the representation of women in the STEM disciplines has increased across all disciplines in the last 50 years, women remain heavily underrepresented in STEM.

Preparation and achievement. In the 1980s and 1990s, a major explanation for women's continued underrepresentation in STEM focused on inadequate preparation. Girls consistently underperformed on standardized tests of mathematics achievement (Robinson & Lubienski, 2011), took fewer STEM courses in high school, and were less likely to take advanced placement examinations for the STEM disciplines (Corbett, Hill, & St. Rose, 2008; Halpern, Benbow, et al., 2007).

The gap between boys' and girls' performance in high school coursework has recently closed. Girls now earn more science credits and higher grades in science classes than boys in high school (Hill et al., 2010; Nord et al., 2011; Todd, 2012). Girls still lag behind boys on standardized tests in math and science, however (CollegeBoard, 2014; Hill et al., 2010; Nord et al., 2011). Girls, while taking more credits in math and science than in the past, are still less likely to take more challenging coursework in mathematics and physical sciences (Nord et al., 2011; Todd, 2012). Using data from the High School Transcript Study (HSTS), Nord et al. (2011) found that girls were more likely to fail than boys at achieving the various levels of curriculum (standard, mid-level, and rigorous) due only to missing science credits. These curriculum levels are defined by the number and types of courses taken by students and represent a degree of achievement and skill. Standard-level curriculum is considered the minimum to have attained an adequate high school education, while a rigorous curriculum level is aligned with expectations for high-achieving students with college expectations (Nord et al., 2011).

Using the same HSTS data set along with National Assessment of Educational Progress (NAEP) scores, Todd (2012) found that though girls took more science credits than boys overall, they earned fewer credits than boys in physics, engineering, astronomy, and geology courses. They made up the difference in science credits with biology and chemistry courses. Most girls missing the rigorous curriculum level due to science credits were short specifically in physics credits. Males missing the rigorous curriculum level were more likely to be short in English and foreign languages (Nord et al., 2011).

Examining NAEP scores, Todd (2012) found that the number of science and math credits taken as a whole were not as good at predicting the gender gap in NAEP scores as specific courses were. Accounting for the discipline and quality of courses actually lowered the predicted gender gap from 5.7 points ($SE = 1.3$) to 4.3 ($SE = 0.6$). Credits in rigorous, high-quality courses (calculus, chemistry, and physics) contributed the most to predicted NAEP scores, while low-quality courses actually lowered predicted NAEP scores. Girls were more likely to take lower-quality courses than boys and less likely to take physics, a strong predictor of NAEP performance in the model.

Girls also represent a smaller proportion of students taking advanced placement (AP) exams for college credit in STEM disciplines (CollegeBoard, 2014). Figure 5 shows the relative percentages of students taking STEM AP exams. Girls are at or near parity in taking AP exams in biology, chemistry, and the first section of calculus. Their participation drops in more advanced mathematics, physics, engineering, and computer science.

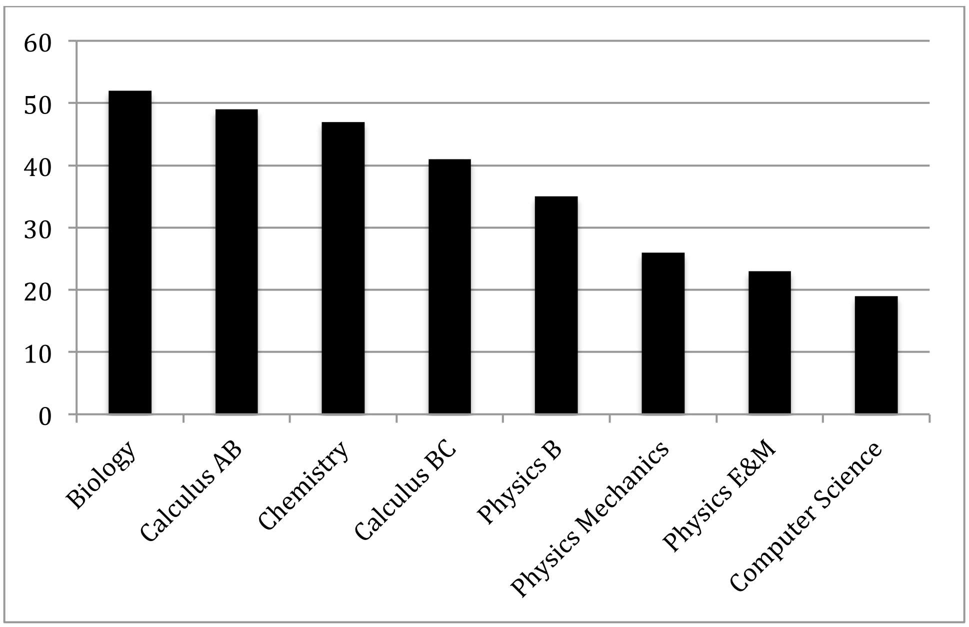


Figure 5. Percentage of Students Taking AP STEM Exams Who Are Female (CollegeBoard, 2014).

Taking AP exams and earning AP credit in STEM disciplines are strong predictors that students will select STEM studies in college (CollegeBoard, 2014). Students receiving AP credits are also more likely to persist and succeed in STEM studies (Dougherty, Mellor, & Jian, 2006; Geiser & Santelices, 2004). Though Klofpenstein and Kathleen (2009) argue that results finding that AP exams predict college success are actually measuring students highly correlated non-AP activities, the exams are still heavily used in college admissions.

Equity and access summarized. Though there are some small measureable cognitive differences between men and women (on average), scholars are overwhelmingly in agreement that these differences do not contribute in any substantial way to gender disparities in STEM. Furthermore, girls' continual improvement in STEM coursework and on standardized tests have all but closed the gender gap. The only area in which girls are still lagging behind their male peers is in completing enough credits in the physical sciences. The picture presented shows that girls are capable and permitted access to courses and exams but are choosing not to do so.

Curriculum and pedagogy. As overt barriers to access by women were removed, literature on gender disparity in STEM began to focus on the more subtle cues diverting women from science (Brotman & Moore, 2008). STEM curriculum and pedagogy were the primary identified sources of disparities investigated by researchers in the 1970s (Blickenstaff, 2005). Women and girls were rarely pictured in science textbooks, and the contributions of female scientists were seldom mentioned (Halpern, Aronson, et al., 2007). When depicted, women were often presented as passive, subjects rather than actively engaged in science, or as assisting males (Walford, 1981). The wording and approach of many problems and examples was found to be problematic, employing scenarios and metaphors that were not relatable to girls, such as sports analogies (Walford, 1981). Research has also found that girls prefer and perform better with texts and teaching styles that emphasize depth of understanding over breadth, while texts of the time sought to encompass a wide range of topics (Sadler, Sonnert, Hazari, & Tai, 2012).

Teachers' approaches to science instruction and their ideas about boys' and girls' capabilities in science have also been shown to both influence girls' performance and teacher assessment. Studies from the 1980s and early 1990s revealed a range of biased teacher behaviors in the science classroom. Blind studies demonstrated that teachers gave higher marks to work attributed to boys than to identical submissions attributed to girls (Spear, 1987). Later studies showed that quality of instruction was cited as a primary contributor to the decision to leave STEM studies and had a disproportionate impact on women (Seymour, 1995). Studies have shown that teachers spend more time with boys than girls, regardless of subject (Sadker & Sadker, 1981; Wilkinson & Marrett, 1985), are more likely to ask boys follow-up questions, and give girls less feedback (Blumenfeld, Marx, Patrick, Krajcik, & Soloway, 1997; J. Eccles & Blumenfeld, 1985; M. G. Jones & Wheatley, 1990).

It is difficult to say if science teacher-student interactions have changed much in the intervening years. Many researchers have moved on to examining students' attitudes and interests in science (Dawson, 2000; Ing et al., 2014; M. G. Jones, Howe, & Rua, 2000; Low, Yoon, Roberts, & Rounds, 2005; Phillips, Barow, & Chandrasekhar, 2002; Tracey, 2002). A more recent meta-analysis of studies addressing gender equity in the classroom found that teachers initiated more overall interactions and more negative interactions with male students (S. M. Jones & Dindia, 2004). Positive interactions were initiated at equal rates between the sexes (S. M. Jones & Dindia, 2004). Jones and Dindia's study covered all subjects, however, not just science. Another study comparing mathematics and language arts teachers found that male and female teachers interacted more with male students than female students in science classes (Duffy, Warren, &

Walsh, 2001). In a very recent study, the teacher-graded math scores for 3,000 6th grade students in Israel were compared to gender-blind scores given by outside graders. Researchers found that teacher scores were biased by gender with both male and female teachers scoring girls' work lower than boys' (Lavy & Sand, 2015). International comparisons are problematic given cultural differences; however, the study does point to ongoing problems of teacher gender bias that may be at play in the United States as well.

Research in the 1990s began to focus on developing gender-inclusive curriculum. Educational researchers proposed that gender-inclusive curriculum should (a) draw on boys' and girls' experiences, interests, and ideas about the world, (b) prioritize active participation over passive learning, (c) include self-driven projects, (d) utilize open-ended assessments, (e) emphasize collaboration and communication, (f) use real-life contexts, and (g) incorporate social relevance into science (Brotman & Moore, 2008). Results of research on gender-inclusive types of curriculum and pedagogy were mixed. Qualitative studies found that the environment created by gender-inclusive curriculum and teaching styles empowered both students and teachers and brought girls into the science classroom in a more active and participatory way as both experts and learners (Brotman & Moore, 2008; Howes, 1998; Rennie, 2003; Roychoudhury, Tippins, & Nichols, 1995). Some quantitative studies found no benefits to students (male or female) in gender-inclusive classrooms. Others found benefits that were equal between girls and boys (Haussler & Hoffman, 2002; Lagoke, Jegede, & Oyebanji, 1997).

Research also exists on teachers' responses to gender-inclusive curriculum and practices. Some teachers experienced difficulty, even resistance, from students when attempting to introduce gender awareness into the classroom and curriculum (McGinnis

& Pearsall, 1998). Some teachers actively resisted implementing gender-inclusive pedagogy (McGinnis & Pearsall, 1998; Plucker, 1996; Zohar & Bronshtein, 2005). Brotman and Moore (2008) call for more research in the impact teacher education and professional development can have in bringing gender inclusivity effectively into classrooms, and assessing what impact these curricula have on boys and girls.

It is clear from the research that in the past curriculum and pedagogy were not inclusive of girls. It is less clear what the current status of curriculum, pedagogy, and teacher attitudes are, but there is still some bias against girls in STEM. The impacts of this bias are uncertain.

N**ature and culture of science.** A third theme in research on gender disparities emerged in the 1990s. This theme moved focus away from girls' deficits and differences relative to boys, and moved the focus on to the subject of science itself. Established female scientists began to speak out about the conditions of science careers for women and feminist scholars began deconstructing assumptions about the nature of science that were culturally rather than factually created.

Masculine worldview of science*.* The most common associations with science are traditionally masculine associations. Science is viewed as rational, dispassionate, objective, and competitive (Howes, 2002; M. G. Jones et al., 2000; Miller, Blessing, & Schwartz, 2006). Science is presented as only for high achievers and the naturally gifted. Science curriculum tends to reinforce these ideas (Carlone, 2004). Women, on the other hand, are viewed as creative, collaborative, holistic, and emotional (Barton, 1997; Barton & Osborne, 2001)—implicitly more suited toward arts, humanities, and social sciences (Tolley, 2002). The masculine and feminine are presented as oppositional and irreconcilable binaries (Gilbert, 2001). Thus, when science is associated with the masculine, it is implicitly exclusive to the feminine. These perceptions are deeply culturally ingrained as typified by the now-iconic "Draw a Scientist Test." Thousands of individuals of all ages, genders, and races from around the world have been asked to draw a picture of a scientist in numerous settings. Overwhelmingly, the participants draw white male scientists regardless of their own race and gender (Chambers, 2006; Steinke et al., 2007). Exceptions to this result were found in countries with more egalitarian views toward gender and science (Weisgram & Bigler, 2007).

Science is also presented as unbiased; however, historically, scientific authority has been used to justify the oppression of women and other minorities. Scientists used their positions as "unbiased" experts to forward beliefs that women were not equal to men intellectually due to menstruation (Kleinman, 1998), skull size (Blickenstaff, 2005), and the danger that their reproductive organs might detach and float about their bodies if they exercised their mental faculties (Tasca, Rapetti, Giovanni Carta, & Fadda, 2012). Similar false statements of "scientific fact" have been used against racial and ethnic minorities (Kleinman, 1998).

Feminist scholars argue that scientific knowledge, as collected and analyzed by human beings, is just as susceptible to bias as other disciplines (Brickhouse, 1998, 2001). One way to inoculate science from bias is to broaden participation and inclusivity to provide multiple perspectives and critiques of potentially biased research and claims (Brickhouse, 2001; Haraway, 1991; Harding, 1991). Scholars who write on the topic of the masculine worldview of science advocate for open discussion of both science and gender as social constructs in the STEM classroom.

"Chilly" climate of science. The perceived nature of science as inherently masculine is a powerful deterrent to women seeking educational opportunities. Some women do of course pursue STEM and their numbers have grown, however, there remain obstacles to persistence. Once women "arrive" and secure postdoctoral and tenure-track positions, they still leave STEM at higher rates than men. Attrition at this level is attributed to the "chilly climate" of science. Female faculty report fewer peers and mentors than male colleagues (Carrell, Page, & West, 2010; Maranto & Griffin, 2011). They also report a lack of family-friendly human resource policies (Bayer Corporation, 2010; Hill et al., 2010) and lack of support for spousal hires (National Science Foundation, 2010). Though many interventions designed to keep women in science have been tried with some success, climate remains an important issue for women in STEM (National Science Foundation, 2010).

Acknowledgement and awards are an important part of successful science careers. Research finds that women receive acknowledgement in the form of awards, fellowships, and positions in prestigious labs at lower rates than male colleagues regardless of skill and accomplishment (M. Holmes, 2011; Lincoln, Pincus, Koster, & Leboy, 2012; S. V. Rosser, 2004). Women have also had their research attributed to other scholars or outright stolen. Notable female scientists whose research resulted in awards given to men in their place include Rosalind Franklin (discovery of DNA), Jocelyn Bell Burnell (discovered pulsars), Esther Lederberg (how viruses infect bacteria), Chien-Shiung Wu (disproved the law of parity and worked on the Manhattan Project), Lise Meitner (fundamental principles behind nuclear fission), Nettie Steven (discovered XY sex chromosomes), and Celia Payne (characterized the composition of the sun as primarily helium) (Brones, 2013). Knowing that your accomplishments will likely be overlooked or even outright stolen contributes to a hostile climate for women in science.

Preparation for STEM careers requires more than taking classes and earning good grades (Lovitts, 2005). Developing as an independent researcher is a crucial transition for any scientist (Wieman, 2007). Scientific research is its own culture, and an important aspect of becoming a scientist is becoming part of that culture; however, it is a culture nested in white, male academia (Smith, Pedersen-Gallegos, & Riegle-Crumb, 2002). Navigating the STEM culture and the many unspoken cues presented by insiders can be a baffling and frustrating experience for women (Lee, 2008; Taconis & Kessels, 2009). As mentioned in chapter I, attrition among mid-level women in STEM is many times higher for women than men (Glass et al., 2013).

Nature and culture of science summarized. Science, as it has been socially constructed, is neither inviting to nor supportive of women. The cultural presumption of science as inherently masculine and the opposite of feminine, coupled with an oppressive history, has not proven an attractive educational or career option for women. This is borne out by the experiences of many female scientists who have been isolated, unacknowledged, and undervalued by their colleagues and society in general.

Identity. Much has changed from the 1970s when researchers began examining barriers to women's access to STEM. There have been many changes to curriculum and teacher training, and steps have been taken to improve the climate of science. However, there is still more that can be done in these areas. Given the number of well-prepared girls graduating high school for the last 20 years, there should be more women at all levels of STEM careers, but there are not (Kulis et al., 2002). In fact women's gains in

STEM have slowed, stalled, and even reversed in some disciplines (Hill et al., 2010). Researchers looking to understand why the growth of the number of women in STEM has stalled have turned to research on identity formation (Blickenstaff, 2005; Brotman & Moore, 2008).

Identity formation is the process by which individuals develop personalities, incorporate personal schema, internalize affiliations, and create a discrete sense of self (Erikson, 1968; Files, Blair, Mayer, & Ko, 2008; Kanter, 1977). Research in this area often focuses on one of three identity-related sources of gender disparities in STEM: girls' attitudes toward and interests in STEM, the absence of female role models, and cultural pressure to conform and fulfill gender roles.

Attitudes and identities. A large body of research addresses girls' interest in and attitudes toward science. Findings in the area of girls' attitudes toward STEM are consistent. With the exception of the biological sciences, girls have less positive attitudes toward science than boys (Alexander, Johnson, & Kelley, 2012; Archer et al., 2010; Christidou, 2011; Cvencek, Meltzoff, & Greenwald, 2011; Dawson, 2000; Hazari, Sonnert, Sadler, & Shanahan, 2010; Ing et al., 2014; Kitts, 2009; V. Parker, 2000; Sorge, 2007). These findings have been largely consistent over time as well (Dawson, 2000). Researchers have explored a number of factors that might contribute to this differential in interest between the genders.

Interest and opportunities to explore science have been shown to be different by gender at a variety of ages. A longitudinal study of 192 preschool and elementary children showed that girls' early interest in science drove their access to science opportunities over time, while boys were given the same amount of science opportunities by parents regardless of initial interest (Alexander et al., 2012). That is, girls who demonstrated an early interest in science tended to have more opportunities to engage in informal science later in their lives. Boys, on the other hand, while initially following the same pattern, ended up having the same number of opportunities regardless of early interest. This means that boys who initially did not have an interest in science were provided with more opportunities to gain an appreciation of science than girls who did not initially have an interest in science. The researchers also found in general that boys had higher initial interest in STEM and opportunities to engage in STEM than girls.

Applying expectancy theory (J. S. Eccles, Adler, & Meece, 1984; J. S. Eccles & Wigfield, 1995) in a study of 367 adolescents, Else-Quest, Mineo, and Higgins (2013) found that girls reported lower self-concept, attitudes, and expectations toward science than boys. Two key elements of expectancy are perceived ability and personal relevance. Girls in the study reported lower relevance of science to their lives. The researchers also found that girls' attitudes toward science predicted their achievement in science, with poor attitudes toward science correlating with lower achievement. In a study of 324 high-achieving high school students, Stake and Nickens (2005) found that the girls reported less peer support for science interest than did boys, and that the presence of peers was related to students' ability to envision themselves in the role of scientist.

Across domains, ability and interest have been strongly associated. That is, individuals who demonstrate skill at a task or in a subject area tend to report enjoyment in that subject (Bloom, 1976; Fensham & Harlen, 1999). In a study of middle school students, Mattern and Shau (2002) found that ability was unrelated to interest in science in middle-school-aged girls. Girls who demonstrated skill in science were no more likely to report an interest in the subject that those who performed poorly. This would suggest that for girls, the association of ability with interest does not hold in the domain of science. One possible explanation is that science is not considered to be consistent with girls' gender identities. Else-Quest, Mineo, and Higgins (2013) found that among 10th grade students, when accounting for ethnicity, attitudes (value for the subject and confidence in ability) did predict math and science achievement in girls. Among college students, Cundiff et al. (2013) found that women who evidence strong gender-science stereotypes (associating science with males) had weaker science career aspirations.

Kitts (2009) found that stereotypes about girls and science that were believed to contribute to STEM disparities were not in evidence in their study of 2,535 middle and high school students. They found that girls feel capable at science, value science, and feel their parents would be proud of them if they were to become scientists. However, girls still had lower interest in pursuing STEM careers. Kitts (2009) also found that girls were not identifying teachers as science role models and that the lack of mentorship might be contributing to women self-selecting themselves out of the sciences.

Taken together these findings are complex, though not entirely contradictory. Girls can value math and science and perform well in the subjects, however, their gender identities may not be consistent with the study of math and science, leading to lower interest, which in turn influences the likelihood they will pursue STEM education and careers.

Role models. Another factor influencing girls' science identity formation is the absence of female STEM role models. As shown above, women participate in STEM careers at much lower levels than men. This also means that there are few role models for girls and women who might be interested in STEM careers. Furthermore, Blickenstaff (2005) argues that not only are the numbers of women low, but the types of women likely to succeed in the masculine culture of science are those who fit that culture well. These women provide a narrow representation of what types of women belong in STEM. Byrne (1993) argued that the presence or lack of diverse female role models signals the low viability of the STEM environment for foster female success. Research into 8th grade girls' processes of identifying role models from their environments found that girls did not initially believe that a career as a scientist was a viable option. (Buck, Plano Clark, Leslie-Pelecky, Lu, & Cerda-Lizarrage, 2008) The researchers also found that women who might be potential role models were intimidated by a perceived need to portray the "perfect" scientist. After an intervention that brought female scientists and girls together, both groups revised their expectations. The girls found relatable role models and expressed the belief that science was a viable career option. Female role models also adjusted their conceptions that suitable role models needed to display perfection as a scientist.

Reigle-Crumb and Moore (2013), using national data from the Longitudinal Study of Adolescent Health, found that a community's degree of traditional gender expectations influenced girls' participation and performance in high school physics coursework. In areas with a high proportion of women working in STEM fields, differences in participation between boys and girls in high school physics coursework disappeared. The presence of female STEM practitioners in the community was the only statistically significant factor when controlling for income and school quality. As noted above, high school physics coursework is a key area in which girls still lag behind boys (Nord et al., 2011). It can be thought of as a bellwether of women's progress in STEM.

Social learning theory (Bandura, 1976) points to role modeling as a potent force in human development and behavior. Children in particular emulate the behavior of older role models (Bandura, Ross, & Ross, 1961). The more similar the role model, the more likely the child will follow the modeled behavior. Individuals are particularly sensitive to gender cues for behavior (Bandura, 1976). Female STEM role models signal to girls that STEM careers are a viable option. An absence of these role models signals that STEM careers are not viable or gender appropriate.

Gender identities and stereotypes. Girls' learning trajectories and interest in STEM may also be influenced by gendered factors well before they reach middle school. Studies on implicit bias have shown that as early as second grade, most girls have internalized the gender stereotype that girls are not good at math (Cvencek et al., 2011; Farenga & Joyce, 1999), despite the fact that girls are now performing on par with boys in math and science (Nord et al., 2011).

Stereotypes about science that make it an unattractive career option to most girls (Andrew, Whigham, Hendrickson, & Chambers, 1999; Cundiff et al., 2013; Cvencek et al., 2011; Markowitz & Puchner, 2014; B. A. Nosek et al., 2009; Scott & Martin, 2014), lack of peers willing to express interest in science (Olitsky, 2007; Stake & Nickens, 2005; Taconis & Kessels, 2009; Todd, 2013), a lack of mentors and role models (August & Waltman, 2004; Evans & Whigham, 1995; Ferrieira, 2001; Horn, 1997; MacDonald, 2000; Nolan, Buckner, Marzabadi, & Kuck, 2008; Xu, 2008), and a system of education that favors a traditionally white male approach to learning science (Barton, 1997;

Haraway, 1991; Harding, 1991) are substantial, though often difficult to quantify, barriers to girls' engaged participation in science education and careers.

Gendered perceptions about performance in STEM can influence girls' and women's choices to pursue specific careers. Research in introductory STEM coursework has found that when equally competent males and females are asked to assess their STEM abilities, women are harsher in their self-assessments than men (Correll, 2001). That is, women and men who achieve at the same levels will assess their own competence differently with women providing a more pessimistic conclusion about their own abilities. Cimpian & Leslie (2015) found that women were less likely to pursue careers in disciplines (STEM and non-STEM) with a reputation for requiring "brilliance." The authors conclude that women have less confidence in their own innate talent than male colleagues. This lack of confidence is directing women away from disciplines such as mathematics, physics, engineering, economics, and computer science where stereotypes hold that practitioners must be naturally gifted.

Identities summarized. The studies reference above are presented as exemplars, and taken together, this research paints a picture of a cultural climate that differentially supports girls' and boys' interest in science. For girls, science is not consistent with gender identities (Ahlqvist, London, & Rosenthal, 2013; Archer et al., 2012, 2013). Girls do not see science as relevant to their interests (J. S. Eccles et al., 1984; Else-Quest et al., 2013), and they do not have the necessary peer networks and role models to support their interests in science (Stake & Nickens, 2005). Furthermore, women are less drawn to disciplines believed to require natural "brilliance."

Though negative stereotypes about girls and science seem to be on the decline, girls are still less likely than boys to express interest in STEM (Kitts, 2009). This lack of interest does not seem to be from lack of access or inadequate preparation, however. Differences in the opportunities to experience science, lack of role models, and the inherently masculine worldview of science may be contributing to girls' lack of identification with and interest in science.

The gender filter. Blickenstaff (2005), in addressing each of the common explanations for gender disparities in STEM, argues that these explanations (supported in the research or not) represent a series of challenges that constitute a filter, rather than leak, a filter that disproportionally impacts women. This filter allows ever-smaller numbers of women through to the next stage of STEM careers. The term "leak" implies girls leave STEM as a result of chance. Blickenstaff argues that the biases against women in STEM are systematic, cumulative, and represent a substantial barrier to the advancement of women in STEM.

The literature presents a conundrum as to why women remain underrepresented in STEM. Traditional explanations, biological differences, overt obstacles to access, and inadequate preparation, though still of concern, no longer appear to be substantial barriers to female STEM participation. Rather than being overtly excluded, girls and women are self-selecting out of the STEM pipeline. The most promising remaining explanations for women's underrepresentation in STEM center around the culture and climate of science, gendered stereotypes about science, and inadequate identity formation opportunities for girls and women in STEM. This study will focus on identity formation as a means of addressing gender disparities in STEM.

The remainder of this literature review will focus on the theoretical and conceptual frameworks underlying this dissertation. First the theories that inform the research will be described and related to the issue of gender representation in STEM. Next the theories will be grounded in key concepts and operationalized for study in the field.

Theoretical Framework

This dissertation draws on theory from Erikson's (1968) stages of psychosocial development, Bandura's self-efficacy work (1997b), and Dweck's research in mindsets (2008). These theories are employed both to understand why gender disparities in STEM exist and how interventions can be designed to counteract the gender filter.

Identity formation. In his seminal work, Erikson (1968) developed eight stages of the life cycle, each defined by a critical psychosocial crisis. His work is rooted in psychology and anthropology, particularly the importance of rites of passage in healthy psychosocial development (Gennep, 1909). The largest and most cited portion of Erikson's work was dedicated to the fifth phase of development that he situated in adolescence (ages 12–18). This phase is titled "ego identity vs. role confusion," also commonly referred to as identity formation.

Erikson defined the process of identity formation as a cyclical progression of integrating both positive and negative feedback from exterior sources to develop a sense of self and belonging. Though this process is an internal one, the role of external forces—family, peers, mentors, authority figures—in providing positive and negative feedback is crucial (Files et al., 2008; Kanter, 1977). Other scholars have built on Erikson's work and extended the application of identity formation beyond youth to illuminate issues of race, gender, and vocation into an understanding of how individuals integrate into groups (Brickhouse, Lowery, & Schultz, 2000; Gandara, 2001, 2006; Malone & Barabino, 2009; Olitsky, 2007). Failure to develop an identity will result in *role confusion* or an *identity crisis* which is associated with rebellion, unhappiness, and an inability to settle on a sense of self (Erikson, 1968).

Erickson focused on a general holistic identity formation process in adolescence. The final resulting self-concept (a collection of beliefs the individual holds about herself) is the foundation upon which healthy adult development is based (S. J. Schwartz, Zamboanga, Luyckzx, Meca, & Ritchie, 2013). Though this phase is associated with a particular age, Erikson resisted the notion that identity formation was unique to this life phase and many subsequent researchers have applied identity formation theories to processes throughout the lifespan (Benson, 2003; Sokol, 2009). Many researchers hold that Erikson's stages of the life cycle are in fact socially and culturally situated. Modern research extends the identity formation phase into what is now called *emerging adulthood*, a life stage unique to the last part of the 20th and early 21st centuries. In the past, individuals emerged from adolescence as adults with all the responsibilities and privileges attendant to that status. There were expected to pursue careers and families at this stage and become directly contributing members of society (S. Schwartz, Luyckx, & Vignoles, 2011). It is much more common now for individuals to delay careers and families in pursuit of further education or exploration. Ages of marriage and first childbirth are increasing and the period of the late teens and early twenties is viewed as a liminal state between childhood and full adulthood. In response to this cultural shift, identity formation appears to be extending well into individuals' mid-twenties and even beyond (S. J. Schwartz, 2001; S. J. Schwartz et al., 2013).

In addition to emerging adulthood, many researchers have explored vocational identity formation. Research shows that independent of preparation, ability, or aptitude for a particular career, the ability to internalize the values of that career culture and develop an identity as a member of that culture is a strong predictor of retention in a career (Blustein, Devenis, & Kidney, 1989; Côté & Levine, 2002; Savickas, 1985). The induction phase into a career can vary in length. In the case of STEM careers, the training and indoctrination period can span more than a decade. As Brainard and Carlin (1998) showed, factors associated with identity formation were better predictors of female exit from STEM graduate studies than achievement. That is, women were leaving the program because they lacked a sense of belonging, rather than because they were unable to perform at the level required. This is consistent with Glass's (2013) findings about women who leave STEM careers. It would appear that women at all stages of STEM education and careers are not forming the requisite identities as members of the STEM community.

If women are not forming STEM identities, then something must be missing in the identity formation process that is present (or at least more present) for men. What are the key elements of identity formation and how might gender differentially impact the delivery of these elements? Recurring themes that appear in literature on identity formation are experience, feedback, and confidence and competence (Erikson, 1968; Gennep, 1909; Marcia, 1966; S. Schwartz et al., 2011; Sokol, 2009).

Experience. Identity formation is an ongoing cyclical process through which new identities are formed and added to existing identities (Files et al., 2008; Kanter, 1977). New identities are adopted (or abandoned) based on the sum of positive (identity reinforcing) and negative (identity negating) events an individual has experienced related to the identity in question; if the *net* experience is positive and sustained then the individual will eventually adopt the new identity (Kanter, 1977). It should be noted that negative experiences have been shown to have a greater impact on personal beliefs about the self than positive experiences (Bandura, 1997b). It may take a number of positive experiences around identity to balance out even a single negative experience.

Experiences can take a number of forms, but the key elements include role-taking and opportunities to develop skills or insights in the identity area (Erikson, 1968; Marcia, 1966). Role taking, role playing, or symbolic enactment are a major part of childhood development (Bergen, 2002). Children often play dress-up or mirror adult activities, using toys in place of adult tools to pretend tasks such as cleaning, cooking, yard work, and construction. These symbolic acts are powerful ways for the young to identify with identity roles. One way learners may begin to identify as scientists is by wearing the garb (e.g., lab coats and goggles) and using the tools of scientists (glassware, chemicals, measurement instrumentation) as part of scientific activities (Bell, Lewenstein, Shouse, & Feder, 2009).

Opportunities to build skills or insight are another major way to gain identity experience. Girls' experiences in STEM are often the focus of research studies in STEM gender disparities. Calbrese-Barton and Brickhouse (2006) discuss women's and girls' interaction with science in terms of engagement rather than achievement, arguing that interest is more important in the formation of scientific identities than aptitude or preparation. Lubinski and Benbow (2006) found that women who are high achievers in math and science are more likely than men to pursue non-STEM studies, whereas male math and science high achievers are more likely to pursue STEM studies. Traditionally, competence and interest are considered to be closely related, however, research in gender and STEM shows that this connection does not seem to hold for girls in math and the sciences (Mattern & Schau, 2002). Often for girls classroom competence does not equal interest. This difference has been attributed to the different ways girls and boys tend to interact with science in classrooms. As has been shown above, girls are performing well in science classrooms, earning better grades and more credits than boys, however, the ways boys and girls engage with science in the classroom has been shown to be quite different. Observations of laboratory activities in mixed-gender groups show that boys tend to take the lead in hands-on manipulation of equipment while girls take on managerial tasks directing activities, taking notes, and ensuring timely completion of work. While these administrative skills will serve students well in STEM careers, they are not associated with increased interest in STEM. Hands-on manipulation and exploration, activities boys are more likely to take part in, are associated with increased interest in STEM (Pajares, 2005a; Trower & Chait, 2002). As Alexander, Johnson, and Kelly (2012) showed, girls are also less likely to have engaging STEM opportunities than boys from an early age.

Experience is the most important component of identity formation (Erikson, 1968; Marcia, 1966). Without a body of positive experiences around the target identity, individuals do not have the deep personal understanding of the role they will be expected to take on as a member of that identity group. Experience is the foundation upon which identity is built.

Feedback. Feedback is a crucial form of social identity control. Cote and Levine (2002) identify two functions of feedback in identity formation: reinforcement and social control. Confirmatory feedback in the form of praise, special privileges, and gifts provides individuals with interactions that reinforce identities through reflection. Social acceptance of the identity through feedback from others helps to codify and refine the identity. Feedback also provides society with a partial control of identity (Kerpelman, Pittman, & Lamke, 1997). That is, individuals expressing identities not socially accepted will receive negative feedback that denies rather than confirms the identity.

In their study of race and identity formation in science careers among minority graduate students, Malone and Barabino (2009) identify three factors that contribute to the formation of science identities: (a) integration versus marginalization, (b) value and recognition of contributions, and (c) racial identity as a burden. Minority students in this study had difficulty attaining the desired science identity and expressed a lack of positive identity feedback as the key obstacle to integration into the science culture (Malone & Barabino, 2009). Though race and gender do not perfectly map onto one another, feelings of exclusion, lack of recognition, and being the “only one” (Malone & Barabino, 2009) are also often expressed by women in science (Bayer Corporation, 2010; Hill et al., 2010; National Science Foundation, 2011b). One can easily replace “race” with “gender” in this analysis and observe the parallels. Women are implicitly excluded from the masculine world of science. They are marginalized when they participate and receive less recognition (M. Holmes, 2011; S. V. Rosser, 2004).

Feedback is most powerful from role models who are similar to the individual and who are perceived as authorities or members of the identity group (Bandura, 1976, 1977). The dearth of female role models in STEM signals to girls that scientist is not an appropriate identity (Riegle-Crumb & Moore, 2013). Most girls' earliest science role models are teachers. While many teachers are women, science teachers are predominantly male (Blank, Langesen, & Petermann, 2007). This lack of female role models most likely exacerbates the differential attrition from STEM between boys and girls. Boys are far more likely to have a relatable male role model to foster their interest in science than girls are to have a relatable female role model.

Furthermore, research into implicit association shows that even as overt bias against women has diminished, implicitly held negative stereotypes about girls' and women's competence in math and science persist in 70% of the worldwide population (B. A. Nosek, Banaji, & Greenwald, 2002, 2002b). Furthermore, women demonstrate a susceptibility to stereotype threat to science performance and identity (Ambady, Shih, Kim, & Pittinsky, 2001; Steele & Aronson, 1995). In addition, they judge their own skills in math and science more negatively than their male counterparts (Correll, 2001, 2004). This cumulative negative feedback regarding the appropriateness of science as an occupation for girls presents a problem for science identity formation.

Confidence & competence. Erikson (1968) described identity formation as an internal conflict that builds to crisis and resolves as either identity formation or rejection. Experience and feedback provide the evidence that justifies or negates identity (Erikson, 1968). Abundance of evidence produces competence, which in turn bolsters confidence and encourages the adoption of identity (McKinney, 2010).

Research on STEM identity formation in girls partially conflicts with this theoretical model. Mattern and Schau (2002), for example, found that middle school girls' interest in science, unlike that of boys, is not influenced by their performance. High performance or even improved performance (typically associated with confidence) does not increase girls' interest in science (Mattern & Schau, 2002). The difference between the interests of boys and girls in science is believed to be a function of direct engagement. Boys are more likely than girls to express their confidence in science and to directly engage in science activities that involve manipulation of equipment and experimentation, activities that have been shown to increase competence and confidence in science among both genders (Pajares, 1996, 2005b; Trower & Chait, 2002). During laboratory activities, girls typically take secondary roles such as note-taking and coordinating. These activities are not associated with interest and confidence building (Alper, 1993).

Correll (2001) found that girls self-assessed their competence in mathematics more negatively than equally competent male peers self-assessed their competence. Furthermore, boys of equal competence were more likely to enroll in advanced mathematics courses and to choose STEM careers than their female peers (Correll, 2001). In a later study, Correll (2004) found that women held higher standards than men for what constituted "high ability," contributing to a belief among women that they must perform at exceptionally high levels in math and science to successfully pursue STEM careers. Seymour (1995) found that a disconnect between women's expectations of performance and actual performance contributed to high attrition rates in introductory college level STEM coursework. That is, women who did not earn the high grades they expected to left science and engineering programs at higher rates than men who achieved more poorly than expected (Seymour, 1995; Seymour & Hewitt, 1997).

Science stereotypes and gender identities. Individuals adopt many different identities; once adopted, an identity may lose prominence for the individual, but will rarely disappear altogether (Erikson, 1968; McKinney, 2010). Identities can complement one another (good student, good scientist) and they can also conflict with one another (good girl, good scientist). Archer et al. (2010) found that perceptions of scientists were incongruent with girls' ideas about acceptable feminine identities (pretty, cautious, obedient). Girls expressed an interest in science, but an aversion to being a scientist because their mental image of the scientists was incongruous with their mental self-images as females (Archer et al., 2010).

Many authors have cited stereotypes that people hold about girls as not being suitable for STEM education and careers (Bayer Corporation, 2010; Hill et al., 2010; Stake, 2003; Stake & Nickens, 2005) as a contributing factor to gender disparities in STEM. More recent research with 2,535 high school students showed that students did not hold negative stereotypes about girls' science abilities (Kitts, 2009). Furthermore, the study also showed that girls in the study felt that science was interesting and that their parents would favor careers in science. However, it also showed that girls in the study simply were not interested in science. This implies that stereotypes about girls' capabilities in science were not holding them back. Expectations and stereotypes about science, however, can impact girls' assessments of the suitability of STEM careers for women. Given the relative parity in achievement between boys and girls, researchers are now looking at how the cultural landscape influences girls' ideas about science and science careers.

Archer et al. (2012, 2013) found that among elementary and middle school children, stereotypes about scientists were inconsistent with many girls' gender identities. Science and scientists were not perceived as feminine, caring, and active, which were traits girls identified with themselves. Stereotypes play a strong role in negative associations with science identities (Archer et al., 2010) and these stereotypes emerge early (Crowley, Callanan, Tenenbaum, & Allen, 2001; Cvencek et al., 2011). Children associate scientists with danger, poor physical hygiene, poor social skills, and being overwhelmingly male (Chambers, 2006; Steinke et al., 2007). The implication here is that stereotypes that are influencing girls' choices are not necessarily the stereotypes about girls as scientists, but the stereotypes about scientists that are not consistent with girls' identities and self-concepts.

Interventions that target the interest of girls in science through direct engagement in science activities, with manipulation of instrumentation and exposure to real scientists, may increase their likelihood of pursuing the rigorous academic preparation required for STEM careers (Eisenhart, 2008; Paulsen & Bransfield, 2010; Plant, Baylor, Doeer, & Rosenberg-Kima, 2009).

Girls and science identities. Research on girls' experiences, feedback, and confidence in science indicates that girls are positioned to succeed in STEM. They are prepared and view science as generally interesting and desirable. However, girls are not receiving the specific types of experiences their male peers are in terms of quantity and quality of science experiences (hands-on, exploratory) (Pajares, 2005a). Girls often do not have access to as many role models, though when they do, gender perceptions and disparities in STEM pursuit narrow or disappear (Riegle-Crumb & Moore, 2013; Buck et al., 2008). General societal messages about science present an image that is inconsistent with traditional gender identities (Byrne, 1993). These differences are contributing to a situation in which girls achieve in science, but do not ultimately form identities as scientists and as such are at risk of leaving STEM studies in favor of disciplines that are consistent with their identities and to which they feel more closely connected.

Self efficacy. Another aspect of persistence in any area of study or practice is self-efficacy, the beliefs individuals hold with regards to their ability to perform a task within a given domain (Bandura, 1977). Self-efficacy is not a surrogate for self-esteem or general confidence, but rather a dynamic, specific, and context-dependent set of beliefs. Individual self-efficacy, a component of social cognitive theory (Bandura, 1997b), is created by the individual's interpretation of input from four sources: personal mastery experiences, vicarious learning experiences, social persuasion experiences, and physiological state.

Mastery experiences. Personal mastery experiences are those that derive from successful completion of tasks of the same or similar nature to the task at hand. Successful completion of tasks perceived to be similar increases self-efficacy around a proposed task. Failure to complete similar tasks will result in reduced self-efficacy around a proposed task. Perceived failure has a more powerful impact on self-efficacy than perceived success (Bandura, 1997b).

Mastery experiences are analogous to experience in identity formation. In order for an individual to go through the process of adopting an identity, she must first gain experience with that identity. That balance of positive and negative experiences will play a major factor in the final identity status. Mastery focuses specifically on the individual's belief that she can be successful at tasks in the identity domain and the degree to which she feels successful. The greater the perceived mastery of a task, the stronger the self-efficacy (Bandura, 1997b). Perceptions of mastery can be highly specific, whereas identities are more general. An individual may have an identity as a scientist, and yet still have low self-efficacy in a particular discipline or domain. She may feel very confident in algebra and unskilled in geometry.

Mastery experiences are generally considered the most important component of self-efficacy; however, some researchers argue that statistical results of the effect size of mastery experiences have been biased by the order in which researchers enter variables into models (Pajares, 1997). Furthermore, context and past experience can play a role in the salience of different components of self-efficacy and in some domains may differ between genders—as is sometimes the case with another component of self-efficacy, vicarious learning.

Vicarious learning. Vicarious learning experiences are those that result from observing others perform a similar task. The process of observing others succeed (and fail), particularly individuals who are perceived to be similar to the observer, is another powerful predictor of self-efficacy (Bandura, 1997b; Zeldin & Pajares, 2000). Some research has found that in the STEM domains, vicarious learning is more predictive of success in women than men (Zeldin & Pajares, 2000).

The presence of similar peers and role models involved in an activity can bolster an individual's vicarious efficacy. As with identity, the chance to interact with and observe relatable individuals engaged in activities associated with an identity is a powerful signal of belonging. In the case of self-efficacy, vicarious learning opportunities bolster the individual's belief in her ability to try and succeed at new or novel tasks.

Social persuasion. Social persuasion experiences are the feedback received from influential persons (teachers, in-group members, authority figures, peers) about the individual's capabilities (Bandura, 1997b). Feedback can be overt or subtle verbal and social messages. Bandura (1997b) argues that social persuasion experiences are most powerful when individuals already have positive self-efficacy around a task. Social persuasion is also similar to micro-aggression and micro-inequities (Haslette & Lipman, 1997) and can have a strong role in discouraging women and minorities in areas outside of traditionally acceptable roles (Hackett & Betz, 1989). Social persuasion is analogous to feedback in identity formation.

Physiological state. Physiological state is often presented as a mediating source of self-efficacy that is highly context sensitive and works to enhance or reduce confidence in ability derived from other sources of self-efficacy. Mood, stress, and physical comfort can influence the individual's interpretation and assessment of abilities. Physiological state will not be discussed in depth here, but will be addressed briefly in analysis of fidelity in chapters III and IV.

Applied self-efficacy. Self-efficacy theory holds that perceptions of ability will predict the amount and duration of effort an individual will invest in an activity (Bandura, 1997b). Effort in turn is a strong predictor of success. In simple terms, an individual's belief in her ability to succeed is a strong predictor of motivation to persist in an area of study. Research into the self-efficacy of women and choices in careers has also shown that women's career choices are heavily influenced by self-efficacy and that self-efficacy is influenced by perceptions of the gender appropriateness of career types (Betz & Hackett, 1981). Gender, in fact, is a statistically significant predictor of self-efficacy above and beyond the four sources of self-efficacy, with women experiencing an average lower self-efficacy in STEM disciplines (Matsui, Mastsui, & Ohnishi, 1990). Fencl and Scheel (2006) found that certain types of instruction predicted lower self-efficacy in female physics students than in their male peers.

Mindsets and Science Persistence

In the 1980s Dweck, a student of Bandura, conducted a series of studies in how children responded to tasks that were designed to be too difficult for them (Dweck, 2007). What she found was quite surprising. Some students became frustrated, sought to avoid the tasks, or even reported they would try to cheat if a similar situation arose. Other students tackled the challenge with enthusiasm seeming to enjoy the frustration. From these early works Dweck developed the concept of *mindset*. She found that students who avoided the challenges were operating from a fixed mindset. That is, they believed that intelligence and talent are fixed, therefore challenges presented evidence of their lack of intelligence and talent. Students who enjoyed the challenge had adopted a growth mindset. These students viewed challenge as an opportunity to expand their understanding and grow their intelligence.

Dweck has identified four primary elements that influence the adoption of fixed or growth mindsets: process-based feedback, setting high expectations, challenge seeking, and teaching plasticity in learning.

Process-based feedback. Modern neuroscience clearly shows that human intelligence is not fixed, and that individuals can continue to learn and grow throughout the life cycle (Huttenlocher, 2009). However, an individual's mindset can influence the decisions she makes and the challenges she takes on. In fact, many girls adopt fixed mindsets around math and science while boys adopt a growth mindset (Dweck, 2006). This seems to be the result of the differing types of praise boys and girls receive in the classroom. Boys, often rambunctious and behind girls in the development of social skills, are praised for effort and process in science, while girls, often better behaved in the classroom, are praised for product and innate talent. Process-oriented praise contributes to the growth-oriented mindset, while praise for results and intelligence foster a fixed mindset (Dweck, 2007; Halvorson, 2011). Dweck and colleagues also demonstrated that mindset can be altered through liberal application of process-based praise and emphasizing to students the flexible nature of intelligence (O'Rourke, Haimovitz, Ballwebber, Dweck, & Popovic, 2014).

Setting high expectations. A rich body of research spanning several decades shows that students are more likely than not to meet the expectations of teachers and other authority figures, regardless of the level or quality of expectations (Hattie, 2003). Dweck argues that setting high expectations helps children develop resilience, as defined by Marsten (2001) as positive outcomes in the face of danger of failure or threats to adaptation of development. High expectations on the part of teachers and role models signals to learners that they are trusted, which encourages students to try harder and put more effort in correcting mistakes (Yeager et al., 2014).

Challenge seeking. Dweck and her colleagues found that children with a fixed mindset found challenges threatening. For these students being required to put effort into a task meant that they were not naturally gifted and challenged their sense of worth. For these students, effortless skill is a sign of success. Children with growth mindsets viewed challenge as an opportunity to learn and equated success with hard work (Dweck, 2008). Dweck advocates using process-based feedback (above) and framing as a method to shift students into growth mindsets. Teachers and mentors can encourage challenge seeking by framing hard work as a sign of growth and using mistakes as learning opportunities rather than simply praising students for easy tasks (Dweck, 2007, 2008).

Teaching plasticity. Dweck also emphasized the importance of explicitly teaching neural plasticity (Dweck, 2006, 2008; Yeager & Dweck, 2012). That is, fostering the idea that humans can become smarter with effort and practice. A key element of the fixed mindset is that talent and brilliance are innate to the individual, therefore, if she is not automatically good at something she cannot improve over time. Societal messages about science and gender foster fixed mindsets in girls. Dweck found that girls were more likely than boys to adopt fixed mindsets with regards to math and science and less likely to persist through failures in STEM activities (Dweck, 2006, 2008). Fostering the idea that intelligence is flexible and framing failures as part of a learning process helps individuals adopt a growth mindset and resilience.

The inevitable frustration and failures that come with studying science rapidly prove unattractive and disheartening to students with the fixed mindset (Dweck, 2008). Rather than continue down a path the constantly affirms their lack of intelligence and talent, girls and women often focus their efforts in areas where they have a growth mindset. Recent studies show that emphasis on innate talent over growth is contributing to women's choices in careers. Women, more than men, opt for careers that do not emphasize innate talent as a prerequisite for success (Leslie, Cimpian, Meyers, & Feeland, 2015).

Integrating identity, self-efficacy, and mindsets. The foundational theories discussed above overlap substantially, but also provide a unique lens on the issue of gender disparities in STEM. Figure 6 represents a synthesis of the relationship between the theories graphically. Identity and self-efficacy share the closely related elements of experience and mastery. Self-efficacy and mindsets are both built around fostering expectations/vicarious learning by mentors and through examples. Mindsets and identity share the need for confidence building through challenge seeking and perceived successes. All three theories share feedback as a core element.

Another key element shared by all three theories is that they are all based in the beliefs of individuals. Whether or not an experience builds identity or self-efficacy is not the result of any objective measure, though the individual's assessment may be based somewhat or entirely on external assessments. Two individuals may interpret outcomes very differently. In Dweck's early studies children faced identical challenges, but their interpretation of the activities and their own performance varied widely depending on their mindset. Individuals may view a very difficult puzzle that they fail to solve as a success, because they learned something new. Or they may view an easy challenge they succeed at as a failure, because they did not perform to their own high standards. These areas of overlap present concentrated opportunities to help build identity and self-efficacy around science.

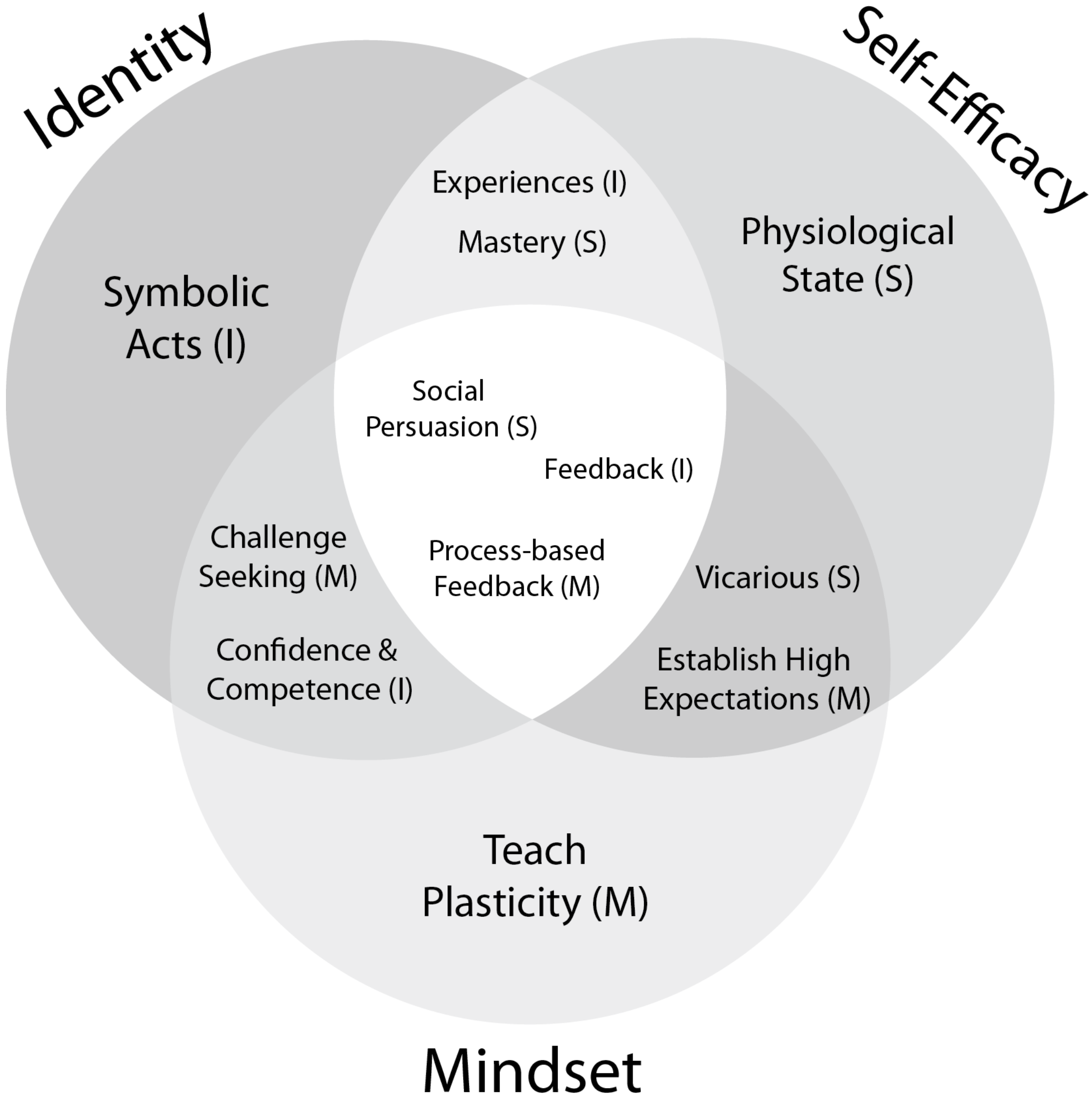


Figure 6. Venn diagram of the overlapping elements of the theories of identity, self-efficacy, and mindsets.

With this in mind, the success of an activity can be rooted more in the framing of the results than in any objective measure of success at a task. The feedback elements of each theory are crucial in helping individuals frame their experiences in a positive identity/self-efficacy building light.

The theories also differ in specific ways. Identity is more generalized and related to an individual's wider self-concept. Self-efficacy, on the other hand, is typically specific within disciplines and domains. To build a strong sense of identity, the individual will need to build efficacy in many small ways. Mastery of one sub-task is unlikely to build a strong overall science identity. Mindsets are likewise specific. Individuals may have very different mindsets about different disciplines and even between very similar tasks. Fostering a growth mindset in science will generally involve fostering the mindset in many more specific areas.

Identity and self-efficacy can be cultivated, and once established can be expected to persist. Individuals with strong identities and efficacy will be more likely to seek out positive experiences in these domains, so in a way, identities and efficacy can be viewed as self-sustaining—though over time, negative experiences may undermine these identities. Mindsets in a domain may also persist, however, they do not implicitly contribute to interest in a subject area. Individuals may have growth mindsets around science, but not adopt a strong interest or identity. For this reason, mindset should be thought of more as a tool for fostering identity and self-efficacy.

Conceptual Framework

The theories of identity, self-efficacy, and mindsets provide the foundation for developing an intervention that will help girls build science identities and self-efficacy. The SPICE program has been designed to operationalize these theories into practice by providing experiences that contribute to identity formation and self-efficacy building using techniques designed to foster growth mindsets in science. Figure 7 provides a logic model for how theoretical elements have been operationalized into program elements, the expected manifestations of successful intervention, and the final goal.

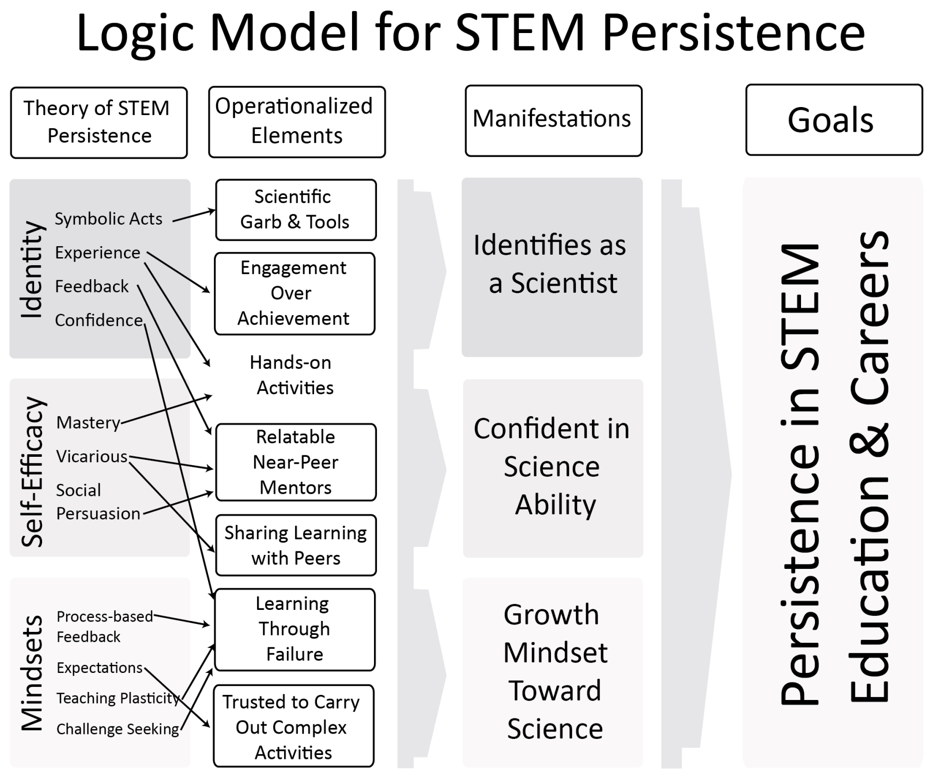


Figure 7. A logic model for applying theories of identity, self-efficacy, and mindsets to an informal science outreach intervention with the expected manifestations of successful implementation.

This study will examine if SPICE participants demonstrate evidence of the desired manifestations of identity, self-efficacy, and mindsets. The study will also explore participating girls' attitudes toward science and preferences for STEM education and careers, both in relation to the program and in their lives in outside of the program.

The foundational theories of identity, self-efficacy, and mindsets will inform the methods, analysis of the data, and the interpretation and implications of the results. Theory and practice from the world of informal science education and gender theory will also be employed to provide context for the results. This study will also go beyond the theoretical framework described above to develop new theory in how girls in the study form science identities, what these identities represent, and how they differ between girls.

The key constructs under examination will include participating girls' science identities, science efficacy, attitudes toward science, personal interest in science, perceptions of societal gender expectations, and preferences for science engagement. Figure 8 shows a map of the full conceptual framework including the sources of gender disparities in STEM, foundational theories, and key concepts.

A number of sources of disparities in gender representation in STEM have been presented in this literature review. This dissertation will focus on girls' science identities, or lack thereof, as the disparity source of primary interest. Utilizing the theoretical framework developed above, this dissertation employs an informal science intervention targeting middle-school-aged girls to identify and analyze methods of operationalizing identity formation principles. The study and the program are also informed by best practice recommendations from informal science education experts. These best practice recommendations will be discussed in further detail in chapter IV (results) and chapter V (discussion). Research data will be collected to measure the expected manifestations of successful science identity formation: science interest, science efficacy, identifying as a scientist, and attitudes toward science.

Research will employ mixed methods for two broad purposes. First, hypothesis testing using primarily quantitative data will assess program fidelity and outcomes to determine if participants demonstrate an increase in science identities, efficacy, attitudes, and interests. Second, primarily qualitative data will be used to build theory around participants' science identities. This theory will address how girls develop identities, what kinds of identities they develop, and how teachers and parents can support science identities in girls.

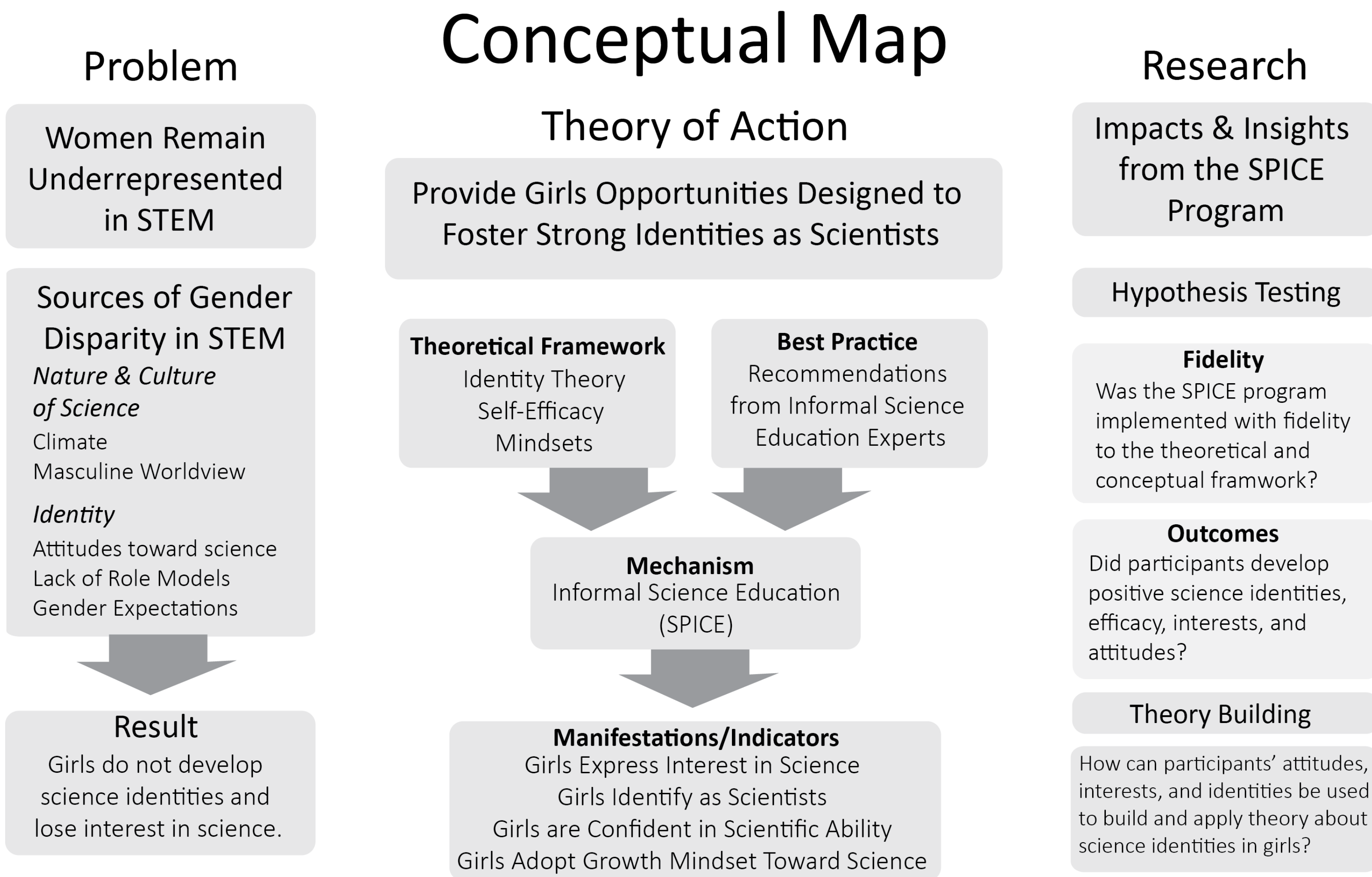


Figure 8. A concept model outlining the problem, problem sources, theory, and concepts informing the theory of action and the study components.

CHAPTER III

METHODS

This dissertation addresses the issue of gender disparities in STEM using data collected from participants in an informal science outreach intervention for middle-school-aged girls. The study employs a mixed-methods approach with three components. Component 1 (research question 1) addresses program implementation fidelity using data from participant evaluations, fidelity rubrics, and qualitative observations. Component 2 (research questions 2–5) addresses participants' science affinities using pre- and post-intervention survey data, observational notes, focus group interviews, and individual interviews. Component 3 (research question 6) employs observations, focus group interviews, and individual interviews to build theory about the types of science identities participants develop and the implications of these identity types for encouraging more girls to pursue STEM education and careers.

This chapter is presented in eight parts:

- Introduction and road map (this section)
- Study components overview
- SPICE program implementation
- Research design
- Sample
- Instruments and measures
- Data collection and timeline
- Analysis

The study components overview section will revisit the research questions relevant to each study component, present hypotheses as appropriate, and briefly discuss the approach for each component. SPICE program implementation will address the unique features of the program as they relate to the theoretical and conceptual frameworks. Sample will provide relevant details about study participants, the selection process, and participant attrition. Instruments and measures will present all of the research instruments utilized in this study as well as information about their development and validation. The study history will be chronicled in the data collection and timeline section. Next, the research design will be described for each component. Lastly, a detailed description of the analyses conducted, organized by research component, will be presented.

Study Components Overview

The results of the study will be presented in three components. These components are fidelity, science affinities, and science identity theory building. The components are differentiated by the purpose behind the related research question(s).

Component 1—Fidelity. As with any intervention study, fidelity of implementation is an important component for both understanding the results and drawing inferences from the data. Correct implementation reduces uncertainty and thereby increases internal validity. Research question 1 explores program implementation. The ability to clearly answer research questions 2 through 5 (component 2) is predicated on the assumption that the program was implemented with fidelity to the conceptual framework. Failure to implement correctly would compromise the results, introducing ambiguity into any inferences. For example, if the program was implemented with poor fidelity and girls reported low science affinities after camp, was this due to outside factors or to the poor quality of program implementation? For this reason, fidelity of implementation was included as the first research question.

The SPICE program does not employ a formal curriculum, nor are there any required learning outcomes. Fidelity of implementation resides in responsiveness to student engagement. Instructors are required to maintain a balance between keeping campers with different science backgrounds and skills interested and challenged by activities without making tasks so difficult that students become frustrated. Camp activities are structured to be short and high impact. Activities range from 20 to 40 minutes in the 6th grade camp and increase in duration and difficulty in subsequent camps. Instructors are trained to recognize when students are disengaging and to take action. If an activity is not engaging students, instructors can solicit camper feedback on how to improve the activity, take a break, or stop the activity early and move on to something else.

What does fidelity look like at SPICE camp? Based on the foundational theories, SPICE camp activities should be primarily hands-on and employ the language and tools of real scientists whenever possible. Students are led by enthusiastic relatable role models and have ample opportunities to share their learning process with peers. Instructors should provide context for learning through failure, and provide process-based feedback and praise. Participants engaged in a SPICE camp activity are expected to show evidence of engagement such as asking questions, making observations, sharing observations with peers, and to demonstrate upright engaged posture, animated speech, or voluntary active note-taking. Participants should not be slumped, doodling, sighing, expressing boredom, or actively disrupting the activity for others. These are signs of disengagement. Of course, it is not possible to sustain a high level of engagement for all campers at all times. A reasonable level of fidelity requires that the majority of campers be enthusiastically engaged with activities at any given time.

The question of fidelity of implementation was addressed using a fidelity rubric, camper evaluations, and observations of participants engaged in camp activities. The fidelity rubric was designed to reflect the theoretical framework and contained operationalized elements of identity, self-efficacy, and mindsets. Additionally, campers completed evaluation forms at the end of week 1 of the camp. These forms were used by instructors to inform activities for the second week of camp, but are also included in this analysis as a direct report of camper engagement, a key element of implementation fidelity. Lastly, the researchers took field notes during observations, which they turned into formal research notes. Data analyses included descriptive statistics on scores from the fidelity rubrics and camper evaluations, inter-rater reliability statistics, and qualitative review of observational notes. Rubrics, inter-rater reliability statistics, and camper evaluation forms will be presented in detail in the instruments and measures section of this chapter.

The purpose of the fidelity component of this study is to provide evidence that the program was implemented as intended and to provide an extra measure of internal validity. As 2014 was the seventh year of the SPICE program, the directors have had many years to refine and improve program implementation. Based on the program history, it was hypothesized that the program would be implemented with high fidelity to the theoretical framework.

Component 2—Science affinities. Research questions 2 through 5 address the predicted core manifestations of science identity formation, referred to here as science affinities. These affinities are: interest in science, efficacy in science, attitudes toward science, and identifying as a scientist. Each question will be addressed using pre- and post-camp survey data, as well as focus group interviews and individual interviews. Measures mentioned below will be discussed in detail in the instruments and measures section later in this chapter.

Participants in this study are girls attending a science summer camp. As such, they are expected to have high initial science affinities. In order to substantiate this assumption, data was also collected from a comparison group from another outreach program on campus targeting high-achieving students. The comparison program does not have a science focus, though there are some elements of the program that have science elements. The only data collected from these campers included gender and quantitative measures of pre-camp science affinities. These participants will be discussed in greater detail in the sample section of this chapter.

Preferences and interests. Research question 2 addresses campers' preferences and interests with regard to science. Interest is a large component of identity formation. Individuals are unlikely to form an identity around a subject they are uninterested in (Erikson, 1968; Marcia, 1966). It is therefore desirable to explore both how interested participants were in science and the nature of their preferences and interests in science. The question of how interested campers were in science was addressed using a quantitative instrument designed to measure personal interest in science that was administered before and after camp. The nature of participants' preferences and interests in science was addressed using focus group and individual interview data.

The hypothesis was that SPICE participants would have higher initial interests in science than the comparison group. Furthermore, SPICE participants were hypothesized to show an increase in interest in science from pre-camp to post-camp on the personal interest scale. Qualitative data was used to elaborate and explain these results in girls' own words.

Science efficacy. Research question 3 addressed participants' science efficacy. For the purpose of this research, girls' efficacy in science is defined as both perceived ability and value for the subject matter. SPICE girls may perceive themselves and their female peers as capable scientists, but lack the requisite interest to motivate the development of skills and identity. As shown in the study by Mattern and Shau (2002), interest and ability may not be correlated for girls of this age group in the area of science. The addition of value for science to the measure of confidence in science helps to provide nuance to girls' science efficacy. These two concepts have also been paired by other authors (J. S. Eccles et al., 1984; Else-Quest et al., 2013; Fredricks & Eccles, 2002). The purpose of this question was to probe SPICE girls' ideas about both their ability and interest in science. The question of camper science efficacy was addressed using a quantitative instrument designed to measure confidence in scientific ability and value for science education. Data from the focus groups and individual interviews provides context and nuance for the quantitative findings.

The hypothesis was that girls would have higher initial science efficacy than the comparison group, and that their efficacy would increase from the pre-camp to post-camp time frame as measured by instruments for confidence in scientific ability and value for science education.

Attitudes toward science. Research question 4 addressed campers' attitudes toward science. Attitudes toward a domain are expected to play a strong role in identity development. Negative attitudes toward a domain associated with an identity will tend to push the individual away from adopting an identity. If other sources of identity formation in that domain are strong (feedback and experience), negative attitudes can contribute to role confusion, a state in which the individual does not adopt identities positively and may actively rebel against identities endorsed by authorities (Erikson, 1968). Science identities are more specific than the general self-concept that Erikson theorized. Students with negative attitudes toward science will most likely simply not adopt a science identity. The question of camper attitudes toward science was addressed using a quantitative instrument designed to measure attitudes toward science. Camper attitudes toward science were also informed by qualitative data from the focus groups and individual interviews.

The hypothesis was that SPICE girls would have higher initial positive attitudes toward science than the comparison group. Furthermore, it was hypothesized that the initial interest would increase from the pre-camp to post-camp time frame as measured by the scale of attitudes toward science.

Identity formation. Research question 5 addressed campers' emergent science identities. The SPICE program was designed to create conditions expected to support identity formation. This research question addresses identity by querying campers directly about their identities. The question was addressed using a quantitative instrument designed to measure science identity, and through the focus groups and interviews in which campers were directly and indirectly queried about their science identities.

The hypothesis was that SPICE girls would show an increase in science identity from the pre-camp to post-camp time frame as measured by the scale of science identity. Qualitative data will provide additional context for these findings.

Component 2—Purpose. The intent of component 2 is primarily hypothesis testing. The questions in this component seek to explore the impacts of the program, though no causal claims can be made given the research design (see below). Is there evidence that the program is providing the kind of experiences that foster identity? If so, what manifestations of successful intervention appear in girls? These questions are answered with quantitative data and given context by the qualitative data, though results will reach beyond simply answering the research questions yes or no. The focus group and interview data collected go beyond girls' opinions about the SPICE program into their more general views about science, society, and gender.

Component 3—Science identity theory building. Component 2 of this study seeks to answer the questions "how much" (how much do attitudes toward science increase or decrease in SPICE girls) and "what" (what do SPICE girls think about science and scientists). Component 3 addresses the questions "how" and "what kind." This component (research question 6) shifts from the hypothesis-testing frame of component 2 into building theory around how girls develop science identities and what forms those identities take. Results for this component will cover new ground outlining five distinct new identity types derived from study of the SPICE participants. Data for this component is drawn from observations, focus groups, and interviews.

The purpose of this component is to move beyond a monolithic understanding of girls' science identities that focuses on between-group differences (girls vs. boys) into a more nuanced realm for understanding the within-group differences. These differences are manifested in the girls' varied identity styles and how these identity styles interact with gender expectations.

Next the discussion moves on to an overview of how the SPICE program operationalizes the theoretical framework, including the program approach, curriculum, and instructor training and expectations.

SPICE Program Implementation

As an informal enrichment program, SPICE is not bound to particular learning outcomes. While science activities are all designed to be informational and help students build skills, the program philosophy and approach is to maintain high energy and enthusiasm around science. For that reason, activities are designed to be highly hands-on, with minimal lecture and instruction. Campers are encouraged to experiment and explore. Instructors are trained to act as facilitators and advisors. Though the camps' themes are fixed, specific activities shift from year to year based on feedback from campers and the interests and skills of current instructors.

Engagement and fun are the major program emphases—for this reason, instructors are empowered to abandon or take a break from activities that are not sufficiently engaging campers. If overall engagement among campers diminishes to the point that the majority are displaying boredom or disinterest in the activity (e.g., heads down, doodling, side conversation), instructors can wrap up early and move on to the next activity, or take a break by going outside or playing games. Likewise, if an activity is very popular with the campers, instructors have latitude to extend the activity or revisit it again later during camp, as time allows.

The theory of action underlying the SPICE intervention is to facilitate girls' identity formation and self-efficacy through hands-on experiences and feedback from peers and relatable mentors. Girls with developed science identities are hypothesized to be more likely to pursue STEM education and potentially future STEM careers. Research in identity and career persistence indicates that many women who leave careers such as engineering do so in part because they have not developed identities as professional practitioners of their chosen field of work (Brainard & Carlin, 1998; Glass et al., 2013). Developing strong, early science identities is hypothesized to be a precursor to developing future professional identities (Tai, Qi Liu, Maltese, & Fan, 2006). No extant research on the long-term persistence of early science identities has been identified; however, anecdotal evidence suggests that early interventions can be effective in engaging girls' interest in science (Dukeshire, 2014; Ride, 2012). Many current practitioners identify an early positive learning experience such as a passionate teacher or a special program that sparked their interest in a particular STEM field (Dukeshire, 2014; Ride, 2012).

Curriculum. SPICE does not have a set curriculum that is reused each year. Each camp has a theme and instructors assemble a curriculum from an existing pool of tested curriculum and by developing or adapting their own new curriculum. Program guidelines require that activities fit within the camp theme, and that they meet the criteria for operationalizing the foundational theories. That is, activities should be predominantly hands-on, engaging, use the tools and language of science, and explore subject matter through inquiry. Instructors work closely with the director to ensure that curriculum meets camp standards for providing identity and efficacy building opportunities.

Curriculum goals and rigor increase with each year of camp. Discovery camp curriculum is largely episodic, covering a range of topics and approaches, though data collection remains a theme in the majority of activities. Activities in the Forensic Investigation camp follow the theme of data collection and analysis, with a focus on using deductive reasoning to eliminate possible explanations for each crime scenario. The Engineering and Computer Science camp is the most rigorous, with each activity providing a new skill or tool necessary for the pinball machine construction. A full list of camp activities is provided in appendix A. An account of the program history and description of each camp is provided in appendix B.

In addition to curriculum-based science activities, instructors also prepare a host of fun group-based games with science themes. Games are used to provide a break between activities, fill gaps in the schedule if an activity is cancelled or takes less time than expected, and to help students release pent-up energy if campers have been sitting inside for too long. Instructors are encouraged to use games to help students refocus and relax if they become disengaged or show signs of stress from a challenging activity.

At the end of camp, girls present their favorite activities, crime scenes, or pinball machines in small groups to an audience comprised of fellow campers, instructors, and parents. Though learning outcomes are not the focus of SPICE camp, the girls consistently display mastery of new terminology, scientific concepts, and skills during these presentations.

The "M" in STEM. Mathematics is an integral part of STEM education, it however, and area in which SPICE has traditionally been weak. Math skills and positive attitudes toward math are an important part of developing as a scientist (Dweck, 2006, Halpern et al., 2007). Historically, girls have performed more poorly in mathematics than boys, though the math gap has all but disappeared (Nord et al., 2011). There are no activities included in SPICE camp that *explicitly* focus on mathematics. However, math concepts and skills are employed in a subset of SPICE activities.

The Science Scavenger hunt carried out on the first day of SPICE camp uses basic mathematical concepts. Campers float rubber ducks down the Cascade Charlie waterfall and calculate average descent times in order to receive a clue. At the Autzen Footbridge over the Willamette River, they use "analog measuring tools" (their own limbs and bodies) and proportional relationships, to measure the width of the river. In the Forensics Investigation camp, girls used simple force and acceleration formulae to estimate the speed of cars involved in accidents using simulated skid marks. In the stride length analysis activity they calculate individual heights using stride lengths measured from footprints. They then plot the results and examine the graph for relationships between stride and height. During pinball machine construction, girls measure components and distances for proper installation. They calculate angles, radii, and arcs in flipper construction. They also explore mathematical relationships during programming to determine optimal intervals for sensor input and outputs for lights and sound.

Historically, SPICE girls have resisted some computational activities such as the skid mark analysis, but have embraced others, such as the stride analysis. Their willingness to engage in computation, as with other STEM activities, seems to be related to the hands-on nature of the activity. Stride analysis involved active movement and measurement, where the accident reconstruction took place mostly at a table. Discovery camp girls sometimes needed prompting before they understood what is being asked of them in the analog measurement activities, however, once they grasp the underlying concept, they engaged with enthusiasm. Engineering campers' enthusiasm for mathematical tasks appears directly related to their perception of an interesting application for their own pinball machine.

Instructors. SPICE instructors are primarily drawn from University of Oregon undergraduate and graduate science students. Each camp has two paid lead instructors who are responsible for setting the schedule of activities, assembling supply lists, and directing other instructors. Volunteer instructors assist the lead instructors, direct activities, develop curriculum for camp activities, and work with small groups of campers on projects. Each camp typically has 6 to 8 volunteer instructors, mostly undergraduate students. Camp alumni also return as assistant instructors. Assistants perform a range of duties from helping with the coordination and organization of supplies to escorting campers around campus, roleplaying parts in the forensics mysteries, and assisting with instruction. Additionally, five former SPICE campers returned as junior assistants in 2014. The junior assistants helped with setting up activities, ran errands, and assisted younger campers with activities.

Instructor selection. Instructors are recruited through academic departments and student groups on the UO campus using email lists, flyers distributed throughout campus, and through social media. Students with a science background (formal or informal) or teaching experience and interests are encouraged to apply for paid and volunteer positions. The director and associate director review applications and invite promising applicants to interview. Many applicants have already worked with the program on smaller outreach events during the academic year and have a track record with the program. Others have experience working in other science outreach programs, summer camps, or volunteering with after-school programs. Instructors typically start in smaller volunteer roles. Those instructors who show skill and interest are invited to take on lead roles in the camp the next summer. Many lead instructors work with the program for 2 to 4 years before graduating.

Three lead instructors in the 2014 camp were returning to the program from 2013. Three were new to the program and came with strong experience in sharing science in informal environments.

Instructor training. Instructors are trained in basic pedagogy of science outreach, introduced to major learning theories, and the camp theory of action. Instructors attend a series of trainings prior to camp, including introduction to science outreach and pedagogy, learning theories, and brain-based learning. Workshops are taught by the program director and experienced SPICE program instructors and each last for two hours. A fourth workshop provides time for lead instructors to meet with their assistant instructors, test curriculum, and set schedules in consultation with the program directors. Group leaders also meet with the program director several times during the weeks prior to camp to discuss curriculum specifics.

Introduction to science outreach and pedagogy training. The introductory training session includes an overview of the history of SPICE camp and the theoretical perspectives of science outreach as set forth by the national research council (Bell et al., 2009; Duschl, Schweingruber, & Shouse, 2007; Fenichel & Schweingruber, 2010). Theoretical perspectives include rationales for conducting outreach, theories of lifelong learning, integrating scientific learning into everyday life, and the people, place, and cultural positioning of scientific knowledge (learning). This workshop also includes information on the developmental capabilities of school-aged children (Oregon Department of Education, 2009) and a thorough introduction to the camp tenets and approach.

Instructors are trained to gauge camper enthusiasm both in the group as a whole and among individual campers. If an activity is not engaging a majority of campers, the instructors are encouraged to speed up the activity and move along. If any particular campers are consistently showing disengagement across multiple activities, instructors are trained to investigate the sources of camper discontent and make appropriate corrections.

Integrated into the workshop are hands-on activities that are used with children by the SPICE program, such as the "Mystery Box," an introduction to the scientific method through hands-on exploration, and "Paper Airplanes," an introduction to developing research questions with children. Instructors take the role of children and carry out the activity per trainer instructions. Trainers comment on the process of how to work with children and provide advice and answer instructor questions throughout.

Learning theories training. The learning theories workshop provides a brief introduction to behaviorism (Watson, 1930), constructivism (Piaget & Inhelder, 1969), and sociocultural/sociohistorical learning theories (Vygotsky, 1978), as well as research on girls' preferred ways of learning science (Baker, Krause, Yasar, Roberts, & Robinson-

Kurpius, 2007; Brickhouse et al., 2000; Olitsky, 2007), identity formation (Erikson, 1968), and self-efficacy (Bandura, 1997b). Instructors are provided examples of how to give process-based feedback that supports identity and self-efficacy formation and then practice on each other by taking turns acting as students and instructors while completing a problem-solving activity. The group also discusses how learning theories relate to practice and share experiences.

Brain-based learning training. Instructors are introduced to principles of brain-based learning including memory and attention, neural plasticity, and mindsets as they relate to informal learning (Bransford, Brown, & Cocking, 2000; Dweck, 2007; Scalise, 2012). Activities focus on demonstrating the limits of human attention when dealing with novel tasks and practicing giving process-based feedback. Time is also provided in this workshop for instructors to discuss logistical concerns, to confer on curriculum changes, and develop supply lists for activities.

Program, curriculum, and instructors summarized. The SPICE program is an intervention like many precollege outreach programs, with a specific goal of increasing girls' participation in STEM. However, unlike other such programs, SPICE has no specific expected learning outcomes. The program approach is focused instead on creating an environment that fosters girls' science affinities. Curriculum is selected and developed with this in mind. Instructors are trained to provide science experiences that operationalize the theoretical framework and build enthusiasm for STEM.

Research Design

This dissertation study is presented in three components. The research design for each component is discussed separately below.

Component 1—Implementation fidelity. The research question for component 1 addresses implementation fidelity. The data collected included scored fidelity rubrics, camper evaluations, and researcher observation notes, which were used to answer the question "Was the SPICE program implemented with fidelity to the theories of identity, self-efficacy, and mindsets embodied in the program model?" The design for this component is descriptive. The question requires a summative judgment about the camp implementation based on descriptive statistical and qualitative data. The data set is cross-sectional. Though multiple observations were completed, they took place only during the intervention, and should be considered a collective snapshot of camp fidelity. Both the quantitative and qualitative data provide evidence for the absence or presence of the identified operationalized elements of identity, self-efficacy, and mindset building.

Component 2—Science affinities. This component examines the intervention element of the study using a pre-post research design with a partial contrast group (see figure 9) utilizing mixed methods. In this case, the treatment is the SPICE camp. A contrast group measured prior to an alternate treatment was also examined.

Treatment 0_1 X_1 0_2

Contrast 0_1 X_2

Figure 9. Research design with repeated pre- and post-test measurements and alternate treatment contrast group.

Treatment group participants were administered pretests on the first day of camp to measure their preexisting science affinities. Posttests of the same measures were administered again four to eight weeks later via online Qualtrics survey. Contrast group participants were administered the same quantitative measures on the second day of their program. The contrast group did not participate in interviews and focus groups. Parents for treatment groups were administered the parent questionnaires before and after camp. Qualitative data was collected using observations and focus groups during camp and through interviews of selected campers later in the summer and fall.

Component 3—Science identity theory building. This study component follows an exploratory inductive research design. Unlike a grounded theory design (Miles, Huberman, & Saldaña, 2015), which calls for no prior assumptions or expectations on the part of the researcher, this study began with prior expectations based on the literature about girls and science and results from the pilot study. The purpose of this component was to explore specific ways in which participants build identities with science, the characteristics of those identities, and how the identities framed their experiences with science. There was no hypothesis or goal for this component beyond gaining a better understanding of participants' science identity formation process. Evidence from this research component came from focus group and individual interviews and to a lesser extent from camp observations.

The discussion of methods now turns to the research sample and recruiting.

Sample

The research population for this study was drawn from participants in the SPICE summer science camps. SPICE provides three, cohort-based camps of 20 participants for an annual total of 60 campers entering 6th, 7th, and 8th grades. In 2014, 58 campers were admitted to the program. Of that total, 55 campers agreed to participate in the research study.

Recruitment. Participants are recruited from elementary schools in the Eugene, Bethel, and Springfield school districts, homeschool networks, partnerships with area nonprofits that serve youth, and word of mouth in the community. Program materials were sent to local 5th through 7th grade teachers and principals, and through science outreach LISTSERVs, community calendars, newspaper advertisements, partner organizations that work with middle-school-aged students, and the offices of nontraditional student programs at the University of Oregon. The cost of attending camp was $300 for the full two weeks. Scholarships of varying amounts were made available to all campers. No camper has been refused for inability to pay.

Most students are recruited during their 5th grade year with the expectation that they will stay with the program for the full three years. However, a few students are recruited following the 6th and 7th grade years to replace students who drop out of the program. Each cohort consists of approximately 20 campers. Of the 55 participants from 2013 camps, 31 returned for 2014. Of the nonreturning campers, 20 graduated and four elected to leave the program. The total number of new campers was 27.

Application to camp can be completed online or through a paper form. The application requires contact and demographic information only. There are no competitive aspects (e.g., essays, transcripts, letters of support) to the process. If applications exceed the number of spots in camp a random draw is conducted. In 2014 the number of campers who applied to the program by the application deadline did not exceed the available spaces.

Summer Enrichment Program contrast data. SPICE campers are predicted to have high starting science affinities. As such, detecting changes in affinities may prove challenging. In order to confirm this hypothesis and provide context, a pre-intervention contrast group was identified. Contrast data was provided by another program that takes place on the UO campus: the Summer Enrichment Program (SEP), who provided access to their students for this study. Of the 90 domestic students participating in SEP, 74 consented to be a part of this study.

SEP has been functioning on the University of Oregon campus for 30 years (Nolan, 2014; Youth Enrichment Talented and Gifted, 2014). It is a residential program, meaning participants stay overnight in campus housing for the duration of the two-week program. Most participants come from Oregon—however, a number also come from across the country and even internationally. SEP covers students in grades 6 through12, though most participants are in 6th through 8th grades.

SEP is a program for “academically motivated” students. Most participants have been identified as “talented and gifted” in their regular schools. Applicants must complete a rigorous application process that includes multiple essays and can involve the submission of work examples including art pieces and academic reports (Nolan, 2014; Youth Enrichment Talented and Gifted, 2014). The cost of attending SEP was $1,600. The program awarded $30,000 in financial aid, the equivalent of 19 full scholarships or 21% of participants. By contrast, SPICE provides financial aid equivalent to 24 full scholarships or 40% of participants. In 2014, 60% of SPICE campers received partial or full scholarships. Limited demographic information was available for the SEP students. SEP administrators provided only gender identity.

SEP uses a block-style schedule with participants attending four classes per day. Classes cover a wide range of disciplines from humanities to social sciences to STEM. Approximately one-third of courses in summer 2014 had science or math as a component of coursework. Most classes were interdisciplinary in nature. A complete schedule of classes taught in 2014 is included in appendix D. Classes are taught by experts in their field, many of whom are university professors, professional educators, or researchers. Instructors must submit comprehensive proposals for the classes they plan to teach well in advance of camp (Nolan, 2014).

SPICE is an informal science outreach day camp serving 11-to-14-year-old girls, most of whom have a preexisting interest in science. More than half of SPICE campers received scholarships. Admission to the program is open to all girls entering 6th through 8th grades. Application is not competitive. SEP is a residential, formal enrichment program for talented and gifted students. The cost of attending the program is high, with scholarships available at a much lower rate than SPICE. Admission to SEP is highly competitive and requires the completion of multiple essays, teacher letters of support, and substantial parent involvement in the process. Applicants range in age from 11 to 16. SEP coursework ranges from the humanities to the sciences, though no exclusively science-bases course were provided in 2014. Given the different focuses and methods employed by these two programs, it is reasonable to expect that the two groups also differ in terms of their science engagement and affinities.

Research with human subjects. Approval for research with human subjects was obtained from the UO Institutional Review Board prior to data collection. Consent forms detailing the study purpose and activities were collected from parents. The research project was described directly to both the SPICE and SEP campers by the researcher in person and then written assent was obtained. Anonymous ID numbers were used on surveys and other written materials so only the researcher could link responses to a specific participant. Participants were informed that individual interviews would be kept confidential, but that focus groups could not be considered confidential due to the presence of other participants. Participants were discouraged from divulging sensitive or private information in the focus groups.

The researcher and assistants, who were included as personnel on the approved human subjects protocol, transcribed interviews and focus groups. Transcription and analysis took place in the researchers' offices on secured computers. No sensitive data was collected during this study, but precautions were taken to protect participants' identities nonetheless.

Instruments and Measures

Instruments employed in this study include questionnaires and surveys, a fidelity rubric, research notes and memos from observations of camp activities, and focus group and individual interview transcripts. Additional data, such as demographic information, were collected from program administrative data. This chapter will detail each research instrument, the associated constructs they are designed to measure, and the means by which they were administered or completed.

Treatment fidelity measures. Three data sources were employed to determine treatment fidelity. The first, a fidelity rubric, provided a structured way for researchers to rate implementation of the operationalized foundational theories. The second data source used was participant evaluations. Lastly, research notes and memos produced through unstructured observations of participants engaged in camp activities were used.

Fidelity rubric. The researchers used an observational rubric developed from the conceptual framework for the study. The rubric required the rater to assess the degree to which an activity was implemented. The rubric contains six sections with a total of 36 operationalized indicators of adherence to the key principles of identity, self-efficacy, and mindsets (see figure 10). Raters selected from four options indicating the degree to which the activity was in alignment with each item. The options were represented as percentages. Raters were instructed to indicate how much of the activity, in terms of time or content as appropriate, were spent on each item. Rating options were 15%, 40%, 60%, or 80%. Not all items on the rubric were relevant for every activity. In cases where items were not appropriate, raters were instructed to mark the item "not applicable."

Observations were made in all three camps on seven of the nine days. In order to assess inter-rater reliability, two observers conducted 16 of the 23 observations. Researcher schedules did not permit the presence of two raters at each observation. Early observations were videotaped and reviewed at the end of day by the researcher and three researcher assistants. Researchers compared protocols and notes at the end of each day to review rubrics and discuss areas of disagreement for the first two days of observation.

Research assistants participated in all-instructor trainings prior to camp including identity, self-efficacy, camp theory of action, and the pedagogy of outreach. Additionally, the researcher and research assistants reviewed transcripts from the pilot data from 2013 as practice for improving consensus in observations and the types of responses that can be expected.

Camper evaluations. At the end of the first week of camp the participants in the Discovery and Forensics camps completed evaluations of the activities in which they had participated. Instructors in the Engineering camp neglected to collect the evaluations. Evaluations were anonymous and provided on paper. Campers rated each activity

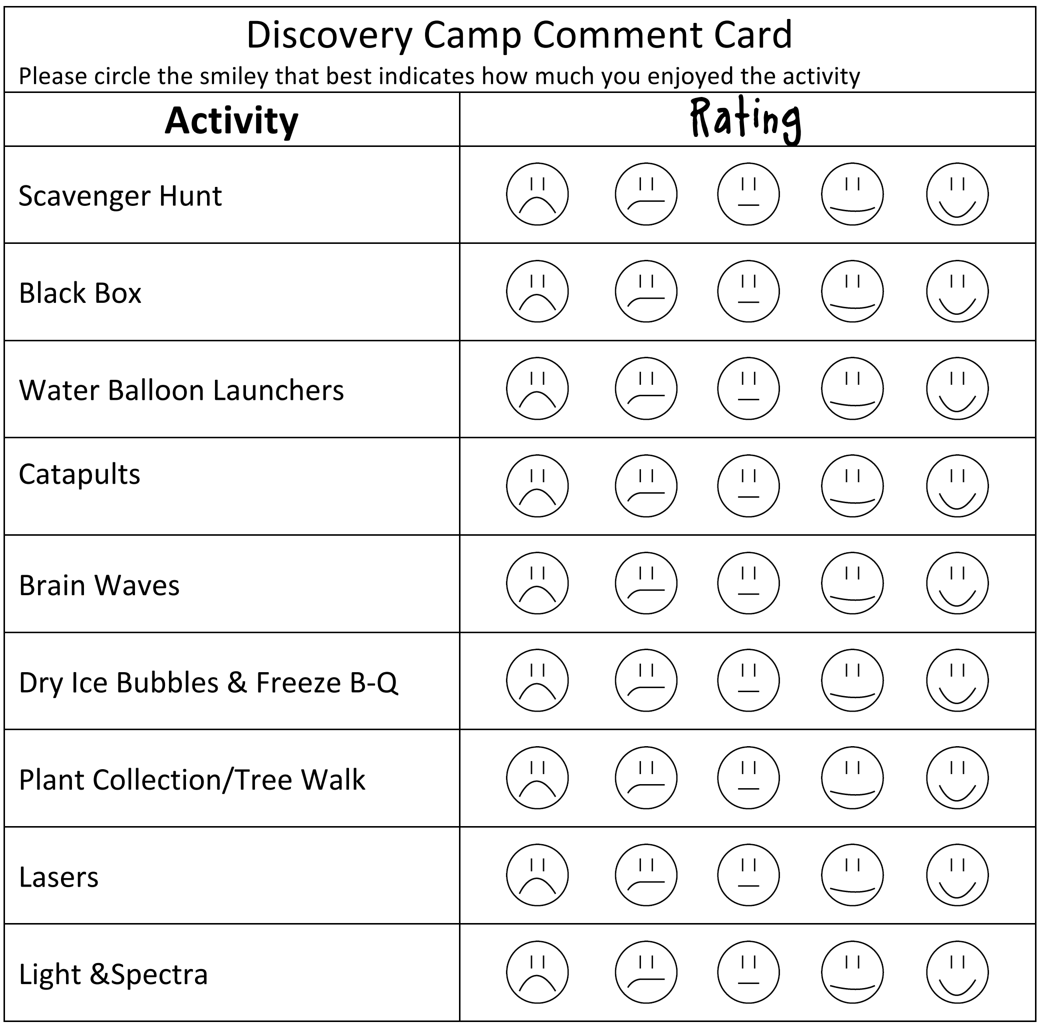
Fidelity Rubric

Mastery/Confidence and Competence	15%	40%	60%	80%
Students are engage directly in hands on activities				
Instructors Make sure that all student have opportunity to try out tasks				
Subset of students are **not** dominating equipment manipulation				
Challenges are properly calibrated				
Activities are novel and challenging				
Activities are not so difficult that failure and frustration are likely				
Vicarious				
Students have the opportunity to observe others performing tasks				
Instructors demonstrate tasks				
Students demonstrate tasks				
Students have the opportunity to share strategies for success with each other				
Social Persuasion/Feedback				
Student receive feedback from peers and mentors				
Instructors comment on student processes				
Instructors provide context for what constitutes success and failure				
Praise is meaningful and appropriate				
Instructors create an environment in which failure is safe				
Physiological State				
The environment and context are safe and comfortable				
Physical space is comfortable				
Students are supported				
Conflicts are handled appropriately				
Student stress and anxieties are addressed appropriately				
Students are not forced to perform activities that cause anxiety				
Role Models/Acculturation				
Instructors model science identities and behavior				
Instructors use appropriate technical language				
Technical language is introduced using double-talk				
Instructors reference their relationship to scientific topics				
Instructors share experiences of learning science				
Instructors induct students into the science culture				
Students are encourage to participate in science				
Students are encouraged to offer ideas and suggestions				
Instructors refer to students in inclusive language				
Curriculum & Context				
Activities are designed for maximum impact				
Lecture and instruction time are minimized				
Worksheets and written activities are directly relevant to activities and learning outcomes				
There is no "busy work"				
Activities are predominantly hands on and involve any of the following: manipulation of equipment, manipulation of environment, measurement, observation				
Key concepts and activities are related back to "real world applications" or students lives				

Rater: __________________ Date: _______________ Activity: ___________________

Figure 10. The rubric used to assess implementation fidelity.

on a 5-point ordinal scale. Instead of numbers emotive faces were used to represent campers' opinions about the activities. The faces were designed to encourage the participants to provide feedback by presenting a familiar scale similar to icons used frequently in their day-to-day lives. Figure 11 shows the evaluation form for the Discovery campers. Means for the activity evaluations are expected to be generally high.


Discovery Camp Comment Card

Please circle the smiley that best indicates how much you enjoyed the activity

Activity	Rating
Scavenger Hunt	
Black Box	
Water Balloon Launchers	
Catapults	
Brain Waves	
Dry Ice Bubbles & Freeze B-Q	
Plant Collection/Tree Walk	
Lasers	
Light &Spectra	

Figure 11. Discovery Camper Evaluation Form.

Observations. In addition to completing the fidelity rubrics, the researcher and assistants took notes during the observations. Observation notes focused on how campers approached science activities and on verifying that instructors were implementing instruction in alignment with the camp theory of action. Observers looked for physical signs of engagement such as upright posture, attentive expressions, raised hands, engagement with materials, note-taking, and interested talk among participants during activities.

Observers also focused on evidence of the elements of identity formation and self-efficacy. Observers attended to how campers approached problem-solving and handled challenging or frustrating tasks. Observers looked for ways in which campers developed mastery through hands-on exploration and employed vicarious learning through observing instructors and their peers. Observers also watched how campers responded to social persuasion—praise of process—in science activities. Special attention was paid to language and behaviors that indicated identity work. Observers took handwritten notes and transcribed them into typewritten research notes and memos that were included in the qualitative data set.

Observation notes were used primarily in that fidelity of implementation analysis (component 1), but are also included in analyses for components 2 and 3.

Surveys and questionnaires. Three quantitative instruments were used for data collection in this dissertation study. These instruments were a parent survey administered before camp, and a science affinities survey administered to participants at the beginning of camp and again several weeks after camp. Data collected from these measures was used for the analysis of component 2 of the study. The sections below describe each instrument and the included measures.

Parent survey. Parents were asked to fill out two questionnaires: one prior to camp and one later in the summer after camp. Only the first questionnaire was used as a source of data for this study. The parent questionnaire explored the participating child's preexisting interest in science and participation in science activities both in and out of school. The data from this questionnaire was used to compute the variable for participant science engagement to be used as a covariate in analysis of the science affinities responses. The first survey was provided on paper along with the required camp registration materials. The parent survey can be found in appendix E.

Science affinities survey. Participants were administered a survey of science affinities both before and after SPICE camp. The affinities survey included six scale measures. Only four measures related to the predicted key manifestations of developing science identities and efficacy were used in this analysis. These were the scales for science interest, science efficacy, science attitudes, and science identities. Each measure, the source of the measure, and information about development of the measure are detailed below. The survey with all scale measures can be found in appendix F.

Science interest. The scale used to measure participants' interest in science was taken from the Colorado Learning about Science Survey (CLASS) (Adams et al., 2006). The full CLASS consists of 36 items divided into six scales. The CLASS scale measuring personal interest was employed for this study. The scale was initially developed using responses from more than 5,000 introductory physics students. Researchers originally collected data on 42 questions and subjected those questions to exploratory factor analysis to confirm the theorized factor structure. Reliability was assessed using test-retest reliability. Correlations between responses ranged from .88 to .99.

The CLASS instrument was originally developed for use in college-level physics courses (Adams et al., 2006). It has subsequently been adapted for chemistry and biology students in grades 6 through 16. Test-retest reliability for the adapted scales ranged from

.86 to .99 (Barbera, Adams, Wieman, & Perkins, 2008; Semsar, Knight, Birol, & Smith, 2011).

The personal interest scale measures how much personal interest students have in the subject of science beyond the desire to complete coursework. For this study the word *physics* has been replaced with the word *science*. The same approach was used in development of the chemistry and biology variants (Barbera et al., 2008). Each item is in the form of a 5-point ordinal scale question ("strongly disagree" to "strongly agree"). Scale items are:

- I think about the science I experience in everyday life.
- I am not satisfied until I understand why something works the way it does.
- I study science to learn knowledge that will be useful in my life outside of school.
- I enjoy solving science problems.
- Learning science changes my ideas about how the world works.
- Reasoning skills used to understand science can be useful in my everyday life.

Science efficacy. Participants' science efficacy was measured using two scales from the work of Eccles, Adler, & Meece (1984). The first scale measured self concept of ability. The second was a scale of student task value. Both scales have been employed many times since their initial creation and validation. The scale has been used primarily with middle and high school aged students to measure gender and race differences in science and math attitudes and perceptions (J. S. Eccles et al., 1984; Else-Quest et al., 2013; Fredricks & Eccles, 2002).

Each scale consists of three items on a 5-point ordinal scale (“not at all good” to “very good”). Cronbach’s alphas for the scale of self-concept of ability have ranged from .80 to .95 (Else-Quest et al., 2013). Cronbach’s alpha for the scale of task value was reported s .81 (Else-Quest et al., 2013). Each scale item is listed below.

Task Value

- How important is it that you learn science?
- How interesting is science to you?
- How important do you think science will be to you in the future?

Self-Concept of Ability

- How good at science are you?
- If you were to rank all the students in your science class from the worst to the best in science, where would you put yourself?
- Compared to most of your other school subjects, how good are you at science?

Science attitudes. Participants’ science attitudes were measured using the Attitudes Toward Science in School Assessment (Germann, 1988). This instrument measures students’ attitudes toward science with particular emphasis on studying science in schools. Original respondents were 7th and 8th grade students. Reliability was high ($\alpha = .94$) in the study sample. This scale consists of 14 items on a 5-point ordinal scale (“strongly disagree” to “strongly agree”). The full scale is presented below.

- Science is fun.
- I do not like science and it bothers me to have to study it.
- During science class, I usually am interested.

- I would like to learn more about science.
- If I knew I would never go to science class again, I would feel sad.
- Science is interesting to me and I enjoy it.
- Science makes me feel uncomfortable, restless, irritable, and impatient.
- Science is fascinating and fun.
- The feeling that I have toward science is a good feeling.
- When I hear the word *science*, I have a feeling of dislike.
- Science is a topic which I enjoy studying.
- I feel at ease with science and I like it very much.
- I feel a definite positive reaction to science.
- Science is boring.

Science identity measure from the pilot study. The item measuring science identity in the pilot study, "I think of myself as a scientist," was adapted for this study. Added to this question were three items that represent the major components of identity: experience, confidence and competence, and feedback. These items are:

1) I have had enough experience to know that I can be good at science.
2) I am confident in my science skills.
3) I receive feedback from people important to me that says I can be good at science.

A 5-point ordinal scale was used in place of the original four-point scale employed in the pilot study. These items were summed to create a scale score of science identity. This is the only direct measure of science identity available. No suitable extant measures were found.

Science affinities instrument. Survey responsescollected via Qualtrics were downloaded and data were screened and cleaned in Excel. A research assistant entered survey responses collected on paper into the spreadsheet. A subset of data entered from paper responses were checked by the lead researcher for accuracy. No errors were found. Items from the scale of science attitudes that were worded in the negative, (e.g., “Science is boring,”) were reverse coded into new variables prior to analysis.

Focus group interviews. Focus group interviews were conducted in groups of six to eight campers during the second week of camp. Focus group sessions lasted between 35 and 65 minutes. All focus groups were led by the researcher. The research assistants took notes and made observation notes during the focus groups. All focus group interviews were audio recorded and transcribed. A total of eight focus groups were conducted during SPICE camp.

The purpose of the focus groups was to gain a better understanding of how girls think about science, scientists, and gender roles in science. A script was used to help start and direct the focus group discussions; however, conversation between the girls was allowed follow a natural course as long as it stayed in the domain of girls and science (Merriam, 2009; Miles et al, 2015). Discussion did not explicitly focus on SPICE camp unless the girls chose to discuss the program. Focus group scripts can be found in appendix G.

Individual interviews. Interviews with 11 campers were conducted in August and September of 2014. These interviews were semi-structured with a list of questions and probes (Merriam, 2009; Miles et al, 2015). A subset of girls who represent a range of nascent science identities as evidenced in their responses to the various instruments and in the focus groups were selected for in-depth interviews. These interviews took place in a variety of settings, including the UO campus, campers' homes, and public places like restaurants. Parents opted not to sit in on interviews, though they were given that option. Interviews lasted between 35 and 70 minutes. Two interviewees were from the Discovery Camp, four were from the Forensics Camp, and five were from the Engineering camp.

Interviews were guided by a script, but often followed unique conversational threads that emerged from the subjects' thoughts, attitudes, and interests (Gibbs, 2001; Merriam, 2009; Miles et al, 2015). This script was altered somewhat after the first few interviews to improve questions and focus on more fruitful lines of inquiry. The interview script can be found in appendix H.

Instruments and measures summarized. Data collected for this study include both quantitative measures and qualitative evidence. Each instrument was intended to provide a piece of the puzzle for understanding how SPICE impacts girls or how girls relate to science in a more general sense that can inform SPICE and other programs like it. Table 2 lists each instrument, what constructs the instrument measures, and the variables or evidence produced by the instrument. The table is organized by research component.

Data Collection and Timeline

The research activities outlined here were carried out between July 2014 and March 2015 (see figure 12). Participants in the treatment group were administered pretests on the first day of camp to measure explicit and implicit preferences for science careers. Posttests of the same measures were administered again 3 to 6 weeks later. The data was entered/transcribed and analyzed August 2014 through February 2015.

Table 2

Instruments and Measures Employed in the Study Organized by Research Component

Instrument	Constructs	Variables/Evidence
	Component 1—Fidelity	
Fidelity Rubric	Implementation fidelity to conceptual framework	Scale scores for: Mastery, Vicarious, Feedback, Physiologic, Role Models, & Curriculum
Camper Evaluations	Enjoyment, interest in camp activities	Activity ratings
Observations	Implementation fidelity to conceptual framework	Qualitative evidence of implementation fidelity
	Component 2—Science Affinities	
Parent Survey	Participant science engagement Parent perception of camper science identity	Pre- and post-camp scores for engagement and identity
Science Affinities Survey	Science interests Science efficacy Science attitudes Science identities	Factor scale scores for each construct
Focus Group Interviews	Science interests Science efficacy Science attitudes Science identities	Participant statements
Individual Interviews	Science interests Science efficacy Science attitudes Science identities	Participant statements
	Component 3—Science Identity Theory Building	
Focus Group Interviews	Participants' science identity types Participant statements	Participant statements
Individual Interviews	Participants' science identity types Participant statements	Participant statements

The researcher secured a grant from the Center for the Study of Women in Society to support the research project. Funds from this grant were used to pay two research assistants with experience and/or training in primary data collection. A third research assistant volunteered to assist with the program to gain experience in qualitative research. Research assistants were familiarized with identity formation and self-efficacy and trained in camp tenets. The researcher and research assistants worked closely before, during, and after camp to ensure high-quality data collection. The researcher and assistants carried out observations, assisted with focus groups and interviews, and transcribed audio recordings.

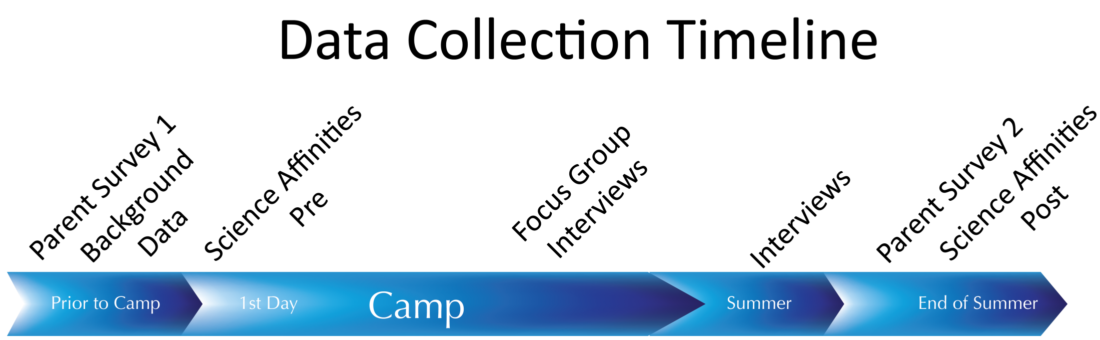


Figure 12. Research timeline for SPICE participants.

SEP. The survey instruments containing the science identity and attitude scales were administered to the SEP participants in the morning of the second day of the program (August 5, 2014). Parent surveys (37 responses) were sent on the first day of camp via email with a link to a Qualtrics survey. Post-camp parent (14 responses) and student (16 responses) surveys were also administered via Qualtrics survey. Due to the low response rate on the parent and post-camp surveys, only the pre-camp student responses are used in this analysis. This data was used as a baseline comparison of science attitudes and identities.

Analysis

Data from this study consisted of quantitative and qualitative measures. Details of how the data were analyzed are organized by research component below. In the interest of brevity, analysis techniques used in multiple components will only be described once in the most relevant component and cross referenced in other sections as necessary.

Component 1—Fidelity of implementation analysis. Data for the analysis of implementation fidelity consisted of rater scores from the fidelity rubric, camper evaluations, and observation notes.

Fidelity rubric analysis. Mean scores for each subcategory (mastery, vicarious, social persuasion, physiological state, role modeling, and curriculum) of the fidelity rubrics were calculated for every observation. Subcategory means were used as not all items on the rubric applied to every camp activity. Items deemed non-applicable were not included in the average calculations. In these cases, the total number of items used in the average calculations were reduced by the total number of non-applicable items. This process prevented biasing scores downward. Raters who worked in pairs met after the observations to agree on which items did not apply to the activity under observation. Raters who worked alone were the sole determiner of the applicability of items. The lead researcher was designated the tie-breaker in cases where raters could not agree. However, no such disagreements occurred.

Inter-rater reliability scores in the form of intra-class correlation coefficients (ICC) were calculated using the subcategory average scores. Traditionally, inter-rater reliability is calculated using Cohen's kappa. However, kappa is suitable only for dichotomous scoring (Hallgren, 2012). An ordinal scale was employed in this study to capture the degree of implementation over a simple yes or no determination. In cases of ordinal or continuous rater variables, ICC is the standard (Hallgren, 2012).

Following assessment of inter-rater reliability, all of the subscale scores were then averaged across cases and descriptive data (minimum, maximum, mean, and standard deviation) were presented.

Camper evaluations. Evaluation data were entered into a spreadsheet with the "frown" face on the left converted to 1 and the "smile" face on the right converted to a 5. Descriptive statistics were then calculated. Those statistics will be presented and discussed in chapter IV.

Observational data. In addition to completing the fidelity rubrics, observers also took fields notes on camp activities, focusing on the elements of implementation fidelity. Field notes were reviewed by the observers and rewritten for clarity. Summaries of observed themes in activities were added to the notes. Final research notes were added to the qualitative data collected. They were later coded and used in this analysis. A full description of the coding and codebook development process is provided in description of analysis for component 2.

Component 2—Science affinities analysis. The analysis of data for component 2 involves both quantitative and qualitative data. In the results section of this dissertation (chapter IV) the quantitative and qualitative results for each research question will be presented together in the same section, with the quantitative data presented first and the qualitative data presented second. Each of the four research questions—interest, efficacy, attitudes, and identity—will be approached using the same methods and techniques. These methods are presented below first for the quantitative analyses and then for the qualitative analyses, beginning with a description of the development of the qualitative codebook.

Quantitative data analysis. Quantitative data were collected using the survey of science affinities, the parent survey, and administrative data. Data were checked and cleaned in Excel spreadsheets and then imported into SPSS 21 for Macintosh operating systems.

Table 3 lists the variables and constructs they represent below. The outcome variables are the scale scores for science interest, science efficacy, science attitudes, and science identities, derived from the science affinity measures discussed above. Science efficacy consists of two variables: the scale scores for self-concept of ability and task value. Predictors include variables for preexisting science engagement, years in the SPICE program, and scholarship status. The variable for science engagement was developed from parent reports of participant science engagement outside of SPICE and school. The years in program variable was determined from administrative data. Campers who joined the program in successive years (7th and 8th grade) were only counted as active for the number of years they participated, not the level of camp they attended. Scholarship status was also determined from administrative data. All campers who requested and received a scholarship, ranging from $75 to the full camp fee of $300, were coded as scholarship students. Variables were also calculated for interactions between the predictor variables.

Table 3

Science Affinity Constructs and Variables

Construct	Variable	Description
	Outcome Variables	
Science Interest	Science Interest Scale	Continuous Factor Score, 6 items
Science Efficacy	Self-Concept of Ability Scale	Continuous Factor Score, 3 items
	Task Value Scale	Continuous Factor Score, 3 items
Science Attitudes	Attitudes toward Science in School Assessment Scale	Continuous Factor Score, 14 items
Science Identities	Science Identity Scale	Continuous Factor Score, 4 items
	Predictors	
Engagement	Parent Engagement Reports	Trichotomous variable (none, some, high)
SPICE exposure	Years in the Program	Dichotomous (0, 1+)
Scholarship Status	Scholarship Status	Dichotomous (0, 1)

A variable for student engagement. A trichotomous variable for science engagement (no engagement, moderate engagement, high engagement) was calculated using responses from the parent survey completed prior to camp. Parents were asked to report on a number of possible science engagement activities their child might have participated in over the 12 months prior to camp. Activities listed in the survey included visits to science museums, after-school clubs, workshops or other summer camps, events other than SPICE camp presented by the SPICE program during the school year, watching science-based TV or internet shows, or playing science-based games. Parents indicated which activities their child had participated in and estimated how many times or times per week their children had engaged in these activities. The survey also included space for parents to detail their child's activities with text. This presented a complex set of data to distill into one variable to represent science engagement. Some participants had not engaged in any of these activities. Others had engaged in many and often. In retrospect, fewer or even one question asking parents to gauge participant science engagement would have been a better approach.

The engagement variable was computed through a multistep process. First, open-ended responses were assigned to either an existing response category or added as a new miscellaneous science engagement variable. For example, one parent reported that a child had completed a self-initiated project in conducting a backyard wildlife census. This example was entered the new miscellaneous science engagement variable as it did not fit under any of the predefined science activities presented in the survey.

Responses were next collapsed into two variables: SPICE engagement and other engagement. Distributions for both variables were examined. Roughly half (43%) of campers had not engaged in any SPICE-related activities prior to camp. The remaining campers had engaged in between 1 and 4 SPICE events. Average number of SPICE activities engaged in outside of the 2014 camp was 1 ($SD = 1.0$). Distribution for the other engagement variable ranged from 0 to 4 engagement types, with 31.4% of participants having no other engagement with science. The average engagement other science engagement was 1.1 ($SD = 0.7$). In the interest of simplicity these two variables were converted to dichotomous variables in which a score of 0 remained 0 and a score of 1 or greater was coded as 1. These two variables were then summed to yield the final trichotomous engagement variable. Campers with a total engagement score of 0 were labeled as *not engaged*, campers with a total engagement score of 1 were labeled as *somewhat engaged*, and campers with a score of 3 or higher were labeled as *engaged*. The mean score was 1.0 ($SD = 1.0$). Twelve campers (23.5%) were not engaged, 26 (51%) were somewhat engaged, and 13 (25.5%) were engaged.

Missing data. Every effort was made to avoid missing data. However, inevitably, some data was missing from the final dataset. Given the small sample size, every data point matters. Individual item responses missing from the scale scores were replaced by the mean of scale. Cases with substantial missing data were dropped from the relevant analysis. Four SPICE participants failed to respond to follow-up requests for data after camp and do not appear in these analyses. The final analyses used 51 cases from the SPICE participants. As noted above, attrition and missing data among SEP respondents was so low following the program that no post-intervention data was used in this analysis.

Missing items were found in 23 items across 8 cases in the SPICE responses. Among the SEP respondents 17 items were missing across 12 cases. Most missing items were seemingly at random, a single item missing among otherwise complete responses. Missing data were replaced using mean imputation. The limitations and implications of mean imputation will be discussed in chapter V.

Scale score development. Item responses on each of the science affinities scales were subjected to exploratory factor analysis. Principal axis factoring with oblimin rotation was employed. Oblique rotation was used as the constructs underlying these scales are closely related and can be expected to intercorrelate (Costello & Osbourne, 2005; Preacher & McCallum, 2003). Eigenvalues, scree plots, the minimum average partial test, and parallel analysis were used to examine the factor structure (O'Connor, 2000). Correlations between scale scores were also examined to determine the extent of overlap between the measured constructs.

Reliability was examined using Cronbach's alpha. Unless an item reduced the reliability of a scale by more than .10, it was retained. A reliability difference of .10 was chosen based on heuristic standards for reliability. Reliability of .70 and above is generally considered acceptable, above .80 is good, and above .90 is excellent (Gleim & Gliem, 2003). A difference of .10 in reliability would bring the entire scale reliability up into a higher category.

The data set includes three sets of responses to the science affinities survey, the pre-camp SPICE participant responses, the post-camp SPICE participant responses, and the pre-camp SEP responses. A factor analysis was conducted for each set of responses in the interest of thoroughness. The results of the pre-camp SPICE data were used to determine the final factor scales.

Once the final items for each scale were determined using factor and reliability analysis, the factor score was calculated using a simple sum. A number of methods are available for calculating scale scores from identified factors. These methods fall into two broad categories: unrefined and refined (DiStefano, Zhu, & Mindrila, 2009). Unrefined techniques include simple summation, averages, sums of standardized scores, and weighted sum scores. Unrefined scores are believed to be more stable across samples (DiStefano et al., 2009). Refined techniques include regression scores, Bartlett Scores, and Anderson-Rubin Scores. Refined scores have varied advantages (e.g., increasing validity and unbiased estimates), however, they are specific to the data set from which they are calculated. Since this analysis involves comparing scale scores across three sets of responses from two different populations, an unrefined technique was employed. A weighted sum score in which the item value is multiplied by the factor loading would be desirable as it would give items with the highest loadings more weight in the overall score—however, inconsistencies in the loadings (and the basic factor structure) between the response sets makes this problematic. A simple sum score was used to calculate factor scores as this is direct, robust across data sets, and preserves variance (DiStefano et al., 2009).

Statistical power, effect size, and alpha. Published studies on identity in this age group typically focus on racial/ethnic identity, and employ descriptive analyses or use identity measures as covariates in other analyses. As such it is challenging to establish a range of anticipated effect sizes for this study. Research on interventions designed to shift implicit racial biases as measured by implicit association tests and other measures of implicit and explicit bias have reported effect sizes. Devine, Forscher, Austin, and Cox (2012) found an effect size of .6 (Cohen's *d*) between treatment and control groups in a random assignment study designed to reduce racial bias via a voluntary training intervention. Rudman, Ashmore, and Gary (2001) found an effect size of .4 between treatment and a nonequivalent control group for students attending a seminar on prejudice and bias. Both studies employed control groups, which this study does not, and are therefore of limited relevance. However, they are the best signposts available.

Devine's study involved a 45-minute training session after which college-aged participants were asked to put what they learned into practice over the course of 12 weeks. It is difficult to assess how much time participants spent actively engaged with the materials. If participants spent one hour per week in practice, they would spend a total of 13 hours engaged in the intervention and activities. Rudman's study took place over a 12-week college course. Information was not provided on the frequency and duration of the class meeting. Assuming a standard one-credit course, students could be expected to spend about 3 hours per week on the materials for a total of 36 hours. SPICE campers participate actively for six hours a day for nine days over a two-week period for a total of 63 hours, however, not every element of camp is focused entirely on identity building. Sometimes campers are engaged in games or unstructured recreation with little or no science content. Given that the literature referenced is for an older participant group and relates to racial bias, it provides only a rough guide for expected effect sizes. For that reason, for the purpose of this study the expected effect size is small to moderate, or .2 to .4 (Cohen's *d*).

A prospective power analysis (Ellis, 2010) was conducted using G*Power software (Faul, Erdfelder, Lang, & Buchner, 2007). For a one-tailed dependent sample *t*-test with an estimated effect size of .2 and $\alpha = .05$ and power of .8, a sample size of 156 is required to detect a statistically significant finding. For the same analysis with an effect size of .4 a sample of 41 is required. With $\alpha = .1$ and power of .8, the sample size required to detect an effect size of .2 is 114, and for an effect size of .4 is 30. If the effect size actually is as low as .2 it may still be detectible due to the additional power yielded from including covariates in the analysis. The final sample size of 51 participants would only be adequate to detect effects closer to .4 or greater. The limitations of statistical power in this study will be addressed in chapter V.

Multiple testing and alpha adjustment. This research calls for multiple tests on the same set of data. Analyses of this type increase the risk that a statistically significant result will be found purely through chance (Stevens, 2009). Traditionally, researchers apply a correction to the alpha level to compensate for this increased risk (Abdi, 2010).

The most common method, known as the Bonferroni method, uses a simple but conservative approach expressed as:

$$\alpha[PT] = \frac{\alpha[PF]}{C}$$

Where $\alpha[PT]$ is the alpha applied to individual tests, α[PF] is the overall α level applied to the family of tests and C is the number of tests applied.

There is debate among statisticians, however, as to whether routine application of alpha adjustment is in fact appropriate (Armstrong, 2014; Perneger, 1998). Stringent application of alpha adjustments such as Bonferroni assume independence of tests, which is often not the case in social science research (Abdi, 2010). Other less stringent methods include the Holm-Bonferroni Sequential Method (Abdi, 2010), which uses a step-down procedure to apply alpha levels of diminishing strictness to the resulting p-values calculated in the analysis. Sequential methods are more appropriate to nonindependent data and reduce the chance of type II error. Some argue, however, that alpha adjustment is only appropriate for reducing study-wide inflation of type I error (Perneger, 1998). In studies in which the researcher wishes to examine if subsets or even individual variables differ, applying a strict Bonferroni adjustment is inappropriate as it tests the null hypothesis that groups are identical on the entire set of variables, rather than the relationships between specific variables. Armstrong (2014) recommends no alpha adjustment in these circumstances:

- The study is restricted to a small number of planned comparisons.
- The study is exploratory involving post-hoc testing of unplanned comparisons required for further investigation.

- Multiple use of simple tests if the results of the individual tests are important (exact p-values should be reported and discussed in these cases).
- It is imperative to avoid type II error.

Given that this study employs a small number of planned analyses, mostly using simple tests (*t*-test and multiple regression), and there are established research questions and hypotheses, no alpha correction was used.

Analysis of science affinities. Descriptive and inferential statistical methods were applied to the data in the form of *t*-tests and multiple regression analyses. Factor scores were treated as continuous variables. Initially, a series of paired *t*-tests was employed to determine if scores for the developed scales were different in the post-camp condition from the pre-camp condition. Independent *t*-tests were also run to compare the means of SPICE camper initial scale scores to the SEP contrast group. Next, a series of simultaneous multiple regression analyses were employed to predict camper science attitudes and identities from student background characteristics.

The dependent scale score variables for the regression analysis were calculated by subtracting the pre-camp response from the post-camp response. Predictor variables included previous science engagement, years in the program, and scholarship status. Interactions between these three main effects were also included in the analysis.

The models were run first with all predictors and the relevant interaction terms. In the interest of parsimony, nonsignificant terms were then removed and the analysis was run again. Nonsignificant terms were removed one at a time based on theoretical significance. This process was repeated until all remaining terms were significant or no significant relationships were found. Predictor values of zero are meaningful in these models, therefore centering was not necessary to aid interpretation. Multicolinearity was an issue, however, so variables were centered and effect coded. Effect coding complicates the interpretation of regression coefficients, as they are now centered around the grand mean. In this circumstance, statistically significant findings will be discussed in terms of means. Statistically significant interactions will be discussed in terms of the values they predict for given values of the predictor variables, which is possible in this case as the predictors are all dichotomous or trichotomous. Main effects will not be interpreted when interaction terms are statistically significant.

The equation below provides an example of analyses that that were performed for the science affinities variables. Models were run sequentially. Similar analyses were run for each outcome variable.

Model 1

$$\begin{aligned} \mathit{Change\ in\ Science\ Interest} &= \boldsymbol{\beta_0} + \boldsymbol{\beta_1} \mathit{engagement} + \boldsymbol{\beta_2} \mathit{years\ in\ program} + \boldsymbol{\beta_3} \mathit{scholarship} \\ &+ \boldsymbol{\beta_4} \mathit{years\ in\ program} * \mathit{engagement} + \boldsymbol{\beta_5} \mathit{years\ in\ program} * \mathit{scholarship} \\ &+ \boldsymbol{\beta_6} \mathit{engagement} * \mathit{scholarship} + r \end{aligned}$$

Prior to running any models, variables were examined for violations of model assumptions (Pedhazur, 1982). After the first model was run, residuals and indicators such as Cook's *D* and leverage statistics were examined to identify potentially influential cases.

Qualitative analysis of science affinities. Coding and the subsequent qualitative analyses were performed using NVivo for Mac. Observations, focus group transcripts, and individual interview transcripts were coded using a simultaneous descriptive approach with sub-codes and provisional codes (Saldaña, 2013). First a sample of each type of source (interview, focus group, researcher observation, and open-ended questions) was coded using a preliminary codebook developed during the analysis of the 2013 pilot data. New codes were added as ideas emerged that did not fit the existing codes. This initial codebook was not organized into any structure. Following the initial round of coding, the emergent codes were organized into hierarchies according to the theoretical framework. Additional attribute codes were also added. This codebook was used in coding the remaining documents. A few additional codes were added as necessary. After all the documents were coded, matrix queries were run to examine the frequencies of codes and search for codes with high overlap. Some codes were then combined for a final number of 46 non-attribute codes. Table 4 shows the main code groupings. The final codebook with all items and earlier iterations can be found in appendix I.

Attribute codes and codes for organizing data relevant to fidelity of implementation were used to aid in analysis. Memos and matrix queries were employed to develop emergent themes. Visual representations of the data such as outlines and diagrams were also developed (Gibbs, 2011).

Qualitative analysis for component 2 focused on evidence related to the four science affinities of interest, efficacy, attitudes, and identity both as specifically related to the program and more generally. Emphasis was placed on understanding how girls relate to and engage with science. Evidence of how the program does or could better support the ways girls engage with science is of particular interest. Top-level data was quantified to provide a sense of what themes were most common. The number of participants providing responses relevant to particular themes is presented as appropriate. Direct quotes and excerpts from research notes that represent the analysis are also presented.

Table 4

Final Codebook Hierarchy

Descriptive Codes
Attitudes and Stereotypes (11)
Identity & Self-Efficacy
Confidence and Self-Efficacy (5)
Experience and Mastery (12)
Feedback & Social Persuasion (8)
Identity
Vicarious Learning (3)
SPICE Camp
Attribute & Organizational Codes
Interviewer
Respondents (11)
Fidelity
Observation
Third-Party Observations
Numbers in parentheses are the total child codes under a parent code

Component 3—Science identity theory building. Theory building is largely an inductive process, however, in this case, pilot data was available to provide some guidance. Specifically, the pilot data provided evidence that girls' science identities, though overlapping, were not uniform. Girls approached science differently and placed emphasis on different aspects of science as it pertained to their identities. Analysis for this component focused on evidence of different types of identities manifested in girls and how those identity types influence girls' experiences and feelings about science.

As discussed above, matrix codes, outlines, and visual representations of data were also employed for theory building. Key themes were assembled into memos that linked back to the primary data sources. Concept mapping using sticky paper notes was employed heavily during the refinement phase.

Prior to moving on to the results, the role of the participant observer will be discussed briefly below.

Participant observation. The term *participant observer* refers to a method of qualitative fieldwork frequently used in anthropology, sociology, and other social science disciplines. The participant observer, as the name suggests, both observes and actively participates in the practices of the group under study (Merriam, 2009). The purpose of participant observation is to gain a more intimate, detailed, and nuanced understanding of the groups under study. Participation can garner trust from research subjects, lead to greater access to informants, and insight resulting from a more personal experience. One peril of this approach can involve a loss of objectivity. At the same time, no matter how involved the research becomes in the world of her subjects, her own background and worldview will influence her interpretation of the data collected.

This study is not a traditional participant observation. The researcher is more clearly divided from the subjects due to age, implied authority, and the limited time frame for interaction. Adults have become accepted "insiders" in the world of children (Thorne, 1993), but such fieldwork requires time and the ability to distance the researcher from traditional adult roles in the eyes of children. This was not an option in the case of SPICE camp, which takes place over a short frame of time and in which the researcher plays a key role as program director. At the same time, to the SPICE campers, the researcher is not an anonymous person with a clipboard or a distant authority figure. Many campers know the researcher outside of camp from other outreach events and as a public figure. Most campers are comfortable and friendly with the researcher.

As the researcher, I am not an objective observer of what happens in SPICE camp. I am an active participant and key shaper of what happens (and does not happen) every day of camp. I believe that my experience and the voluminous body of research I have consumed over the years make a positive contribution to helping girls find their inner scientist. SPICE requires a tremendous amount of work every year and I have a vested interest in exploring what works, what does not work, and what can be done to make the program better. Every part of this research has been influenced by my commitment to the program and belief that it really does encourage girls to love and pursue science. I hope that if I were to find that the program does not work, I would be enough of a scientist to stop and devote the resources (including my own time) to something more effective. In fact, I know I would. What I must constantly question, though, are my perceptions. If SPICE really is not effective, would I be able to see that? As is the burden of all qualitative researchers, I must constantly check that my own ideas, biases, and desires are not interpreting the data for me.

CHAPTER V

RESULTS

> *"Yeah, and we're little scientists just learning how the world spins and everything that is happening around the world and everything new and everything old and everything!"*
>
> —Alexandria, *age 11, SPICE camp 2014*

The purpose of this study is to explore the girls' affinities for science and build theory about the kinds of science identities girls adopt. Theory in identity (Erikson, 1968), self-efficacy (Bandura, 1997b), and mindsets (Dweck, 2006) provides the conceptual framework for identifying signs of girls' nascent science affinities and the factors that may contribute to girls persisting in STEM education and careers.

This chapter reports the results of the mixed-methods data analysis. The chapter is presented in three segments addressing each of the primary research components, fidelity, affinities, and theory building. Reporting of the results begins with analysis of the data addressing fidelity of implementation.

Component 1—Fidelity of Implementation

The lead researcher and three research assistants carried out fidelity observations during the 2014 SPICE camps. In total, 23 activities were observed. Pairs of observers carried out 16 of these observations for the purpose of assessing inter-rater reliability. Individual researchers conducted the remaining observations. Observers used the fidelity rubric (see figure 10) to assess the extent to which activities were in compliance with the camp tenets and wrote observational notes covering camper interactions, instructor behavior, and curriculum. Raters one and two did not conduct any observations together. This was an oversight on the part of the lead researcher in scheduling.

During the first two days of observation, all researchers met at the end of day to compare observations and review videos of camp activities to ensure that ratings were consistent. Video recording of camp activities was approved by the institutional review board and consented to by parents. After that, pairs met after an activity to agree on which portions of the rubric were not applicable to the activity (e.g., ratings of worksheets in activities without worksheets). Scores from the rubrics were recorded and summed by subcategory: mastery experiences, vicarious learning, social persuasion, physiological state, role modeling, and curriculum and content. Scores on these subscales were the basis of inter-rater reliability statistics.

Inter-rater reliability. Intra-class correlation coefficients were calculated using a two-way mixed model with absolute agreement for each pairing of observers. Hallgren (2012) recommends performing any transformations that will be used for later analyses to the data prior to inter-rater reliability analysis. For this reason, the rubric scores for each observation were averaged by subscale (master, vicarious, social, physiological, role modeling, and curriculum) before the ICC analysis. This yielded six ratings per shared observation.

All five comparisons yielded strong intra-class correlations coefficients. Table 5 shows the results of the intra-class correlation coefficient analysis. The intra-class correlation coefficient was used as it is suitable both for ordinal ratings and for crossed-rater models in which some observations are conducted by a multiple reviewers and some by single reviewers (Hallgren, 2012). Cicchetti (1994) provides the following criteria for assessing the quality of interrater reliability as measured by ICC: less than .40 is poor, .40 to .59 is fair, .60 to .74 is good, and .75 to 1.0 is excellent. Inter-rater reliability in this study ranged from .80 to .99, all within the “excellent” range. However, there are two caveats to a blanket rating of excellent. First, raters 1 and 2 never shared an observation. Second, the distribution of overlap between pairs is uneven. Raters 1 and 4 had high overlap, as did raters 2 and 3, but raters 3 and 4, 1 and 3, and 2 and 4 had very low overlap (one observation each). The absence of any overlap between raters 1 and 2, along with the uneven distribution of overlap between rating pairs, reduces the confidence in overall inter-rater reliability.

Table 5

Inter-rater Reliability of Fidelity Rubrics

	n	ICC	Lower Bound	Upper Bound	Value	df1
Rater 1 and Rater 3	6	.954	.707	.993	25.42**	5
Rater 1 and Rater 4	24	.976	.948	.989	44.61**	27
Rater 2 and Rater 3	36	.989	.978	.994	94.72**	30
Rater 2 and Rater 4	6	.804	.045	.961	4.87*	7
Rater 3 and Rater 4	6	.990	.791	.999	231.07**	5

*$p < .05$, **$p < .01$

Camper affect. Before analyzing the rubric scores a brief discussion of camper affect is in order. Camper affect refers to evidence of participant interest and engagement in camp activities. Camper affect was measured by the evaluation forms campers completed and the fidelity observations conducted by the researchers. Evaluation forms were collected at the end of week one for the Discovery and Forensics campers.

Average scores for Discovery camp by activity are presented in table 6. Ratings for Discovery camp activities were generally high with all over 3.5 points out of 5, and 7 of 10 over 4 points. The average score for camp activities was 4.2 out of 5 points. Only one activity received the minimum possible score. Interestingly, this was an activity presented by an outside group in a visit to a UO research facility.

Table 6

Discovery Camper Evaluations by Activity

	Minimum	Maximum	Mean	Std. Dev.
Scavenger Hunt	3.0	5.0	4.3	0.8
Black Box	3.0	5.0	4.3	0.8
Water Balloons	3.0	5.0	4.7	0.7
Catapults	3.0	5.0	4.6	0.6
Brain Waves	1.0	5.0	4.1	1.3
Dry Ice Bubbles	5.0	5.0	5.0	0.0
Plant Walk	2.0	5.0	3.5	0.9
Lasers	2.0	5.0	3.7	1.1
Light and Spectra	2.0	5.0	3.9	1.1
Camp Average	3.1	5.0	4.2	0.6

n = 18

Table 7 shows the average scores for the Forensics camp activities. The range of scoring was more varied among the Forensics campers, however the average score was the same as for the Discovery camp (4.2). Forensics camp included six more activities in week one than Discovery camp. This was due largely to the amount of time Discovery campers spent on the scavenger hunt on the first day of camp.

Context for camper evaluation scores is provided by observation notes. Observation of camper affect ranged from bored frustration to high levels of engagement and enthusiasm. Typical behavior observed included animated discussion between students about the activities they were participating in, frequent questions for instructors, enthusiastic willingness to answer questions posed by instructors, and a general eagerness to participate in activities.

Table 7
Forensic Camper Evaluations by Activity

	Minimum	Maximum	Mean	Std. Dev.
Critical Observation	2.0	5.0	4.0	1.0
CSI Fact or Fiction	2.0	5.0	4.3	1.0
Deduction	3.0	5.0	4.8	0.6
Lie Testing	2.0	5.0	4.4	1.0
Witness Reliability	1.0	5.0	3.9	1.1
Print Analysis	2.0	5.0	4.4	0.9
Toxicology	2.0	5.0	4.7	0.9
Accident Reconstruction	2.0	5.0	4.6	0.8
Dental Analysis	2.0	5.0	4.2	1.0
Impression Analysis	2.0	5.0	3.9	1.1
Stride Analysis	1.0	5.0	3.8	1.2
Hair & Fiber Analysis	1.0	5.0	3.9	1.5
Pollen Analysis	3.0	5.0	4.5	0.7
Flame Test	1.0	5.0	3.8	1.3
Camp Average	2.5	5.0	4.2	0.2

n = 17

In all, the observers noted engagement among the majority of campers in all observations. Full engagement by all campers was noted in 13 of the 23 observations. Moderate engagement (60% to 95% of students engaged) was observed in the remaining 10 observations. Table 8 summarizes the observation of camper affect.

Table 8
Student Affect During Camp Activities

	Number of Activities
Positive Affect	
All students engaged & enthusiastic	13
Majority of students engaged (60% or more)	10
Less than 60% of students engaged	0
Total	*23*
Negative Affect	
Minority visibly frustrated (20% or less)*	4
Minority visibly bored (20% or less)	3
Exclusion of individuals observed*	3

*Frustration and exclusion overlapped in 2 cases.

Observers noted a variety of ways in which participants showed engaged affect during activities. The following excerpt from one observer's notes exemplifies the types of enthusiasm witnessed at camp: "Their enthusiasm is high as they anticipate the dropping of their egg off the balcony—they are ecstatic when they open their contraption and realize that it worked!"

Not all campers were excited all of the time, however. Frustration among a minority of campers (20% or less) was noted in four activities. Three of the four were programming sessions of the engineering camp where some students got ahead of the rest of the group in the self-paced lesson plans and ran out of activities, and for one group who was having difficulty with the programming. The other observed instance of frustration took place in the Forensics camp when supplies were short in the DNA extraction activity and students were not getting the expected results right away.

Instances of boredom were also noted. During the Light and Spectra session of Discovery camp one observer noted, "To me, students looked challenged by the lecture and content knowledge. Two students were drawing pictures, but at the same time, the four students who sat in the front row took notes seriously." In a mixed group such as SPICE, which draws on students from varying schools and backgrounds, it can be challenging to keep activities engaging and interesting for all students. One of the ways the program deals with differences in camper experience and interest is to keep activities discrete and change focus often, while making sure to try and relate new concepts back to previous activities. Three cases of visible boredom among a minority of campers were noted during the observations.

The instructors also noted cases of exclusion and sought to encourage engagement by shifting group members during teamwork and checking in with excluded students. One observer reported during an engineering camp session, “At one table two of the girls work on the circuit board while the third operates the laptop. I noticed that the third girl was at another table the day before, she informs me that working with her [group] was not working out. I watched them for a few minutes and noticed that she was quite engaged in the activity, much more than the day before.” Exclusion of individual campers was noted in three cases. The subjects of exclusion were one participant in the Forensics camp and one in the Engineering camp.

Overall, camper affect was engaged and enthusiastic. Some instances of frustration, boredom, and exclusion were observed, however, these instances were fleeting. The majority of campers displayed positive affect during all observations. Ratings of camp activities by participants were also high overall.

Elements of fidelity. The rubric contained six elements that measured fidelity. Mean scores for the mean of each subscale were high, ranging from 3.55 to 3.87 out of a possible 4 points (table 9). Overall, raters agreed on activity ratings and found the activities to be highly compliant with the theoretical framework of the program.

Table 9

Descriptive Statistics for Average Subscale Scores

	n	Minimum	Maximum	Mean	Std. Deviation
Mastery	39	1.00	4.00	3.55	0.70
Vicarious	39	3.00	4.00	3.80	0.35
Social Persuasion	39	2.80	4.00	3.83	0.32
Physiological State	39	2.83	4.00	3.87	0.28
Role Modeling	39	3.00	4.00	3.83	0.26
Curriculum	39	2.60	4.00	3.75	0.38

The mean scores for each aspect of fidelity along with qualitative data from the observations will be discussed in separate sections below.

Mastery experience. The mean of rater fidelity scores for mastery experiences (the key element of identity and self-efficacy building) was 3.55 ($SD = 0.70$) of a possible 4 points. Mastery received the lowest mean score of the six elements of fidelity.

Of the activities observed, only three lacked a substantive hands-on component. Two of these received the minimum score of 1 point for mastery. These sessions—introduction to forensic investigation, critical thinking (Forensics), and light and spectra (Discovery)—did have considerable student interaction with the instructors and consistent question-and-answer components. Students were observed to enjoy these sessions, despite the lack of hands-on activity, though some became disengaged, as noted in this observation:

> As the lecture progressed some of the campers begin to appear bored, some had their heads on the table and I was concerned they had fallen asleep. At times there was a discussion when campers were included, but for the most part it was more lecture based.

The remaining sessions consisted primarily of hands-on activities, providing students with ample opportunity to test out approaches. In total, 48 of the 60 unique activities in the program were built around one or more hands-on activities. Researcher observations provided many accounts of students engaged in hands-on activities. The following is an exemplar of the type of activity observed by the researchers in the remaining 19 activities that were executed with a score of 3.0 or greater in mastery experiences: “All campers were at their table working on their circuit boards that will be part of their pinball machine. At one table two of the girls work on the circuit board while the third operates the laptop." Of the 23 activities observed, research notes for 21 included explicit observations of students engaged in mastery experiences.

Vicarious learning. The mean score for fidelity to vicarious learning (self-efficacy) was 3.8 ($SD = 0.35$) of a possible four points. Scores for vicarious learning ranged from 3 to 4 for all observed activities. A large part of all three camps involves teamwork and testing out ideas. Campers have ample opportunity to observe others carrying out tasks and to share their own ideas and experiences with one another. Research notes for all but two of the observed activities included descriptions of vicarious learning among participants. The researchers observed many instances of vicarious learning during camp activities. This quote from one researcher's notes shows a typical example of types of vicarious learning observed: "One group learned very quickly that a smaller balloon travelled farther than a larger balloon. This was shared among the groups and there was a lot of competition for the smallest balloons."

Not all teamwork produced vicarious learning opportunities. While the activities in general were rated highly for providing vicarious learning, sometimes campers were disengaged or excluded by peers. One instance of this was noted in the forensic investigation camp.

> During the activity, specifically in two groups, some students dominantly took the lead, while others had either less or no opportunity of participating in the activity in person. In this group, one student kept drawing a picture while other students dominantly led the activity.

Social persuasion. The mean rating for social persuasion was 3.83 (*SD* = *.32*) out of a possible 4 points. Scores for social persuasion ranged from 2.8 to 4.0 with 25 out of 39 scores rated 4.0. Social persuasion is the measure of how well instructors are providing feedback that supports participants' development of science efficacy, science identities, and growth mindsets in science. SPICE camp instructors were trained in the application of these three theories in the informal science environment. They were instructed to provide process-based feedback, focusing on aspects of the activity under the camper's control, to those who were struggling. The researchers observed many instances of instructors providing positive, process-based feedback and encouragement to persist beyond frustration. Research notes documented examples of instructors providing encouraging process-based feedback in 19 of the 23 observations. The following is typical of the observations made about SPICE instructors.

> The instructors walk around the room checking in with each group to make sure that the girls are performing the activity and to ensure there are no questions. The instructors are caring and attentive during the activity and give their full attention to each table. The instructors stop by the tables and discuss the activity quite often in order to make sure the girls are staying on task and to praise them. The instructors have a friendly disposition and the campers appear quite comfortable in performing the activity.

Physiological state. The physical conditions and emotions a student experiences moderate self-efficacy development. Physiological state is only an issue when the student is experiencing some sort of distress, either physically or psychologically. The average score for elements of a supportive environment was 3.87 of a possible 4 points. Average scores ranged from 2.83 to 4.0. Only one observation scored physiological state below 3.0.

Instructors can help mitigate problems by creating a space that is physically and psychologically comfortable. On the whole, campers appeared happy and comfortable during activities. A few circumstances arose in which conditions became a detriment to learning. In particular, the indoor space used by the Forensics camp was small and full of furniture, which hindered some activities, and resulted in the only activity scored below 3.0 on the physiological state measure. Both observers noted the discomfort. “Our observation was rather hindered today because the size of the room coupled with two UO photographers walking around taking pictures made it difficult to walk around and observe different tables. The smallness of the room plus too many adults made the instructor a little irritable and it was a bit uncomfortable.” This was the only observation in which factors contributing to poor physiological state were mentioned in the research notes.

Role modeling. A major aspect of identity formation, access to role models helps girls envision themselves as scientists. SPICE camp instructors are trained to act as stereotype-defying examples of real scientists engaged in real scientific activities. The average score for role modeling in the observed activities was 3.83 (*SD = 0.26*). Average scores for the operationalized aspects of role modeling for science identities ranged from 3 to 4 points out of 4. Examples of teacher role modeling were described in the research notes for all but two of the observed activities.

A number of tactics are used to provide this role modeling. Double-speak introduces campers to important scientific terminology by pairing technical terms with simple descriptions. Instructors talk about their own experiences learning science, refer to their own interests in science, and actively role model scientific behavior. Many examples of modeling were observed during camp. Nineteen of 23 observation notes specifically mentioned examples of role modeling during activities. The following extended note description exemplifies the type of role modeling observed during camp.

> Before the activity, the instructor started the lecture by asking questions about the scientific concepts and terms related to the activity and consistently used double-talk. She also had students repeat the words (e.g., *catalyst*) to help them feel more familiar and comfortable with the terms. Introducing the new terms and concepts, the instructor also related them to our everyday lives. Example questions are "Do you know what yeast is?" "Do you know a food that has yeast in it?" "Do you know what peroxide is?" "Do you know how it feels when it touches your skin?"

Curriculum. Camp curricula are intended to be hands-on, engaging, and interesting. The content is expected to be thematically appropriate for the topic of the camp and also provide the campers, whenever possible, with a unique experience they likely have not had before in school or their personal lives. The average fidelity score for camp curriculum was 3.75 out of 4. Scores ranged from 2.6 to 4.0. Twenty-one of the 39 observations scored curriculum fidelity average at 4.

Activities should be sufficiently challenging to keep campers interested while not proving overly difficult. A certain level of frustration is expected from time to time. Instructors are trained to help campers deal with frustration and persist in the face of failure. Part of the researchers' observational duties involved assessing how well the curriculum met these standards based on student engagement and affect. The description below captures one of the most popular camp activities, Dry Ice Bubbles—notably, this activity was the only one to receive a perfect average score of 5.0 from the camper evaluations.

> Instructors, from start to finish, provided specific explanations to help students understand better and demonstrated tasks clearly; thus, students knew well what they were expected to do for the given activities, and performed the activities well too. On top of that, instructors continuously tried to connect the content knowledge on dry ice and the hands-on activities that students were engaged in to real life using a variety of examples.

Most activities were observed to be in line with the theoretical framework, though there were some exceptions. Only one activity, dental impressions, received a score under 3.0 for curriculum fidelity.

> The kids were given sets of bite marks on sheets of paper and were told to match the bite marks with the evidence. They were not provided with much information on what to look for or how to go about looking for similarities. The instructors went around the room and helped individual groups and instructed them further on what to look for. I think the concepts of what to look for could have been better grasped if the scenario was presented in a more interesting way than reading from a piece of paper.

Most activities fell closer to the dry-ice bubble activity in terms of average fidelity score for curriculum. Positive participant response to and engagement with the curriculum was described in research notes for 21 of the 23 activities observed.

Interpreting fidelity. Overall, fidelity of implementation was high. Camper evaluations of activities from week one of the camp were high. Intra-class correlation statistics show excellent agreement between raters, though some rater pairings were missing or small in sample size. The fidelity scores produced were consistently high as well. Observations provide additional evidence that camp activities were engaging, instructors were knowledgeable and attentive to students, and the proper role modeling was taking place. Though some instances of boredom, frustration, exclusion were observed, these were few and did not persist for the duration of the camp. All of the hypothesized operationalized elements for producing strong science self-efficacy and identities were in place.

Component 2—Science Affinities

This component addresses SPICE camp participants' interests, efficacy, attitudes, and identities around science, referred to collectively as science affinities. Data used to analyze campers' science affinities includes quantitative and qualitative elements. Outcome variables for the quantitative analysis are the individual scores for the scales developed above. Predictors include variables for scholarship status, years in the SPICE program, and a variable measuring participant engagement with science outside of SPICE camp. Qualitative data is derived primarily from the focus group and individual interviews, and to a lesser extent from the camp observations.

SPICE participants were all females between the ages of 11 and 14. SEP participants were male (n = 27) and female (n = 45) between the ages of 12 and 16. No other demographic data was available for SEP participants. Table 10 provides an overview of SPICE camper characteristics. Race/ethnicity summary information is provided, but due to low sample size and small number of nonwhite students, race/ethnicity was not examined in any analyses.

Table 10

Demographics and Descriptive Information about SPICE Camp Research Participants

Variable	Number of Campers N = 51	Percentage of campers	Percentage of Oregon Population
Received Scholarship (SES)	32	62.7	54.6*
Years with SPICE (0/1/2)	30/10/11	-	-
Grade Level (6/7/8)	19/18/14	-	-
White	42	82	83.6
Asian	5	10	3.7
African American	2	4	1.8
Pacific Islander	1	2	0.3
Native American/Native Alaskan	1	2	1.4
Hispanic	7	14	11.7

Note: Campers are invited to indicate all race and ethnicity identifications. *Percentage of Lane county public school students eligible for free and reduced lunch (Oregon Department of Education, 2014; United States Census Bureau, 2014).

Overall, SPICE campers were slightly more diverse than the population of Oregon with higher participation by minorities and underrepresented groups. The percentage of SPICE campers receiving scholarships was slightly higher than the percentage of children in Lane County (where SPICE is located) eligible for free and reduced lunch (Oregon Department of Education, 2014).

Analysis of the data for component 2 will begin with the development of the science affinity factor scales and examination of the resulting scale scores. Next each science affinity (interest, efficacy, attitudes, and identity) will be analyzed using the developed factor scores and the qualitative data. Finally, the findings for component 2 will be summarized and analysis will move on to component 3.

Factor scale development. SPICE campers and SEP participants were administered the science affinities survey instrument at the beginning of their respective programs. The full survey contained nine scales relating to science affinities. SPICE campers were administered the same instrument in the weeks following camp. Most surveys were completed in late August 2014. A few were returned as late as November 2014.

Four scales are used in this analysis. Two scales were eliminated for redundancy. One scale, as developed by the original author, shared two items with the personal interest scale and was eliminated prior to factor analysis to avoid the complication of interpreting cross-loaded items. Two more scales proved unreliable. Reliability analysis showed that removal of multiple items would improve the Cronbach's alpha statistic more than .10. Removing these items would have resulted in scales of two and three items with still quite low reliability statistics. In the interests of brevity, results of the factor analyses for the scales not used in the final analysis for this study are not presented here.

Exploratory factor analysis (EFA) was conducted on the pre-camp SPICE responses to determine the underlying factor structure (Stevens, 2009). EFA was also performed on the post-camp SPICE responses and the SEP responses. Analyses of all three sets of responses yielded the same final factors. Only results of the EFA on the pre–SPICE camp response will be presented here.

The items representing personal interest in science, attitudes toward science, and science identity were each subjected to factor analysis separately, as each scale was developed separately. The items representing task value and self-concept of ability were subjected to factor analysis together as they were originally developed together and are used here to represent science efficacy. EFA results and reliability statistics for each science affinity are presented below.

Personal interest. The personal interest in science factor consisted of six items on a 5-point ordinal scale. The Kaiser-Meyer-Olkin measure (KMO) of adequacy was .769, indicating the data were sufficient for EFA. Bartlett's test of sphericity χ^2 (15) = 154, $p < .001$ showed that there were pattern relationships between the variables. Using Kaiser's rule, an eigenvalue cutoff of 1.0, the analysis extracted one factor accounting for 54% of the variance of the 6 items. Visual inspection of the scree plot confirmed one factor. Additional measures of factor retention, Velicer's Minimum Average Partial (MAP test) and parallel analysis (O'Connor, 2000) also supported a one-factor solution.

Item communalities were generally moderate (h^2 = .63 – .70) with the exception of item 4 (h^2 = .074). Inspection of the factor matrix revealed high loadings (.74–.83) with the exception of item 4 (.27).

The EFA was run again without item 4. Communalities for the factor were all above the cutoff h^2 = .3. The factor accounted for 64% of the variance of the items. The final factor pattern matrix is presented in table 11. Factor loadings ranged from .748 to .839.

Reliability for the now 5-point scale was high (Cronbach's Alpha = .90). Reliability was not predicted to increase with the removal of any items, so all were retained. The items in this scale focus on the individual's feelings toward a personal application of science. The deleted item, "I am not satisfied until I understand why something works," implies a level of mastery of science that is appropriate for the college-age respondents used to develop the scale, but may not be appropriate for the middle school respondents of this study who are not yet independent learners.

Table 11

Factor Matrix for Exploratory Factor Analysis of Science Interest Scale for Pre-Camp Data

Item number and text	Factor loadings	h^2
5 I study science to learn knowledge that will be useful in my life outside of school	.839	.70
2 Reasoning skills used to understand science help me in my everyday life	.838	.70
1 Learning science changes my ideas about how the world works	.784	.62
3 I think about the science I experience in everyday life	.780	.61
6 I enjoy solving science problems	.748	.56

Science efficacy. The measurements of science efficacy consisted of the items comprising the original factor for task value and the items comprising the original factor for self-concept of science ability. These two scales were analyzed together. The KMO statistic was .763, indicating the data were sufficient for EFA. Bartlett's test of sphericity χ^2 (15) = 142, $p < .001$ showed that there were pattern relationships between the variables. Using Kaiser's rule, the analysis extracted only one factor accounting for 52% of the variance of the six items. Visual inspection of the scree plot confirmed one factor. Map and parallel analysis also supported a single-factor solution.

Item communalities were all above (h^2 = .3). Inspection of the factor matrix revealed moderate to high loadings (.49–.86). Table 12 shows the results of the factor matrix. Reliability for the single scale was high (Cronbach's Alpha = .85). Reliability was predicted to increase (Cronbach's Alpha = .86) with the removal of item six, however the predicted change was slight, so the item was retained. These items were presented as two scales in the original literature, but they were also known to form only one scale together (Else-Quest et al., 2013). All items were retained as one scale of science efficacy.

Table 12

Pattern Matrix for Exploratory Factor Analysis of Science Efficacy Scale for Pre-Camp Data

Item number and text	Factor	h^2
5 How interesting is science to you?	.875	.79
1 How good at science are you?	.832	.75
2 If you were to rank all the students in your science class from the worst to the best in science, where would you put yourself?	.787	.81
4 How important is it that you learn science?	.729	.73
3 Compared to most of your other school subjects, how good are you at science?	.510	.54
6 How important do you think science will be to you in the future?	.487	55

Science attitudes. The scale of attitudes toward science consisted of 14 items on a 5-point ordinal scale. The Kaiser-Meyer-Olkin measure (KMO) of adequacy was .922, indicating the data were sufficient for EFA. Bartlett's test of sphericity χ^2 (91) = 729, *p < .001* showed that there were pattern relationships between the variables. Using Kaiser's rule, the analysis extracted one factor accounting for of 67% of the variance of the items. Visual inspection of the scree plot supported a single-factor solution. Parallel analysis also supported a single-factor solution. Velicer's Minimum Average Partial (MAP) test indicated a two-factor solution. The responses for post-camp SPICE participants and SEP participants also yielded single-factor solutions.

Item communalities were generally moderate to high, with the exception of item 5 (h^2 = .1). Factor loadings were also high with the exception of item 5 (.345). The model was run again omitting item 5. The analysis yielded 1 factor accounting for 72% of the variance in the model. The pattern matrix is presented below in table 13.

Table 13

Factor Matrix for Exploratory Factor Analysis of Science Attitudes Scale for Pre-Camp Data

Item number and text	Factor	h^2
9 The feeling that I have towards science is a good feeling.	.912	.84
12 I feel at ease with science and I like it very much.	.890	.80
6 Science is interesting to me and I enjoy it.	.889	.78
1 Science is fun.	.886	.79
8 Science is fascinating and fun.	.884	.78
11 Science is a topic which I enjoy studying.	.878	.77
13 I feel a definite positive reaction to science.	.868	.76
4 I would like to learn more about science.	.861	.74
14 Science is boring.*	.838	.71
7 Science makes me feel uncomfortable, restless, irritable, and impatient.*	.828	.69
2 I do not like science and it bothers me to have to study it.*	.757	.57
10 When I hear the word *science*, I have a feeling of dislike.*	.739	.54
3 During science class, I usually am interested.	.738	.55

*These items were reverse coded prior to analysis.

Reliability for the scale was high (Cronbach's Alpha = .96). Reliability was not predicted to increase with the removal of any items, so all were retained. The items in this scale focus on the individuals' attitudes toward science in general.

Science identity. The measure of science identity consisted of four items on a 5-point ordinal scale. The Kaiser-Meyer-Olkin measure (KMO) of adequacy was .769, indicating the data were sufficient for EFA. Bartlett's test of sphericity χ^2 (6) = 65, $p < .001$ showed that there were pattern relationships between the variables. Using Kaiser's rule, the analysis extracted one factor accounting for of 52% of the variance of the items. Visual inspection of the scree plot confirmed a one-factor solution. Parallel and map analyses also supported a single factor. All items were retained.

Item communalities were moderate. Factor loadings were moderate to high. The pattern matrix is presented below in table 14.

Table 14

Factor Matrix for Exploratory Factor Analysis of Science Identity Scale for Pre-Camp Data

Item number and text	Factor	h^2
3 I am confident in my science skills.	.827	.68
1 I think of myself as a scientist.	.733	.54
2 I have had enough experience to know that I can be good at science.	.728	.53
4 I receive feedback from people important to me that says I can be good at science.	.583	.34

Reliability for the scale was high (Cronbach's Alpha = .81). Reliability was not predicted to increase with the removal of any items, so all were retained. The items in this scale focus on the operationalized manifestations of science identity formation as presented in the conceptual framework.

Examining factor scores. Analysis of the science affinities factors begins with inspection of the data. Descriptive statistics reveal minimums, maximums, means, and standard deviations within expected ranges (table 15).

Table 15

Descriptive Statistics of Pre- and Post-Camp Science Affinities Scale Scores

	Min	Max	Mean	Std. Dev.	Skew	Kurtosis
Pre- Interest	8	25	19.03	4.01	-0.51	0.29
Post- Interest	9	25	19.27	3.37	-0.56	0.48
Pre- Efficacy	9	30	25.43	3.47	-2.20	8.91
Post- Efficacy	13	30	26.58	3.56	-1.32	2.26
Pre- Attitudes	13	65	53.81	10.28	-0.85	3.29
Post- Attitudes	36	65	59.01	9.28	-0.55	-0.88
Pre- Identity	4	20	15.14	2.89	-1.00	2.85
Post- Identity	10	20	15.77	2.63	-0.11	-0.60

n = 51

Skewness and kurtosis does appear to be an issue for some of the scales. The pre-camp data for the scale of science efficacy demonstrates fairly severe kurtosis (8.91). The post-camp scale for science efficacy also demonstrates evidence of less severe kurtosis

(2.26). Visual inspection of the histograms (figure 13) shows what appears to be a cluster of responses near the high end of possible values. The distribution of the pre-camp science efficacy scores is also somewhat skewed (-2.20) for the same reason (figure 14). Caution should be taken in interpreting results of based on this scale for analyses that assume a normal distribution.

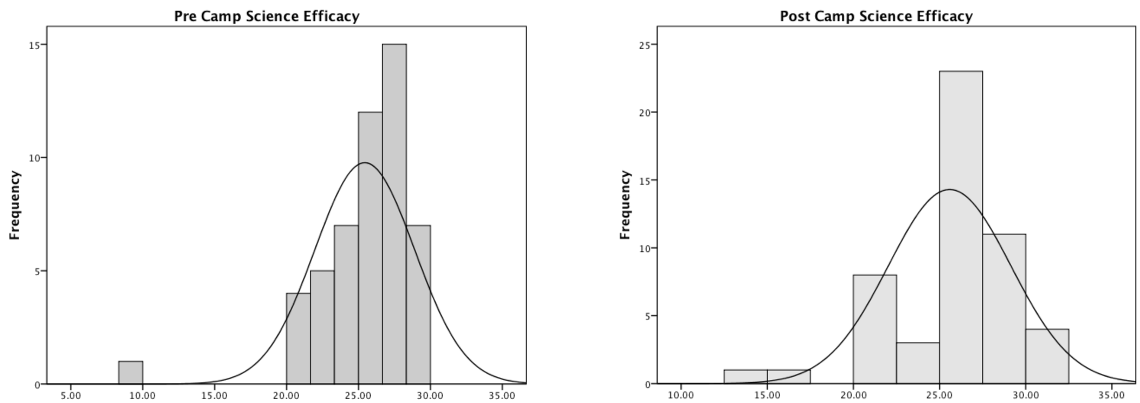


Figure 13. Distribution of pre- and post-camp science efficacy scales.

Slight kurtosis (2.15) is evident for the pre-camp data for the science attitudes. This appears to be due to an outlier on the low end of the scale and a large number of responses near the high end of the scale. Caution should be taken in interpreting results of based on this scale for analyses that assume normality.

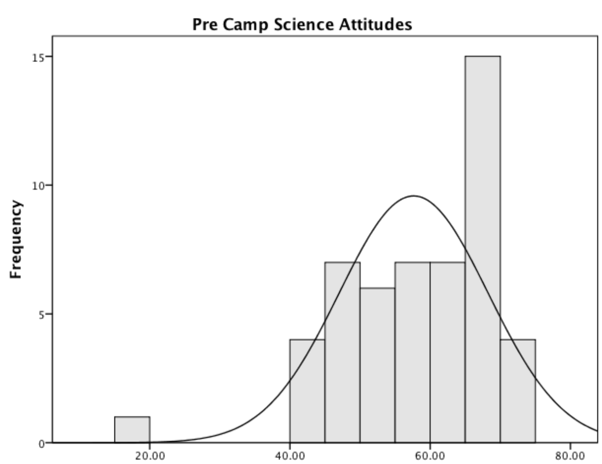


Figure 14. Distribution of self-concept of ability scale.

Next, descriptive statistics for the responses to the science affinities scales from the SEP campers are presented. Table 16 presents the descriptive statistics for the pre-camp responses from the SEP campers.

Table 16

Descriptive Statistics of SEP Science Affinities Scale Scores

	Min	Max	Mean	Std. Deviation	Skew	Kurtosis
Pre- Interest	8	24	17.38	3.65	-0.02	-0.22
Pre- Efficacy	10	30	22.22	4.26	-0.40	0.21
Pre- Attitudes	28	49	40.95	4.56	-0.30	0.10
Pre- Identity	4	20	12.65	3.24	-0.37	0.21

n = 72

Descriptive statistics for the SEP campers' responses to the scales of science affinities indicate that the data were normally distributed. Visual inspection of the histograms confirms the normality of the data.

Next, difference scores for the SPICE pre- and post-camp science affinities responses were calculated by subtracting the pre-camp scores for each scale from the post-camp scores. Descriptive statistics for the resulting difference scores are presented in table 17. Means for the difference scores are within expected ranges. Kurtosis statistics for three of the four scales are above the traditional cutoff of 2.0. This is to be expected given the same issues were found with the pre- and post-camp scales. Examination of the histograms reveals some outliers and clumping of data near the means. The data are slightly non-normal and this will be considered in the discussion of results.

Some non-normality is to be expected. SPICE campers are voluntarily attending a science summer camp, some for the second or third year in a row. It follows that they will have stronger affinities toward science than would be expected in a random selection of children. The impacts of data non-normality and steps taken to address the issue will be taken up in the inferential analysis section of this chapter. Limitations of working with non-normal data will also be addressed in chapter V.

Table 17

Descriptive Statistics of Difference Values for Scales of Science Affinities

	Min	Max	Mean	Std. Deviation	Skew	Kurtosis
Change in Science Interest	-7.5	6	0.23	2.97	-0.73	0.42
Change in Science Efficacy	-8	8	0.15	2.77	-030	2.27
Change in Science Attitudes	-23.5	23	1.06	6.53	-.12	5.38
Change in Science Identity	-6	10	0.64	2.61	0.72	2.74

n = 51

Some non-normality is to be expected. SPICE campers are voluntarily attending a science summer camp, some for the second or third year in a row. It follows that they will have stronger affinities toward science than would be expected in a random selection of children. The impacts of data non-normality and steps taken to address the issue will be taken up in the inferential analysis section of this chapter. Limitations of working with non-normal data will also be addressed in chapter V.

Inferential statistical analysis. A series of inferential statistical analyses were run on the scale scores resulting from the factor analyses. For each developed scale, independent sample *t*-tests comparing SPICE pre-camp responses to SEP pre-camp responses were conducted to determine if SPICE campers had higher starting science affinities as hypothesized. Dependent sample *t*-tests were used to determine if camper science affinities changed between the pre- and post-camp time frames. In addition to *t*-tests, nonparametric test were used in the analyses of science efficacy, science attitudes, and science identities. The Wilcoxon and Mann-Whitney tests are designed as an alternative to the paired samples *t-test* to determine if a change has occurred in repeated measures. They can be used on count, ordinal, and non-normal continuous data (Powers

& Xie, 2008). For the comparisons between the SPICE and SEP participants, the Mann-Whitney test was used. For comparisons between the pre- and post–SPICE camp participants the Wilcoxon signed ranked test was used.

Change in camper science affinities (interests, efficacy, attitudes, and identity) toward science in a sample of 51 participants was examined using a series of models to determine the predictive relationship between scholarship status (SES), years in the SPICE program, science engagement, and interactions between these three variables. All variables were entered simultaneously. Nonsignificant variables and their related interactions were removed one at a time until only significant variables remained, or no significant relationships were found. Cell counts of students with scholarships by years in the program were low. In order to balance the analysis the variable for years in the program was dichotomized and effect coded. Students with no prior experience with the program were coded as -1 and students with one or two years of experience with the program were coded 1. Centering in the form of effect coding was used to reduce multicolinearity in the model. The variable for scholarship status was also effect coded. Table 18 shows the final cell counts.

Table 18

Number of Students by Scholarship and years in Program

	Years	# Students
Scholarship Received	0	17
	1–2	15
No Scholarship	0	13
	1–2	6

Handling of the assumptions of regression and influential outliers. Residuals for the first model containing all predictors were examined to confirm that the assumptions of regression, linearity, independence, normality, and equivalence of variance were met. Scatterplots of the predictors against the dependent variable were examined, as were histograms of the predictor variables, plots of predicted and observed residual distribution, matrix scatter plots of model variables and residuals, and residual variables versus fitted values. No violations of the assumptions of regression were found in the residual plots or histograms.

Residuals were also examined to determine if any outlier cases were unduly influencing model coefficients. Leverage and Cook's Distance statistics were examined and compared to difference in beta results for individual cases. Cases with high leverage and/or Cook's Distance values as well as difference in beta scores were then visually inspected on plots of predictors versus the independent variable. No unduly influential outliers were found on any of the scales of science affinities. All cases were retained in the final models.

Analysis of science affinities. For each of the four science affinities, reporting of the findings follows the same outline. First the inferential statistics will be presented, starting with the comparison of means for the SPICE and SEP groups. Next, means for the SPICE participants before and after camp will be presented. Both *t*-tests and nonparametric tests will be employed as appropriate. Next the findings of the regression analyses will be reported. A brief summary of the quantitative findings follows. The associated qualitative findings are presented next. Lastly, a summary of all findings related to the particular science affinity is presented.

Science preferences and interest. Research question 2 addresses SPICE participants' interests and preferences for science. Comparisons of means of SPICE and

SEP participants prior to their respective experiences show that, on average, SPICE campers (19.03) score higher than SEP students (17.38) on the scale of science interests $t(121) = 2.38$, $p = .02$. Table 19 shows the results of mean comparisons of science interests.

Table 19

Results of t*-test and Descriptive Statistics for Science Interest by Group*

	Treatment Condition							
	SPICE N = 51		SEP N = 72					
	M	SD	M	SD	95% CI for Mean Difference	t	df	Cohen's *d*
Interest in Science	19.03	4.01	17.38	3.65	.28, 3.03	2.38*	121	.43

**p* ≤ *.05.*

SPICE participants were predicted to have higher starting interest in science than SEP participants, due to their self-selection into an exclusively science-themed camp.

Comparison of means of SPICE participants interests in science before and after camp did not yield statistically significant results $t(50) = 1.74$, $p = .58$. Table 20 shows the results of the *t*-test comparing pre- and post-camp science interest means for the SPICE participants.

Table 20

Results of t*-test and Descriptive Statistics for Science Interest by Time*

	Treatment Condition							
	Pre-Camp N = 51		Post-Camp N = 51					
	M	SD	M	SD	95% CI for Mean Difference	t	df	Cohen's *d*
Interest in Science	19.03	4.01	19.27	3.37	-0.10, 1.37	1.74	50	-.06

Regression analysis of science interest scores. The first regression model with all predictors and interaction terms yielded no statistically significant results. A second model removing the engagement variable and the two related interactions was then run, also with no statistically significant results. A third model was run with only the predictor for scholarship status. Again, no statistically significant relationships were found. Table 21 shows the results of the first model with all predictors.

Table 21

Model 2 Regression Analysis of Science Interests with Scholarship Status Controlling for Years in the Program, Engagement, and with Interactions

Variable	Zero Order	***b***	*se*	*sr*	VIF
Intercept		.98	1.06		
Scholarship	-.08	-.26	1.04	-.12	4.24
Years in SPICE	-.03	1.21	0.75	.17	5.83
Engagement	.04*	-.73	0.90	-.05	1.52
Years x Scholarship	-.20	-.92	0.51	-.26	1.44
Years x Engagement	-.08	-.86	0.75	-.16	4.82
Scholarship x Engage	-.11	.23	0.68	.05	3.84
	R^2 = .09, F = .72(6, 44), p = .638				

**p < .05, **p < .01, n = 51*

Quantitative analysis of SPICE participants' science interests summarized. SPICE participants demonstrated statistically significant higher starting interest in science as compared to SEP participants. No differences in SPICE participants' science interest from the pre- to post-camp condition was found. No relationship between campers' change in interest in science and the predictors for scholarship status, years in the program, or preexisting science engagement were found.

Qualitative analysis of SPICE participants' science preferences and interests. SPICE campers show higher initial interest in science compared to the SEP participants. The above measures seek to quantify general personal interest in science. The qualitative findings presented here will address themes in SPICE campers' preferred ways of engaging with science.

Girls come to SPICE with a range of previous experiences. Some are heavily engaged in science inside and outside of school. Some have had minimal exposure to science in elementary school. Despite the variance in their experiences, there was substantial overlap in the ways they prefer to engage with science and what excites them about science subjects. Two primary themes for girls' science preferences emerged from the qualitative data: the role teachers play in girls' development of interest in science and girls' preferences for hands-on engagement with science.

Teachers. Schoolteachers were a source of both joy and vexation for many campers. The girls were always quite animated in discussing their interests in science. During the focus groups they engaged one another in discussion and debate about teachers and their role in fostering or discouraging science interest and engagement. Two of the focus groups spent substantive time discussing teachers and 9 of the 11 girls selected for individual interview commented on the role of teachers in encouraging or discouraging their interest in science. Five participants noted a specific teacher who had fostered in them an interest for a particular discipline. Many more, approximately 40%, cited teachers as a major factor in their enjoyment of science classes in school with nods or short vocal affirmations during focus groups. Four girls reported a decreased interest in a subject they had previously enjoyed due to a particular teacher. One participant provided examples of both positive and negative teacher experiences. Three teacher-related factors play a role in how girls engage with science in the classroom: interpersonal interactions with the teacher, teacher passion for science, and teacher expertise.

Interpersonal interactions with teachers. Interpersonal interactions varied between campers and accounted for at least one disagreement between campers who had been in class with the same teacher. Some declarations were fairly straightforward. In a discussion between girls during a focus group, camper Ava commented that she enjoyed science activities at SPICE camp, but trailed off when discussing school science. Camper Alice responded more bluntly to Ava's polite demurral to speak negatively about her teachers: "The science teachers are really boring. And mine was old and grumpy and hated children," Alice reported.

Clearly, Alice did not feel welcome or engaged in her science classrooms. Another student, Becky, commented in both the focus group and her individual interview that problems with a popular teacher had made it challenging for her to enjoy science in school. "She made me feel like I'm wrong . . . I mean, she's really nice to, but sometimes, just emotionally, it wasn't very safe. Being in that science class it wasn't really fun anymore." Feeling welcome by experts and mentors plays an important role in in the development of self-efficacy and identity (Ferrieira, 2001; Lewis, 2012; MacDonald, 2000). Engineering camper Vidya encapsulated the relationship between her interest toward a subject and her relationship with the teacher. "We have different teachers. If it's a really boring physics teacher I'm not going to like it. But if it's a really fun chemistry teacher, then I'm going to like it."

Some campers were skeptical about their teachers' interest in fostering strong science identities. When asked what teachers are looking for in a science student, engineering camper Dashka responded skeptically: "Good student. Cause you're not really supposed to be creative for school in science because you're supposed to follow the instructions." Fellow engineering camper Elizabeth disagreed. "I guess it depends on the school. Cause my school is completely different."

It is important to remember that middle school teachers are gatekeepers to the more advanced and interesting coursework available in high school. As Brickhouse (2000) concluded in her study of black girls' science identities, teachers make decisions about what courses students will have access to in high school based more on behavior than creativity or aptitude. SPICE girls are well aware that "good" students are more likely to have access to these experiences. Dashka, a girl of color who is very outgoing, social, and likes to challenge her SPICE instructors, is skeptical that her teachers want anything more from her than compliance. Elizabeth, white and a prototypical honors student who is generally quiet and compliant, feels supported by teachers, and views school as place for creativity and exploration. Dashka's and Elizabeth's demeanor and attitudes toward teachers mirror Sheela and Tanisha from Brickhouse's study. Sheela, an all-around good student, reserved and compliant, with only a passing interest in science, was placed into advanced science coursework in high school by her teachers. Tanisha, who evidenced a strong interest in the exploratory aspects of science but who also routinely challenged her teachers when they presented her with boring curriculum, was tracked into the standard science coursework.

Teachers and passion for science. Passion for the subject matter was frequently noted as a way in which teachers encouraged girls to enjoy science. Subjects that they had previously been uninterested in became fascinating when filtered through their teachers' enthusiasm for the subject. Engineering camper Elizabeth attributed part of her interest in science to teacher enthusiasm: "We did lots of hands-on activities . . . and they were excited about science and that kind of made me more excited about science." Pleasure in learning can be contagious when a teacher brings passion for the subject to the classroom. Vidaya, an Engineering camper, recounted how a teacher's excitement about physics converted her into a physics-loving student:

> It also depends on how your teacher is, if he or she is enthusiastic [that] makes it fun . . . Sixth grade year I took a physics class. We had this really, really fun teacher. He made science feel so fun it didn't really feel like the science that we used to do. Everyone really liked that class. [Now] I really like-like physics.

Consistently in interviews and observations, when campers expressed an interest in a specific area of science they had a story about a teacher or an activity they had participated in that got them excited about that area of science. Vidaya's teacher got her interest in physics "against [her] will." A Forensics camper, Janet, was encouraged by her teacher's goofy behavior: "Every time you do a lab with her she's like, 'Now prepare yourselves for SCIENCE!' . . . and she wears a strainer hat." Alexandria, a surprisingly sardonic Discovery camper, deviated from her usual deadpan when talking about her favorite science teacher, "Well, she's just fun! I mean, she won't let you off if you don't finish your homework, [but] she just finds a way to make everything interesting."

Anecdotally, there is an abundance of evidence that teachers play a prominent role in inspiring and supporting girls and women in science (Ride, 2012; Stead & Kelly, 2015). S. Rosser (2012) presents a series of vignettes from successful female scientists citing the role that supportive teachers and mentors have played at all stages of their science education and careers. SPICE girls also note the powerful roles teachers play in their own science interests.

Likewise, a teacher who communicates no enthusiasm for the subject matter can turn a student who enjoys science off of a particular discipline (Brickhouse et al., 2000; Buck et al., 2008; Christidou, 2011; Haussler & Hoffman, 2002). Taylor, a Forensics camper and a self-described science enthusiast with a passion for chemistry, wants nothing to do with geology: "We have one [class] where we study rocks and it's really boring, cause that's all we do. And he doesn't make it fun as you can." When asked if she thought a different teacher could have gotten her excited about geology she responded with an emphatic "yes!"

Teacher expertise. At the beginning of each focus group, campers were asked if they personally knew any scientists or knew of any famous scientists. Only five participants could name anyone they were personally acquainted with whom they thought of as scientists, though nearly all of them had had some science instruction from teachers. Only one camper cited a teacher as a scientist she knew. Even as many participants cite teachers as the source of their interest in a particular science subject, they do not tend to think of their teachers as experts and do not view them as science role models.

Taylor went so far as to elaborate on her feelings that schoolteachers do not qualify as scientists. "Well, I think that *they* think that they're scientists, but they don't do anything sciency. They just show you a presentation about science that they got from online and then they make you do [a] paper about science. And I don't really think that they [are] scientists." When probed further, Taylor elaborated that in order be a scientist a teacher needed to be skilled and knowledgeable in his or her own right. She felt that her teachers were "just saying what the textbook is telling them to say." There is research evidence to support Taylor's assessment of her teachers' skills. Many science teachers may not be up to the challenge of contextualizing scientific learning in a way that produces a coherent understanding of science and convinces their students of their scientific authority (Bianchini, Johnston, Oram, & Cavazos, 2003).

Taylor may not be alone in her skepticism of teachers' ability to provide scientific role models. Munro and Elsom (2000) found that teachers themselves often do not think of themselves as sources of information for potential science careers. They do not see it as part of their job as science teachers to inspire children to envision themselves as scientists (Munro & Elsom, 2000). This is particularly important for girls Taylor's age, as research shows that by age 14 an individual's level of interest in science is formed and students with a strong interest in science are 3.4 times more likely to pursue science careers (Tai et al., 2006).

For Taylor, as for many other SPICE girls, science is about *doing* science. Active engagement in scientific activities is key to a scientific identity for SPICE participants. If being a scientist is about doing science and teachers are not perceived as doing science, their credibility as role models is compromised.

Hands-on learning and deeper understanding. When asked what kinds of science they enjoy, how they learn best, and what makes them excited about science, the first and most often repeated response from campers is a strong preference for hands-on activities. The expression of this preference is almost always coupled with a statement about how much they do not like worksheets, textbooks, long readings, and writing. Learning that children do not like pencil and paper work is hardly a revelation—however, digging deeper, there is also a definite link between their preference for hands-on work and their desire for a deeper understanding of the workings of the natural world. Campers referenced their preferences for hands-on activities in five of seven focus groups and all 11 interviews. In total, 24 campers explicitly mentioned their preference for hands-on science learning. Enjoyment of science is directly linked to hands-on activity, or "doing science." In the coding of camper interviews and focus groups (18 transcripts total) "hands-on" or "doing science" was linked with "enjoyment of science." These two codes occurred simultaneously across 11 transcripts.

Even among academically motivated campers, traditional "bookwork" in science is a source of frustration. Elaine, a Forensics camper who enjoys reading as a hobby and values not only getting good grades but also being the best at her studies, responded as follows when asked how she feels when doing science: "Well, it depends if it's a hands-on thing, or if it's a worksheet. Because worksheets are not very fun . . . personally I hate the worksheet aspects of science." Engineering camper Elizabeth, another self-declared avid reader, who says of herself, "I like to strive for perfection," also does not care for textbooks and worksheets. "I like being able to do hands-on stuff and not just sitting and listening or reading text books. And seeing it happen, not reading about what happens."

These finding are consistent with previous research on girls' science preferences (Billington et al., 2014; Calabrese Barton & Brickhouse, 2006; Halpern, Aronson, et al.,

2007) and children in general (Archer et al., 2010; Bell et al., 2009; Fenichel & Schweingruber, 2010). SPICE participants prefer to learn through hands-on experiences, but as girls, research shows they are less likely to receive hands-on experiences than their male peers (Jovanovic & King, 1998; Leaper, Farkas, & Spears Brown, 2012; Milam, 2012).

Campers do not simply prefer hands-on activities; some directly related their ability to engage with and understand science with these activities. Campers repeatedly refer to the need to "see" scientific principles at work as a key part of their learning process. Worksheets, textbooks, and teacher lectures do not seem to meet this need. They mention three distinct ways in which hands-on activities improve learning: learning through manipulation, retaining knowledge, and figuring out underlying mechanisms. These findings are consistent with other work that examines girls' achievement in science in the context of depth vs. breadth teaching (Hazari et al., 2010; Sadler et al., 2012; M. Schwartz, Sadler, Sonnert, & Tai, 2009; Tai & Sadler, 2001). SPICE participants seek a deep understanding of the subject matter and find hands-on activities to be an effective method for gaining deep understanding.

Understanding: Why & how. SPICE girls value a more nuanced understanding of how the world works. When asked what the most important part of doing science was for them, campers consistently responded that understanding what they had learned, often in conjunction with enjoying themselves, was of primary concern. Sixteen girls, ten from individual interviews and six from focus groups, cited understanding as the most important part of science. In fact, for many SPICE girls, part of the fun is *in* understanding. Audrey articulated a common sentiment when asked what the most important part of science was for her: “Just getting to the point where I can just understand. It's so much easier and I feel like it's more fun to go around the world and know why these things work.”

SPICE girls are not simply interested in getting good grades and passing tests, they crave a deeper engagement with the subject matter. They want to understand science and why they are learning about it. Elaine, a highly academically motivated Forensics camper prioritizes understanding over grades when it comes to science. “I do really think the grades are important, but I just hope I can understand it. It’s probably one of the most important things.” Teaching styles focused on the kind of deep understanding SPICE girls are looking for is linked both to greater interest in science and better achievement (Hazari et al., 2010; M. Schwartz et al., 2009).

Science is also about skill in practice and application. Campers are cognizant that science will play an important role in their future and they want to be skilled, knowledgeable practitioners. They differentiate between what is required to succeed in school and what is required in order to be truly “good” at science. Discovery camper Alexandria draws a line between the knowledge required to “pass the test” and a useful application: “I'm going to have to use science a lot in my life and I don't think that just having the right answers for the test is going to help. I guess I really just need to understand it and be able to utilize that skill.” The desire for scientific learning to relate back to real-world applications is another characteristic of girls’ preferred ways of engaging with science (Christidou, 2011; Osborne, Simon, & Collins, 2003).

Girls also value being given the freedom to work out problems through experimentation and exploration. “Figuring out” is a recurring theme in their reflections of the importance of science. The phrases “figure out” and “figuring out” appear 108 times across 15 documents. “Figuring out” was discussed in an explicitly positive light by 11 girls, four in the focus groups, and seven in individual interviews. Three girls juxtaposed “figuring out” with frustration, noting the fine line between a challenge to be overcome and a problem that could not be solved without assistance. Figuring out is featured prominently in campers’ comparisons of formal (school) versus informal (SPICE) science learning. Elaine enjoys the challenge of being allowed to uncover solutions: “When I'm doing something at school [versus] here at SPICE Camp, they don't tell you the answer. That's always really fun, just the fact that you get to try to figure it out for yourself.” Forensics camper Grace also prefers the opportunity to learn from her mistakes through hands-on exploration. “At school you get a grade. Here we do different experiments to figure out why it was wrong.”

Girls’ interest in figuring out relates back to the challenge-seeking and resilience aspects of mindsets (Dweck, 2008; Yeager & Dweck, 2012). Many girls commented on frustration, in nearly the same breath as discussing their preference to be allowed to figure out science problems. Twenty-three girls referenced frustrations associated with science and scientists. Five of these framed frustration as positive when coupled with perseverance and eventual accomplishment. It appeared that girls were teetering in between growth and fixed mindsets toward science. They expressed strong preference for being permitted to engage with science in depth on their own terms, but the specter of failure loomed large in their minds. Frustration was associated as a major component of being scientists by seven girls.

Of course, it is hardly surprising to find out that exploratory, hands-on activities are more attractive to middle-school-aged children than written assignments, but SPICE girls also express a strong desire for a deeper understanding of what they are learning. Becky explores this desire, while acknowledging that formal education might not provide the time necessary for an in depth approach: “I think I know what everyone else in the class knows, but I don't feel like I know it [well]. They don't have . . . the time to go in-depth.” Becky feels that she knows the material as well as other students, as well as she is expected to know it, but not as well as *she* would prefer. School science is not meeting her need for a deeper understanding.

Safety, trust, and responsibility. Another recurring theme in girls’ conversations about science is danger. In every conversation, girls were asked what they think when they think about scientists and science. Initial responses were fairly stereotypical. They talked about scientific gear (lab coats, goggles), chemical reactions, mad scientists, and explosions—lots of explosions. Safety as a cause for both concern and titillation was addressed specifically by 24 girls (20 in focus groups and 4 in interviews). Some girls expressed a concern that they might cause some damage to themselves or others doing science. The danger was closely linked to the need for expertise for many of the girls. Scientists risk danger, but they control this danger by being knowledgeable and serious. Taylor described scientists as people like anyone else, who have fun, “but at their work, they're serious and they're not joking around when they're holding dangerous chemicals.”

The association of scientists with danger among children (and adults) is well documented. In particular, the Draw-A-Scientist test has been deployed around the world with thousands of individuals. Overwhelmingly, scientists are associated with dangerous chemicals and vaguely maniacal intentions (Chambers, 2006). Danger is both a draw and deterrent to science for young children (Archer et al., 2010). For girls, the allure of danger often comes in to conflict with socially acceptable gender roles (Archer et al., 2012).

For SPICE girls, being a scientist involves danger, but it also requires education, skill, and risk-taking. The prospect of danger was far from off-putting to most campers, though. The idea of risk was for some an impetus to become more knowledgeable. Discovery camper Aurora directly associated the need to be educated with safety and pride in accomplishment:

> You have to be well educated because if you don't know what the heck is going on then you [could] blow yourself up. I thought being a scientist when I was little was just wearing lab coats and making fog, and blowing things up. And then I realize it's not that anymore. Being a scientist, you have to know your facts, and you gotta be proud of it too. You gotta take chances.

For others the danger was a chance to show their skill and responsibility. It was a sign of trust and respect. For Taylor the trust and danger were part of the fun of SPICE camp. “We don't really get to do this in school. They don't give you dangerous chemicals in school. This is where they trust you to have dangerous chemicals and have fun with it.”

Elaine felt particularly strongly about being trusted as a developing scientist. For her, the trust she was given at SPICE camp was an antidote to some of her frustrations in school. “I really do enjoy the stuff here, because it's more on my level and it's really fun, because we're given a little more trust with dangerous stuff.” Elaine’s school science was circumscribed to workbooks and the occasional field trip. She felt that teachers did not trust her classmates with hands-on activities that involved an element of risk or mess. Yeager et al. (2014) emphasize the importance of building trust and setting high expectations for students as a way to foster growth mindsets. SPICE girls like Elaine crave the sort of trust that comes with being a scientist.

A key element of identity formation is induction into in-group status through increasing responsibility (Erikson, 1968). Elaine enjoys science most when she feels respected in her skills and trustworthiness. The potential danger of scientific activities represents a step toward status as a scientist and is a mark of trust. She also notes how camp activities are "more on [her] level." A highly academically motivated student, Elaine appreciates the chance to step into what she perceives to be more challenging activities. Though it should be noted, SPICE camp curriculum is not designed for advanced students. Activities are instead designed for students with a wide range of academic aptitude, providing extension opportunities for campers who want a greater challenge. Still, for Elaine, the perception that SPICE activities are at a higher level, as evidenced by the trust instructors place in campers, increases her enjoyment.

Preferences and interests summarized. Participants in the SPICE program had higher initial interest in science than the comparison group as measured by the scale of personal interest. No change in personal interest over time was found. Many SPICE girls expressed the belief that teachers had played a substantial role in the development of their interest in science. SPICE girls expressed strong preferences for hands-on over passive forms of learning. They want a deep understanding of scientific principles and many crave the trust that comes with carrying out potentially dangerous scientific activities.

The results of analysis of science affinities now moves on to girls' value for science and their confidence in their science abilities. Reporting of the results begins with the scale of science efficacy.

Science efficacy. Comparisons of means of SPICE and SEP participants prior to their respective experiences show that on average, SPICE campers (25.43) score higher than SEP students (22.23) on the scale of science efficacy $t(121) = 4.44$, $p < .01$. Table 22 shows the results of mean comparisons of science interests.

Table 22

Results of t*-test and Descriptive Statistics for Science Efficacy by Group*

	Treatment Condition							
	SPICE N = 51		SEP N = 72		95% CI for Mean			
	M	SD	M	SD	Difference	t	df	Cohen's *d*
Interest in Science	25.43	3.47	22.23	4.26	1.78, 4.64	4.44*	121	.82

$^*p \leq .01$.

The scores for SPICE pre-camp responses to the scale of science efficacy were slightly non-normally distributed. In addition to the standard *t*-test, the nonparametric Mann-Whitney test was conducted as well. The Mann-Whitney test indicated that the science efficacy score was greater for SPICE participants (Mdn = 26) than for SEP participants (Mdn = 22), U = 947, $p <$ 001. Both tests confirm that SPICE participants have higher starting science efficacy than SEP participants.

Comparison of means of SPICE participants' interests in science before and after camp did not yield a statistically significant result $t(50) = .38$, $p = .71$. Table 23 shows the results of the *t*-test comparing pre- and post-camp science interest means for the SPICE participants.

Table 23

Results of t*-test and Descriptive Statistics for Science Efficacy by Time*

	Treatment Condition							
	Pre-Camp N = 51		Post-Camp N = 51		95% CI for Mean			
	M	SD	M	SD	Difference	t	df	Cohen's *d*
Interest in Science	25.43	3.47	25.58	3.56	-0.63, 0.93	0.38	50	.04

The nonparametric Wilcoxon signed ranked test also showed that SPICE participants did not exhibit a statistically significant change in science efficacy in the post-camp time frame (Z = -0.47, p = .64).

Regression analysis of science efficacy scores. In the first regression analysis all three predictors (scholarship, years in program, and science engagement) and the associated interaction terms were entered into the regression model. The first model yielded no statistically significant results. A second model removing the engagement variable and the two related interactions was next run. In the second model, the coefficient for interaction term between years in the program and scholarship status was statistically significant -.33(t = -2.26, p< .05). However, the variance explained by the model was not statistically significant. A third model with only scholarship status was run with no statistically significant results. Table 24 shows the results of model 2.

Typically, coefficients of regression models are not interpreted if the overall model is not statistically significant. However, due to the high chance of type II error, and in order to compare these results to other affinities scale regression analyses, this interaction term was interpreted.

Table 24

Model 2 Regression Analysis of Science Efficacy with Scholarship Status Controlling for Years in the program, and Engagement with Interactions.

Variable	Zero Order	***b***	*se*	*sr*	VIF
Intercept		.27	.41		
Scholarship	.03	-.108	.41	-.04	1.10
Years in SPICE	-.09	.03	.41	.01	1.14
Years x Scholarship	-.33*	-.93*	.41	-.31	1.16
	R^2 = .10, F = 1.88(3, 47), *p* = .145				

**p < .05, **p < .01, n = 51*

In order to interpret the interaction term, the predicted score for each condition (scholarship/no scholarship versus years in program) was calculated (see table 25) and plotted.

Table 25

Predicted Difference Scores for Science Efficacy

	Number of Students	Year in SPICE	Predicted Score
Scholarship Received	17	0	1.34
	15	1+	-0.74
No Scholarship	13	0	-0.58
	6	1+	1.07

Figure 15 shows the interaction in graphical form. For students in their first year of camp who received a scholarship, the predicted difference score on the scale of science efficacy between the pre- and post-camp conditions was 1.34 points. That is, their science efficacy, as measured by the efficacy scale, is expected to increase by 1.34 points after the first camp experience. In subsequent years, the score is predicted to decrease by 0.74 points. For students not receiving a scholarship the expected change in scores is -0.58 in the first year, but is predicted to increase by 1.07 points in subsequent years. Overall, this means that students receiving scholarships start out increasing their science efficacy while non-scholarship students experience decreasing efficacy. Over time, however, it is predicted that scholarship students will begin loosing efficacy and non-scholarship students will gain efficacy.

Figure 15. An interaction between scholarship status and years in SPICE program predicting science efficacy.

Quantitative analysis of SPICE participants' science efficacy summarized. SPICE participants demonstrated statistically significant higher starting efficacy in science as compared to SEP participants. No differences in SPICE participants' science efficacy from the pre- to post-camp condition was found. In the regression of science efficacy, the predictor for the interaction between scholarship status and years in the program was statistically significant, indicating that over time, non-scholarship students will experience gains in science efficacy while scholarship students experience losses in science efficacy. However, the variance explained by the model was not statistically significant.

Qualitative analysis of SPICE participants' science efficacies. In individual interviews, girls were asked about their skills as scientists. All of the interviewees (11 total) responded that they believed they were good at science, though some were hesitant to engage in what they seemed to think constituted bragging by acknowledging their science skills. When asked how others (parents, teachers, and friends) would describe their science interest and skills girls were even more reluctant to answer. Two girls openly indicated others would say they were interested in and skilled as science. The rest demurred. Some indicated that they really did not know what others thought about their science abilities. Generally, girls seemed uncomfortable with the question. Responses to these two questions are illuminating. Even in cases where girls believe themselves to be skilled, they were hesitant to respond affirmatively without qualification. Proudly stating science skills, for most girls, seemed somewhat taboo. Bragging about science, it appeared, is not something girls, even girls at a science camp, do.

Research question 3 addresses girls' beliefs in their science abilities, also known as science efficacy. If girls feel that their gender undermines their chances of succeeding in science then they will also likely have lower efficacy (Ahlqvist et al., 2013; Cundiff et al., 2013). In terms of qualitative data, this question explores girls' science and gender perceptions. Are girls aware of the gender gap in science? If so, what do they think about it? What messages are they receiving and how do they respond to them? Do they perceive differences between their male and female peers? What is the role of female friends in girls' science interests? How do girls respond to being in the minority as scientists? SPICE girls had a number of things to say about gender and science. Their responses in focus groups and interviews reveal both a diversity of attitudes about interests in science, but also some consistent attitudes and frustrations. This section will explore girls' science efficacy through the lens of gender perceptions.

Women's contributions and societal messages. The SPICE girls were clearly aware that women are in the minority in science. They also recognize that messages about traditional gender roles are not consistent with science identities. One focus group in particular was eager to discuss how societal messages were shaping women's contributions to science. Discovery campers Beatrix, Daniela, Alexandria, and Tris associated the lack of women in science with traditional gender roles such as childcare and housework. Without female role models in science, they hypothesized, women were less likely think of science careers as an option. Tris related this back to modern family structures. "I can't really think of a [family] that the man doesn't work and the woman does, but I can think of a whole bunch of relationships where the man works and the woman doesn't. So, it's just, I think that ever since back then people believe that women don't do all the work."

The messages girls are receiving are not merely freeform. As Tris notes, she has personal experience with families where women take on the role of family caretaker, but none in which men take on this role. The girls also touched on how historic roles flow forward into the present. Below, Daniela explores the way in which "back then" ideas shape girls interests and choices today.

> I don't know. Maybe because back then, girls didn't really have the rights to do science. Girls were really house people, so they didn't think girls could do science, so I think it's just the way that it was back then. It just formulates now that a girl shouldn't do science because they're just home people, and boys aren't. I think other girls are saying it to themselves too, "We shouldn't be doing science. We should be taking care of the children." I think they are kind of shy to say, "I

like science. I want to be a scientist and I want to do things in my life that make the world a better place and to make science bigger." [Boys] don't do that and boys are like, "I could do this, so I think I could do anything."

In this complex passage, Daniela tackles societal messages and their consequences. First, she points at that at one point in history women were not permitted to practice science and were expected to fulfill roles as caretakers (Tolley, 2002). Next, she connects these historic circumstances to current women's ideas about their options and capabilities (Andrew et al., 1999; Cundiff et al., 2013). Women are no longer barred from science or careers, however they are hesitant to claim their place as scientists and contributors to something larger (Kitts, 2009). Women, Daniela thinks, "could make science bigger." That is, women have something to contribute beyond what men already contribute to science. This is a point she mentions multiple times during the conversation. Lastly, she comes back around to boys. Boys do not limit themselves, they believe in their skills and their belonging in science implicitly.

Beatrix also touches on how women's internalized gendered ideas can limit their participation in science.

> Another thing, there's like a totem pole of where women and men stand and woman are not completely at the bottom, but they're a lot under men and sometimes, you know how women are discriminated, but sometimes women are discriminating against themselves and it takes them lower and then people don't respect them enough for that, just a couple of people then it takes down the whole gender. "I don't think I can do this," [instead of] "You're strong you can actually go ahead and do that."

These two 11-year-olds have constructed and articulated an argument that is currently being made by scholars of gender disparities in science. Women do, in fact, underestimate their abilities in science (Ahlqvist et al., 2013; Brainard & Carlin, 1998; Corbett & Hill, 2015; National Science Foundation & Directorate for Social, 2011). They are hesitant to claim these identities, while boys readily seize upon them (Ahlqvist et al., 2013). Boys are in fact receiving myriad messages about their skills, talent, and belonging when it comes to science (Dweck, 2006; Halvorson, 2011). These conditions are not going unnoticed by girls. Beatrix and Daniela are most likely particularly sensitive to these issues, growing up with career-oriented mothers: a university professor and an independent businesswoman, respectively. Daniela explicitly notes later in the interview that her own mother, who is quite successful, experiences unique challenges as a female leader.

The accumulation of male examples of science prowess was the focus of many of Flora's comments. In the discussion of role models she mentioned how she was drawn to a female scientist, Ann Moore, and wanted to see more inventions from her. "It was like back in the days the guys they invented more things than the women. Cause we were doing the museum and we looked at inventions and there was mostly guys and there's no girls." Tris concurred that a lack of female role models was part of the reason more women do not pursue science, "Yeah not having role models to say, 'Oh women can be good at science too, not just men.'"

As discussed in the literature review, role models play a part in signaling to girls that science is a valid interest and career option (Buck et al., 2008; Weisgram & Bigler, 2007). SPICE girls' observations follow the same line of thinking. The SPICE girls also seem to be looking for role models to help validate their preexisting interest in science.

Flora herself likes to tinker, working with her father on mechanical projects taking apart the engine of her four-wheeler. She continues her train of thought later in the discussion, referencing her personal interest in mechanics: "Like when guys [say they can] fix cars and stuff and woman can't [because] it's not their spotlight. It can be ours too. I don't like it when they do that. They say like you can't fix the car and stuff like that."

Flora was not alone in her frustration with messages denying women's abilities. Many girls commented on the damaging nature of these messages. Alexandria brought the conversation around to how these messages harm boys as well.

> Alexandria: I actually had someone say this to me once. They said, "this isn't a place for little girls, go back home." But for boys they say, "Boys shouldn't cry," and that's just unfair. Because one, girls can handle this kind of stuff just as well as boys can. And boys should also be allowed to cry. We are just pressuring them into thinking that. . . .
>
> Daniela: They're the manly men, they shouldn't cry.
>
> Alexandria: They shouldn't have feelings, so I think it's bad for a man as well as for a woman.

A large body of literature exists documenting persistent stereotypes about women and science. One of the prevailing stereotypes about gender and STEM is that science careers are more suitable for men (Ahlqvist et al., 2013; Corbett & Hill, 2015; Cundiff et al., 2013; Hill et al., 2010; B. A. Nosek et al., 2002b; B. A. Nosek et al., 2009). The cultural association of science with the masculine creates an artificial binary like the one Flora and Alexandria are confronting (Gilbert, 2001; Gilbert & Calvert, 2003). Science is not for little girls. Science is for boys.

Daniela roots her discussion of women's potential contributions to science in the ways they can help other people and how men are supported in science.

> Daniela: Since men have been contributing for *so many years*, they're the ones who have the great ideas and everything. I think, what if women have even greater ideas? You never know. What if women are or have like the Wright brothers they built planes and Henry Ford built the car, and everything and . . .
>
> Chloe: But they had help.
>
> Daniela: Yeah, they had help. *From other men*. But it's like how do you know if women don't have an idea of making maybe something that could help the earth from people to stop polluting or something like that, they could invent something more [worthwhile] . . . than other stuff. Cause men have been inventing the bad things now.

Here Daniela articulates another point that scholars also make about the value of including women in science. Women need to be a part of science, not just for reasons of equity, because they have something to contribute that is different from what men currently bring, the notion that diversity brings better and different ideas to bear on problems (Brickhouse, 2001; Howes, 1998; Roychoudhury et al., 1995)—that the problems that scientists and society face now are, in fact, in some part caused by narrow perspectives that do not take into account the breadth of human experience and creativity (Haraway, 1991; Harding, 1991; Longino, 1990).

These girls are making fairly sophisticated connections between the messages they are receiving, both implicit and explicit, and how it influences girls' and women's ideas and choices about science. They view these messages as harmful to boys and girls. They feel the absence of role models. This group, more than any other, was eager to dive into the discussion of how gendered messages about science shape the world. They have clearly given the subject thought and are frustrated by the messages they receive. Whether or not these sentiments are the norm is difficult to say. The girls quoted above were passionate and vocal. Some quiet girls nodded along during these discussions, but others remained silent, neither agreeing nor dissenting. Among the interviewees, questions about gender and interest in science revealed a more diverse range of perceptions.

Perceived differences in interest by gender. Girls' lack of interest in science is often cited by teachers, parents, and commentators in the debate over gender disparities in STEM (B. A. Nosek et al., 2009). It would hardly be a shocking result to find that girls attending a science camp are deeply interested in science, but how do their peers feel? How do SPICE girls see the gender divide in STEM? Is science really uninteresting to their female peers? Each girl who gave an individual interview was asked if they had observed a difference in interest in science by gender. The responses varied and reveal something about the link between perceived interest in a subject, conceptions of what makes a good student, and the sometimes gender-circumscribed boundaries of middle school socialization.

Campers were split in their views about which gender is more interested in science: girls (6), boys (2), and both equally (3). Six girls qualified their observations by citing a lack of social interaction outside their gender, enforced participation in coursework, or simply not having enough experience to say for certain. Their explanations for why they perceived one gender as having higher interest are interesting to explore.

Girls who were already highly engaged with science prior to camp and had a circle of friends who shared their interest all cited girls as being more interested in science. Elizabeth, Vidaya, and Taylor observed high engagement with science among their female peers. Much of their observations came from schoolwork, where behavior plays a strong role in defining "good students." For Taylor, interest in science is related to paying attention in class. For her, boys show their disinterest by "messing around." "The boys can get distracted with [science] and they start playing around and messing with . . . stuff . . . We had like an animal skull one day and they were just messing around with it while the girls are studying it and noticing it."

Taylor equates interest with studiousness, with which many adults would no doubt agree. However, "messing around" is one of the ways that students explore science. In fact, the type of physical interaction, touching and manipulating, that Taylor describes boys engaging in is more closely associated with the development of science identities than the observing and note-taking the girls in her class engage in (Fouad & Guillen, 2006). Classically, in the classroom laboratory girls manage activities and take on passive roles like note-taking and observing while boys manipulate equipment, often "messing around" in the process. What students may be identifying as markers of interest, studious behavior, does not often translate into lasting science identities (Fouad & Smith, 1996; Jovanovic & King, 1998). Daniela summed this phenomenon up quite succinctly when asked if she had noticed differences in interest between boys and girls: “More girls *like* science, but more boys *do* science.”

Matilda, a fearless experimentalist and self-proclaimed scientist, observed ways in which gender constrained her male peers from openly expressing interest in science:

> At my school, I think the girls show more interest by voicing their interest. The guys, I know there's a lot of guys that don't show their interest as much. I think [interest] is kind of equal, but the guys tend to share their liking science less at our school actually.

While girls may not traditionally be thought of as scientists, they are stereotyped in formal education as being “good students.” For some girls, there seems to be a conflation between the identity as good student and interest in science. Or, rather, the ability to express interest in an academic subject at school is constrained by gender, so they have limited evidence to go on as to boys’ interest in science. As Vidya noted, from her perspective, girls were more engaged with science, but she does not socialize much with boys, so her observations are limited. “I don't know. I feel like a lot of people now are more encouraged to do these kinds of things. I'm sure a lot of guys think about it too, but my group is mostly girls, so they're all pretty same-minded about science.”

This sentiment was echoed by Becky when she said, “In some ways I think it's more girls, but I think that's just because they're the people I hang out with.”

Tasha and Audrey found the question itself flawed. From their perspective, so few of their peers enjoy science that it was meaningless to try and determine if more girls or boys are interested in the subject. When asked if she knew many girls interested in science, Audrey responded, “Not really. But I don't know many people who are into it in general.”

Elaine unequivocally observed that a much larger portion of her male peers were engaged with science, and struggled to receive acknowledgement for her skills in science. She also noted a clear difference in how her interest in science was treated by peers:

> There is one person in my school who’s been better than me at just about everything, the whole time I've been in school. And the worst part about it is that whenever people are having a chance to try and make fun of people, when they're smart, it's always me. But when people are trying to praise or people are trying to say, “Oh my gosh, that person's really smart,” they're talking about the other person. So that's always very annoying. I honestly don't really care that much when they are making fun of me. But it always really ticks me off when they're talking about the other person, because when they're just, “this person is just so good at this and so is this other person.” And so it's just like, “Oh! I've suddenly turned invisible.” I can just imagine people that I know in school, that no matter what I do, they're still going to see me as the nerd with the braces.

Elaine goes out of the way to use a neutral pronoun when referring to her academic nemesis, but it was obvious to everyone in the room, and she later confirmed, that the “they” in question was a boy. This struggle for recognition is a common theme in research on gender disparities in STEM (Bayer Corporation, 2010; Hill et al., 2010).

Female friends who enjoy science. Elaine’s frustrations do not end with the struggle for recognition. She also grapples with a lack of peers who share her interest in science. She recounted a story about her talented and gifted (TAG) class at school that summed up some of her frustrations. “I just remembered when they set the TAG group up I walked in, and there was like three girls who were in the TAG group, or four. And there was a ton of boys. And I was just like, ‘here we go.’” Elaine is tired of being a minority in science. None of her close female friends are interested in science. She describes their responses to her enthusiasm for the subject as ranging from tolerant to vaguely annoyed. She wishes they were more interested in science, but is careful in policing herself around them.

Elizabeth, on the other hand, describes a vibrant friendship circle with a strong interest in science. “A lot of my friends really enjoy science and a lot of them are in my science class.” She describes a motor dissecting party they had at her house using leftover parts from a school project. She described future plans to extend the activity. “That kind of inspired us to do more dissecting things. We have two dead smoke alarms and one of my friends has a dead clock.”

Elizabeth and Elaine share a fair amount in common. Both are avid readers and highly academically motivated students. They enjoy science and are interested in science careers. They both sport geek-chic glasses and braces and even dress somewhat similarly. Receiving recognition for their accomplishments is important to both girls. Elaine, however, is often frustrated in science. She does not feel acknowledged and she feels the absence of other girls acutely. Elizabeth has an entirely positive attitude toward science. She proudly identifies as a scientist and speaks in glowing terms of her teachers and peers. Though no causal claims can be made on these two cases, they provide an illustration of how supportive peer groups can play a role in developing girls' attitudes and experiences with science.

Audrey also finds a lack of school friends who enjoy science frustrating. "I think anyone can be good at science if you're interested in it. Some of my friends just aren't interested in it. And because they don't do stuff. SPICE really makes me want to do science but at school you get turned off of science because it's not fun." Finding herself in a similar situation as Elaine, Audrey set out to create support by leveraging a non-science friend into an advanced science class. It is uncertain, though, if this arrangement will provide the kind of support Audrey needs. "I got one of my friends to sign up for the good science class and she says that I have to help her with it because she's not good at science."

Girls who were interviewed were asked if they had friends who enjoyed science or with whom they did science activities outside of school. Seven of the 11 responded that they did not have friends with whom they shared an interest in science. Three girls from the focus groups mentioned a lack of friends interested in science as a source of frustration, and several more nodded in agreement. Taconis and Kessels (2009) found that high school students were more likely to identify interest in a science subject area if a peer they perceived as similar to themselves was also interested in the subject.

Proving oneself. All of the girls interviewed were asked if they would be comfortable working in a job with few or no other women around. Nine of the girls expressed no concern about working in male-dominated environments, one said she would not like working without other women around, and one said that she would feel more comfortable working with other women, but that their absence would not preclude a science career choice. Most girls responded to the question without hesitation, and then immediately followed up with a statement similar to this one by Elaine: “I would be fine with it. If anything, it would give me a chance to prove that I'm just as good as they are at it.”

SPICE girls demonstrate awareness that science careers are dominated by men. For the most part, they do not express misgivings about being in the minority. However, there is an implicit contradiction in their statements. *No I’m not bothered. Yes, I feel compelled to work harder to prove myself.* Matilda summed this feeling up, “If there were less women, I would strive to be better than all the other guys.”

The pressure to succeed and prove oneself is tempered by an implicit understanding that in order to be recognized as scientists, girls have to be better than *all* the boys. Beatrix associated the need to prove oneself with a need for respect.

> I was thinking to get respect and appreciation from people, it's going to be a little harder if you're a girl scientist, because it's only been recently that scientists have even been girls. It's always been guys and you need to have some proof of what you can do so people will acknowledge you.

Beatrix makes a point often reported by female scientists. Respect and assumptions of competence are implicitly granted to men in science, but women have to work harder (prove themselves) to receive the same (Bayer Corporation, 2010; Corbett & Hill, 2015). In interviews most campers did not explicitly acknowledge the barriers that being in the minority present, but implicitly they responded to the challenge by expressing their need to be better than boys and men. In almost the same breath, Alexandria downplays the challenge of being a woman in science and then declares her defiance:

> It doesn't matter what other people think of me, whether I'm a woman or I'm a giraffe, or whatever. I think it would be nice to have other women around, but I mean men are fine. I don't have anything against them, as long as they don't make me uncomfortable about working or doing the job as a woman. Then I'll whack them with my wand. It's just like “I'll show you.” I'll be a great scientist no matter what you would think of me.

Gender perceptions summarized. SPICE participants had higher initial science efficacy than the comparison group, as measured by the combined scale of task value and self-concept of ability. There was no difference in SPICE girls’ science efficacy following the camp. The regression model for predicting changes in science efficacy did not explain any statistically significant variance in the model. The interaction between years in the program and scholarship status was statistically significant and predicted that scholarship recipients would lose science efficacy over time while non-scholarship students are predicted to gain efficacy over time. This result, along with similar results from other analyses of science affinities presented below, will be discussed in more detail in chapter V.

SPICE girls differ in their perceptions of differences in interest by gender. These differences in perception seem to be somewhat a function of the availability of female friends who also enjoy science. SPICE girls with a supportive friendship group see girls as more engaged with science. Participants without this support tend to see no difference, or perceive more boys who are interested in science. The girls are well aware of traditional gender roles as they relate to perceptions about girls and science. They overwhelmingly reject ideas that women are less competent or should be restricted, but also recognize how these messages limit girls and women in science. This manifests in some girls as a desire to "prove" oneself better than male peers. The need to prove oneself might motivate girls to excel, but it might also eventually exhaust and turn them away from science. Providing girls with opportunities to engage in science with female peers might help ease the burden of needing to be the best; however, consistently providing peers and mentors for girls as they grow as scientists will become increasingly challenging. The higher women climb in science, the fewer women there are to engage with. Encouraging them to share with younger girls, taking on the role of mentors themselves, might be one solution.

Presentation of the results now moves on to SPICE campers' attitudes toward science. The next section begins with reporting of the analysis of the scale measure of science attitudes.

Science attitudes analyzed. Comparisons of means of SPICE and SEP participants prior to their respective experiences show that, on average, SPICE campers (57.63) scored higher than SEP students (51.43) on the scale of attitudes toward science $t(121) = 4.38$, $p = .03$. Table 26 shows the results of mean comparisons of science interests.

The scores for SPICE pre-camp responses to the scale of attitudes toward science were slightly non-normally distributed. In addition to the standard *t*-test, the nonparametric Mann-Whitney test was conducted as well. A Mann-Whitney test indicated that the science attitudes score was greater for SPICE participants (Mdn = 60) than for SEP participants (Mdn = 54), U = 1225.5, p < 002. Both tests confirm that SPICE participants have higher starting attitudes toward science than SEP participants.

Table 26

Results of t-*test and Descriptive Statistics for Science Attitudes by Group*

	Treatment Condition							
	SPICE N = 51		SEP N = 72		95% CI for Mean Difference	t	df	Cohen's *d*
	M	SD	M	SD				
Science Attitudes	53.81	10.28	40.95	4.56	10.15, 15.57	9.40*	121	1.62

Comparison of means of SPICE participants' interests in science before and after camp did not yield a statistically significant result $t(50) = 1.44$, $p = .16$. Table 27 shows the results of the t-test comparing pre- and post-camp science interest means for the SPICE participants.

Table 27

Results of t-*test and Descriptive Statistics for Science Attitudes by Time*

	Treatment Condition							
	Pre-Camp N = 51		Post-Camp N = 51		95% CI for Mean Difference	t	df	Cohen's *d*
	M	SD	M	SD				
Interest in Science	53.81	10.28	54.87	8.71	-0.78, 2.90	1.16	50	.25

Wilcoxon signed ranked test also showed that SPICE participants did not show a statistically significant change in science attitudes in the post-camp time frame (Z = -1.75, p = .08).

Regression analysis of science attitudes scores. In the first regression analysis, the variables for scholarship status, years in the program, engagement, and the associated interaction terms were entered into the regression model. The coefficient for the interaction of years in the program with scholarship status was statistically significant -2.57 (t = -2.36, p = .023). However, the overall model was not statistically significant. A second model removing the engagement variable and the two related interactions was next run. In this model, the interaction term between years in the program and scholarship status remained statistically significant -1.97 (t = -2.03, p = .048), however the variance explained by the model was not statistically significant. A third model with only scholarship status was run with no statistically significant results. Table 28 shows the results of second model.

Table 28

Model 2 Regression Analysis of Science Attitudes with Scholarship Status Controlling for Years in the Program and Interactions.

Variable	Zero Order	***b***	*se*	*sr*	VIF
Intercept		1.16	.97		
Scholarship	.09	.23	.97	.03	1.10
Years in SPICE	-.11	-.23	.97	-.03	1.14
Years x Scholarship	-.32*	-1.97*	.97	-.28	1.17
	R^2 = .10, F = 1.82(3, 47), p = .156				

**p < .05, **p < .01, n = 51*

As above, the interaction term is interpreted by calculating the predicted scores by camper status. Table 29 shows the predicted scores.

Table 29
Predicted Difference Scores for Science Attitudes

	Number of Students	Year in SPICE	Predicted Score
Scholarship Received	17	0	3.16
	15	1+	-.56
No Scholarship	13	0	-0.58
	6	1+	3.93

Figure 16 shows the interaction in graphical form. For students in their first year of camp who received a scholarship, the predicted difference score on the scale of science attitudes between the pre- and post-camp conditions was 3.16 points. That is, their science attitudes, as measured by the efficacy scale, is expected to increase by 3.16 points after the first camp experience. The amount of the gain is predicted to decrease to -.056 points for subsequent years of camp. For students not receiving a scholarship the expected change in scores is -0.58 in the first year, but is predicted to increase by 3.93 points in subsequent years. Overall, this means that students receiving scholarships start out increasing their science attitudes while non-scholarship students experience decreasing attitudes. Over time, however, it is predicted that scholarship students' attitudes toward science will decrease and non-scholarship students' attitudes will increase. As before, the implications of this result will be discussed in chapter V.

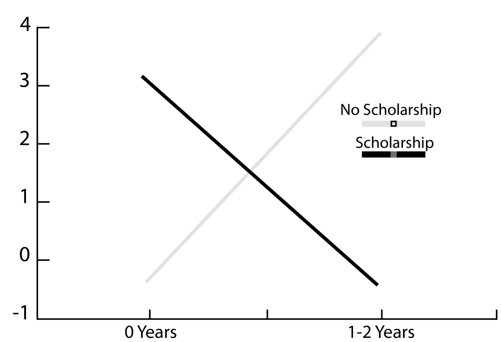


Figure 16. An interaction between scholarship status and years in SPICE program predicting science attitudes.

Quantitative analysis of SPICE participants' science attitudes summarized. SPICE participants demonstrated statistically significant higher starting attitudes toward science as compared to SEP participants. No differences in SPICE participants' science attitudes from the pre- to post-camp condition was found. In the analyses of science attitudes, the predictor for the interaction between scholarship status and years in the program was statistically significant, indicating that over time, non-scholarship students experienced gains in attitudes toward science while scholarship students experienced decreased science attitudes. The variance explained by the model was not statistically significant.

Qualitative analysis of SPICE participants' science attitudes. Research question 4 addressed girls' attitudes toward science. Qualitative data permits this question to be addressed not simply in terms of "positive" or "negative" but in terms of the ideas and stereotypes girls have about science and how those attitudes influence their choices. In focus group and interviews the girls were asked what came to their minds when they thought about science and scientists. Typical responses included lab coats, goggles, chemistry experiments gone wrong, and Albert Einstein. Girls readily acknowledged, without any probing by the researcher, that these ideas and images were based on stereotypes mined from Saturday morning cartoons, movies, and the collective consciousness. Digging deeper, however, girls had many nuanced and sometimes contradictory ideas about science and scientists. Overall, they hold scientists in high regard as people who are smart, passionate about learning, and spend their time solving problems. Alexandria said, "When I think of scientist, I think they are trying to make the world a better place with their research, so I feel a bit of admiration for them." Girls' stereotypic responses and their general sense of admiration for scientists are consistent with what the literature finds about the public's attitudes toward and ideas about science (Chambers, 2006; Christidou, 2011; Falk, Storksdieck, & Dierking, 2007).

The final codebook for qualitative analysis contained 11 different codes under the heading of *Attitudes and Stereotypes about Science and Scientists*. The most commonly used were scientists (210 mentions), gender disparities (77 mentions), attitudes (67 mentions), and hard work (55 mentions).

Beyond their admiration, girls remarked often on how being a scientist is hard work, fraught with frustration and failure, requiring a high level of knowledge and understanding, but granting a measure self-determination not present in all career options.

Hard work and persistence. SPICE girls agree, being a scientist is hard work. Hard work and persistence was the 14th most commonly used code in the transcripts from interviews and focus groups. Hard work was invoked by 25 girls in the focus groups and four girls in the individual interviews. In 13 instances, girls linked hard work with fun or rewards. They expressed a value for persistence and resilience that ends in success. An equal number of girls linked hard work with negative outcomes. There was overlap between the two groups who made positive and negative associations with science and hard work, with five girls making both cases. One girl in a focus group explicitly stated that as women, they would have to work even harder than male scientists to succeed. There was general assent among the other girls in the form of nods and affirmative vocalizations. Other codes were used more frequently than hard work, but the responses invoking this theme were the most homogenous of codes employed in the study. Girls were in alignment in their perceptions that the sciences are challenging fields to pursue.

SPICE girls agreed that science requires hard work, but their subjective responses to the prospect of this hard work, to a certain degree, reflects the differences between the growth and fixed mindsets (Yeager & Dweck, 2012). Ten of the girls clearly felt that hard work is worth it when the task at hand is rewarding, and looked forward to the pride they would feel after persisting through a challenge. Eight girls were clearly not enchanted with the idea getting stuck on challenging puzzles. They expressed impatience and frustration with tasks they were not easily able to manage. Among the girls who expressed enjoyment for challenge, there was a subset of five that expressed an undercurrent of trepidation. They seemed less worried about the personal challenge, and more worried about the personal costs that come with a career in science. They mentioned loss of family, loss of personal time, and loss of sleep. These concerns relate directly to attitudes and beliefs about the personal costs of science as a career. SPICE girls in general seem to be more positive about their prospects as future scientists, but their concerns and reservations are consistent with what others have found about girls' attitudes about science careers (Kitts, 2009; Miller et al., 2006).

Hard work meant several different things for girls. It meant pressure, deadlines, and responsibility, because science is important work. Forensics camper Madison argued that to be a scientist

> You need to work hard and study a lot and put in a lot of effort toward what you do, because some people study really important things like how to find a cure for cancer. That's really important so when you study you have to study really, really hard. If you make a mistake and you think that's the cure and it isn't someone's life could be at risk.

For SPICE girls, science careers are associated with impactful outcomes, specifically, outcomes that benefit other human beings. The scientist needs to get it right and on time. This is also consistent with research about girls' interests in science. Girls and women are more likely to enjoy and engage with science that relates back to helping living creatures, particularly humans (Battle & Wigfield, 2003; Hill et al., 2010; Miller et al., 2006).

Failure and frustration. Girls were asked what made them feel the least like scientists. The most common answer was frustration. Frustration was cited by nine girls in focus groups and five in individual interviews. The frustration born of inability to understand was the most vexing to the SPICE girls. Discovery camper Madison talked about times when she felt the least like a scientist, "You get frustrated to the point that you don't want to do science any more. Like sometimes when you're trying to figure something out and you can't figure it out you get really frustrated. I don't want to quit science even though I love it." Four girls explicitly discussed how failure and repeated frustration had turned them off of specific science topics.

There was also a note of determination in many girls' discussions of frustration and failure. Beatrix talked about science as the process of persisting through frustration, "You work with things and 99% of the time they don't work out, I mean you just have to keep trying." Engineering camper Joy, who plans to study marine biology and loves all science except programming, had a different take on frustration. For her confusion is just another part of being a scientist. When asked if she ever became discouraged about science when she responded to that frustration, she responded it, "made me feel even more like a scientist. Because being a scientist, you create a lot of new things and so you're often confused. And you have to work things out in your head."

Frustration is a problem in science. No one enjoys frustration, and children are not known for their patience. Too many failures will lead girls to turn away from science. Bandura (1997a) observed that negative experiences were more influential in self-efficacy than positive experiences. Psychology research consistently shows that bad experiences are more powerful and long lasting than good ones (Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001). As noted above, four girls reported specific science disciplines or activities that they actively avoided due to past negative experiences. Each time a girl turns away from an aspect of science, one more door leading to STEM careers is closed. As girls accumulate these negative experiences their chances of persisting in STEM diminish. Coupled with girls' diminished access to meaningful science experiences as compared to boys, negative events can have a powerful impact (Alexander et al., 2012; Jovanovic & King, 1998).

Learning to handle frustration, to normalize and contextualize failure, is one of the goals of the SPICE program. Girls are encouraged to learn from the 99% failure and celebrate the 1% success Beatrix mentioned. Some of the girls even note that while failure is frustration, there is a special kind of satisfaction that comes from persevering through difficulty and eventually succeeding. Alexandria sums this up, "I think science is different because well, you might fail but there are so many opportunities [to] make something happen, making something new, something great. And then people can't exactly say that you don't do anything if you do something that even they can't ignore."

Knowledgeability. The requirement for knowledge and skill in science careers has been interwoven throughout the discussion of ideas and attitudes toward science. Seven campers directly referenced knowledge and scientists in conjunction. However, the construct was laced throughout most conversations about science and scientists. Aurora mentioned it in regards to safety, which she summed up with, “you have to know your facts and you gotta be proud of it too. You gotta take chances.” For Daniela, the scientist as knowledgeable is somewhat grandiose:

> I think being a scientist means being someone you always wanted to be and being someone with a lot of knowledge inside of them and being someone creative and wanting to show the world what they can do and show the world what's happening to the world. What's happening in the universe.

On a more down-to-earth scale, Discovery camper Jennifer says that being a scientist is about “experimenting and knowing you have the knowledge, the knowledge of that area in science.” But for many SPICE campers, what makes a scientist is more about what a person does than what she knows. Becky summarizes what many campers reflected on. The true measure of a scientist is in action, intention, and method, over the cerebral world of knowledge. “It means you discover things and how things work. Or why something happens. I think you can be a scientist even if you're not in any profession.” The idea of doing science versus knowing science will be discussed in more detail later.

SPICE girls’ ideas about the knowledgeable scientist relates back to both identity and self-efficacy. Before individuals adopt identities, they build a bank of experiences and mastery that demonstrates to themselves (and usually others as well) that they are capable of enacting the roles required by that identity (Bandura, 1976; Bergen, 2002; Erikson, 1968; S. Schwartz et al., 2011).

Self-determination. A subgroup of girls touched on the idea that scientists, while hard working, have a certain amount of freedom to decide what they will do and how they will go about it. When girls talk about future jobs they would not like, almost all of them invoked clearly distasteful images of "desk jobs" and "paperwork."

While scientific rigor requires meticulous documentation, it seems to be somewhat offset in their minds by the perception that scientists have more control over their work than other occupations. Beatrix commented, "I feel like you have a lot of room to experiment, unlike other jobs. I don't know. Like a mailman, you deliver the mail. You walk around every day, but if you're a scientist you can do whatever you want. You can experiment with everything. It's like a free open environment."

For Tasha and the girls in her Engineering camp group, this freedom is defined in opposition to the structure of school.

> Tasha: At school you have boundaries, like, OK now do this, now do that. But if you're conducting your own experiments it would be whatever you want to figure it out.
>
> Amber: Yeah, you decide what you want to figure out and do it.
>
> Audrey: [And] how to do it.

Control over work process is a priority for these girls, many of who are only just out of elementary school. Adults, clocks, and bells regulate much of their day. They still have a less than complete ability to regulate their own bodies, and yet must sit for what seems like long periods of time paying attention to subjects they have not chosen. The battle for greater independence is a major part of growing up, so it follows that girls would be invested in identifying careers where they have control over their time.

Attitudes toward science summarized. SPICE participants had higher initial attitudes toward science than the comparison group, as measured by the scale science attitudes. There was no difference in SPICE girls' attitudes toward science following the camp. The regression model for predicting changes in science attitudes did not explain any statistically significant variance in the outcome. The interaction between years in the program and scholarship status was statistically significant and predicted that scholarship recipients' attitudes toward science would diminish over time while non-scholarship students' attitudes are predicted to increase over time.

The ideas expressed by SPICE participants form a general narrative of their conceptions of life as a scientist. Scientists work hard. They must study a long time to achieve their goals. They must be meticulous and diligent because the outcome of their work matters to a broader constituency than just their own interests. The pressure of these demands, however, is offset by the native curiosity and passion that scientists have for their work.

A career in science will involve a lot of frustration, wrong turns, failures, and confusion. Some girls find the prospect of this frustration, borne from their own very real experiences learning science, a major threat to their ultimate choice to study science. Others value the frustration as an integral part of the process. Some agree that getting the answer after struggling is satisfying and helps sustain their interest. This points to an important lesson for parents and science educators.

SPICE girls agree that scientists are people with a lot of knowledge about their area of study, but this does not seem to present a barrier to them, because this well of knowledge is driven by the scientist's innate curiosity and interest in her discipline. They also see scientists as people with greater control over their work. Presentation of the results now turns to measures of SPICE camper science identities. Reporting begins with the results of inferential statistics on the scale of science identity.

Science identity analyzed. Comparisons of means of SPICE and SEP participants' science identities prior to their respective experiences show that, on average, SPICE campers (15.14) score higher than SEP students (12.65) on the scale of science identity $t(121) = 4.38$, $p = .03$. Table 30 shows the results of the mean comparison of science identity.

Table 30

Results of t*-test and Descriptive Statistics for Science Identity by Group*

	Treatment Condition							
	SPICE N = 51		SEP N = 72					
	M	SD	M	SD	95% CI for Mean Difference	t	df	Cohen's *d*
Science Identity	15.14	2.89	12.65	3.24	1.36, 3.61	4.38*	121	.11

**p < .05*

The scores for SPICE pre-camp responses to the scale of science identity were slightly non-normally distributed. In addition to the standard *t*-test, the nonparametric Mann-Whitney test was conducted as well. A Mann-Whitney test indicated that the science identity score was greater for SPICE participants (Mdn = 15) than for SEP participants (Mdn = 13), U = 1004.0, $p < 000$. Both tests confirm that SPICE participants have higher starting science efficacy than SEP participants.

Comparison of means of SPICE participants' interests in science before and after camp did not yield a statistically significant result $t(50) = 1.74$, $p = .09$. Table 31 shows the results of the *t*-test comparing pre- and post-camp science interest means for the SPICE participants. Wilcoxon signed ranked test showed that SPICE participants did not show a statistically significant change in science identity in the post-camp time frame ($Z = -1.76$, $p = .08$)

Table 31

Results of t*-test and Descriptive Statistics for Science Identity by Time*

	Treatment Condition							
	Pre-Camp N = 51		Post-Camp N = 51		95% CI for Mean Difference	t	df	Cohen's *d*
	M	SD	M	SD				
Science Identity	15.14	2.89	15.78	2.63	-0.10, 1.37	1.74	50	.23

As before, regression analysis was conducted first with all three predictors and the related interaction terms. The first model predicted 25% of the variance $F(6,44) = 2.40$, $p < .043$.

The intercept, scholarships status, and the interaction term between scholarship status and years in the program were all statistically significant. In the interest of parsimony, the model was rerun without the engagement variable and the related interaction terms (see table 32). The second model predicted 19% of the variance $F(3,47) = 3.56$, $p < .021$.

Table 32

Model 2 Regression Analysis of Science Identity with Scholarship Status Controlling for Years in the program, and the Associated Interactions.

Variable	Zero Order	***b***	*se*	*sr*	VIF
Intercept		.91*	.37		
Scholarship	-.24*	-.82*	.37	-.29	1.10
Years in SPICE	-.19	.13	.37	-.05	1.14
Years x Scholarship	-.30*	-.90*	.37	-.32	1.17
		R^2 =.19, F = 3.56(3, 47), *p* = .021			

**p < .05, **p < .01, n = 51*

In order to interpret the interaction term, the predicted score for each condition (scholarship/no scholarship versus years in program) was calculated (table 33) and plotted.

Table 33

Predicted Difference Scores for Science Identities

	Number of Students	Year in SPICE	Predicted Score
Scholarship Received	17	0	1.12
	15	1+	-0.94
No Scholarship	13	0	0.96
	6	1+	2.5

Figure 17 shows the interaction in graphical form. For students receiving a scholarship, the predicted difference score on the scale of science identities between the pre- and post-camp conditions was 1.12 points. That is, their science identities as measured by the identity scale are expected to increase by 1.12 points after the first camp experience. The amount of the gain is predicted to decrease to -0.94 points for subsequent years of camp. For students not receiving a scholarship the expected change in scores is 0.96 in the first year, but is predicted to increase by 2.5 points in subsequent years.

Overall, this means that students receiving scholarships start out increasing their science at a slightly higher rate than non-scholarship students, but this trend is inverted, so that by the end of their three-year SPICE experience, scholarship campers are predicted to experience decreasing science identities while non-scholarship students are experiencing increasing gains in their science identities. The implications of the pattern of statistically significant interactions between scholarship status and years in the program will be addressed in chapter V.

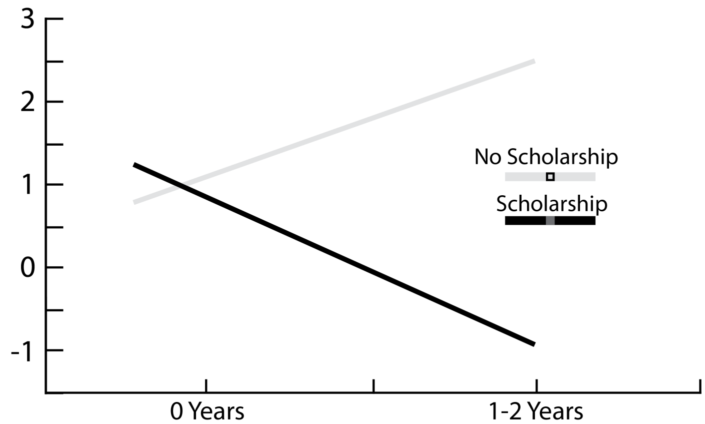


Figure 17. An interaction between scholarship status and years in SPICE program predicting science identities.

Quantitative analysis of SPICE participants' science identity summarized. SPICE participants demonstrated statistically significant higher starting science identities as compared to SEP participants. No difference in SPICE participants' science identity from the pre- to post-camp condition was found. In the regression of science identity, the predictor for the interaction between scholarship status and years in the program was statistically significant, indicating that over time, non-scholarship students will experience gains in science identities while scholarship students experience decreasing identities. The model explained 19% of the variance in respondents' science identities.

Qualitative analysis of SPICE participants' science identity. The themes discussed thus far relate to girls' interests, efficacy, and attitudes toward science, scientists, science education, and the roles women can play in science. These are the foundation upon which their identities as scientists will (or will not) be built. As has been reported, many of these areas are overlapping. Girls' ideas about women and science relate to teachers and other role models. Girls' ideas about differences in interest between the genders relate to the presence of role models and peers who share interest in science. Girls' ideas and attitudes about science are directly connected to the messages they receive about women's competence and belonging in science. The question remains, do SPICE camper display evidence of emerging science identities? How do campers' attitudes, ideas, and interests relate to the formation of identities?

In teasing out emergent science identities in SPICE girls, three elements were consistently present in camper conversations about their own identities: curiosity, symbolic enactment, and doing science.

Curiosity and discovery. When SPICE girls talk about the ways they are like scientists and what makes them to want to do science, they often speak of a driving curiosity and a desire to discover new places, ideas, and things. As reported above, figuring out/creativity was invoked by 11 participants during focus groups and interviews. Discovery and curiosity were used by 10 girls in the focus groups and two in interviews to describe either the most appealing aspects of science or to describe what makes someone a scientist. Campers were particularly intrigued by the idea of uncovering or creating something new with science. Responding to the question "What does it mean to be a scientist?" eight girls identified discovery as a key element to being a scientist. Dorotea summed up a scientist as "an important person who helps discover things."

For SPICE girls, being a good scientist means exploration and curiosity. The quest for discovery is the key characteristic of a scientist as someone who wants to figure out, understand, and discover. Audrey put it this way, "You can't be a good scientist if you don't ask questions or don't want to figure out why or what or how."

Among SPICE girls, curiosity comes in different flavors. There is the curiosity of wanting to understand the concepts and get the answers right. This is the curiosity of knowledge that Daniela was talking about with scientists as "someone with a lot of knowledge inside of them," the scientist as master of her discipline. There is also the curiosity of function, the desire to understand how objects, phenomena, or processes of nature work. Elizabeth and her motor dissecting party exemplify the scientist as explorer and experimenter. Then there is productive curiosity, the desire to create something valuable to others. Alexandria expressed this flavor of curiosity when she said, "there are so many opportunities [to make] something happen, making something new, something great!" For the SPICE girls, curiosity is the spark that starts a scientist on her path. It is curiosity that drives action.

Symbolic enactment. Curiosity is the seed without which girls cannot start the journey, but the tools of the trade are the meat and potatoes of building science identities. When asked what comes to mind when they think about science and what makes them feel the most like scientists, SPICE campers overwhelmingly talked about the trappings of science. Just like small children enjoy dressing up as firefighters, princesses, and superheroes, SPICE girls cannot get enough of lab coats, goggles, gloves, and test tubes.

The focus group and interview transcripts include dozens of quotes referencing how much girls enjoy and value symbolic enactment of science roles. This statement from Discovery camper Penelope in response to the question “When do you feel the most like a scientist?” captures the spirit of the girls’ feelings: “Probably, their signature gear that we put on for when we did the Elephant's Toothpaste, and the flubber, and dealing with the chemicals. Cause I like chemicals.”

“Dress up” may seem like a childish activity, and it is, but symbolic enactment is a powerful part of induction into identity groups and is often incorporated in to rites of passage (Erikson, 1968; Gennep, 1909) and early social development (Bergen, 2002). Clothing is a powerful part of transitions in identity. Children are dubbed “big” girls and boys when they can dress themselves and start choosing their own clothes. A major transition into womanhood for many girls is gaining the privilege of wearing makeup, high-heeled shoes, and jewelry. During camp, when it was time to prepare for an activity using scientific garb, the enthusiasm always hit a crescendo as instructors helped participants resize goggle straps, roll up coat sleeves, and demonstrated the proper technique for donning and removing latex gloves. Forensics campers actually used gloves and goggles for several activities. During an observation, one camper was eager to share with the observers how good she had gotten at taking her gloves on and off without contaminating her samples.

Social and cultural groups often incorporate garb in public rituals (S. Schwartz et al., 2011). Shriners wear fezzes. Graduates don flowing robes. These are symbols of belonging to a group. Just as being handed a diploma from a professor is a powerful affirmative act of inclusion, so is the act of putting on a lab coat with the assistance of a genuine scientist. These moments provide powerful social persuasion and feedback experiences that are the foundation of building efficacy and identity (Bandura, 1977; Erikson, 1968).

Doing science. If curiosity is the gateway, and symbolic enactment is part of ritual induction, then for SPICE girls, the act of *doing* science is the core of being a scientist. As was reported before, SPICE girls express a universal preference for learning science from hands-on activities. This preference extends beyond a preferred method for learning, however; it also represents the act of being a true scientist. Scientists are knowledgeable and creative, but above all, for SPICE girls, scientists *do science*.

Becky teased out some of the circular logic of what it means to be a scientist. Scientists are natively curious yes, but they also choose to be curious and fulfill their identities as scientists by doing science. “If you don’t like to do it you won’t do it as much. I mean a scientce job is different but I mean the scientists *like* science.” Being curious alone is a key jumping-off point but not the end.

Alexandria elaborated on the difference between a person who simply enjoys messing around with science and someone who is a scientist (emphasis added):

> I think being a scientist would be really fun, but to be serious, you have a certain responsibility or else you can't really call yourself a scientist if you're not really *doing science*. I think you have to have the responsibility to at least try to figure things out.

Scientists have an obligation to engage in scientific activities and to do so with purpose. According to Engineering camper Vidya, action is a key component to being a scientist. “Just doing science itself. You realize, you have to do these kinds of things to be a scientist." Vidya, a goal-oriented young woman with strong academic performance, explained a disconnect between bookwork and what she thought of as true science: "But if it's science, it's not just looking at a textbook and reading that out and then taking notes until the next test and watching *Bill Nye the Science Guy*. It's more, you know, actually doing stuff, learning about it. Getting hands-on."

Archer et al. (2010) reported similar findings in their study of elementary science identities. For children, science identities are embodied and performed more than they reside in mastery of subject matter. SPICE campers agree. While many of them enjoy the intellectual side of science and the problem solving, what makes them feel like scientists is ritual and activity. Associating doing science with science identities may be problematic for girls. Research shows girls are less likely to have the opportunity to directly engage with science (Alexander et al., 2012; Hill et al., 2010; Jovanovic & King, 1998). Girls may also find their nascent science identities in conflict with their femininity. The masculine perception of science as rooted in the cerebral, not nurturing, and antisocial, are in direct contradiction to most girls' conceptions of themselves as normal, caring, active, and feminine (Archer et al., 2012, 2013).

Identity summarized. SPICE participants had higher initial science identities than the comparison group, as measured by the scale of science identity. There was no difference in SPICE girls' science identities following the camp. The regression model for predicting changes in science identity explained 19% of the variance in the model. The interaction between years in the program and scholarship status was statistically significant and predicted that scholarship recipients' science identities would diminish over time while non-scholarship students' identities are predicted to increase over time.

SPICE girls define scientists as fundamentally curious people who discover new knowledge or create new inventions that help other people. Girls feel the most like scientists when playing the role using the equipment and gear associated with scientists. Above all, SPICE girls define a scientist as someone who does science. Putting these three elements together, the optimal environment for building identities, for SPICE girls, is to be learning new things though hands-on engagement in science activities while using the garb and tools of real scientists.

Interpreting the results for the analysis of student science affinities. SPICE participants demonstrated statistically significant higher average scores in the pre-camp condition than the comparison group of SEP students for all four science affinities. This provides evidence for the assumption that SPICE campers have higher than average science affinities compared with students of a similar age participating in a broader program. Given this high baseline, detecting any positive change in affinities in the post-camp condition may be difficult with such a small sample. *Ceiling effects* such as this complicate interpretation of results of any analysis of change in mean such as *t*-tests and multiple regression. A ceiling effect occurs when a measure results in an upper limit for responses that does not represent the full range of true scores and responses cluster near the high end of the limit. Ceiling effects can occur may occur for example on tests that are too easy for participants, or in a group like the SPICE campers where a large percentage of participants share a strong preference for an activity. In this case, SPICE campers have demonstrated a strong preference for science affinities. Average scores for the same scales in the post-camp condition were consistently higher than in the pre-camp condition, however, the differences were not statistically significant. This implies that overall, students are sustaining the same level of interest over time. However, ceiling effects can mask change that occurs at the high end of the spectrum and can pose complications for interpreting interaction effects, such as those reported for this study (Hessling, Traxel & Schmidt, 2004). It is possible that the interaction effect detected is not a true interaction, rather the slopes for scholarship and non-scholarship groups only appear different due to the ceiling effect.

Regression analyses of the difference scores for the science affinities scales only explained statistically significant variance for the scale of science identities. For the scales of science efficacy, science attitudes, and science identities the interactions between the number of years in the program and scholarship status show that camper attitudes toward science and intentions toward science careers and education are predicted to increase over time. That increase is moderated by scholarship status, however, with students receiving scholarships having diminishing returns over time. Given that 60% of SPICE campers receive scholarships this is an important finding to note. Socioeconomic status may be an important factor influencing SPICE girls' science affinities.

Figure 18 provides a conceptual composite graphic of predicted SPICE camper affinity scores by scholarship status. Though scholarship campers are predicted to experience decreasing gains over time, they are predicted to end the second year of camp with higher average science affinity scores than they started with prior to the 2014 camp. Non-scholarship students are predicted to experience increasing science affinities over time.

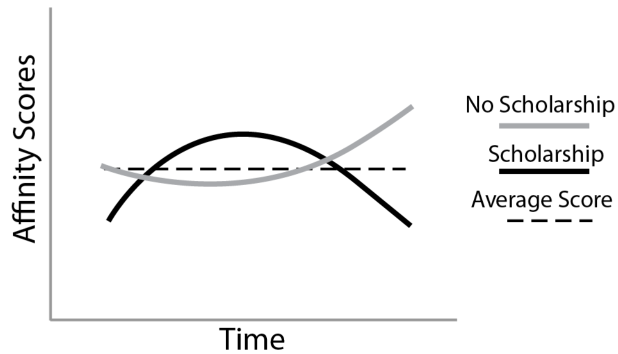


Figure 18. Predicted science affinity scores over time by scholarship status

As the figure shows, scholarship campers initially experience gains in science affinities, peaking after the first or second year and then decreasing over time. Non-scholarship students are predicted to experience only small (or slightly negative) gains in their first year, and increasing gains over time.

The consistency of the finding of a statistically significant interaction between scholarship status and years in the program across three of the four science affinity measures suggests several possible interpretations. First, it is likely that the three constructs measured are closely inter-related for the SPICE participants, which is not surprising given the shared subject matter (science). Second, the pattern implies that science affinities are developed differently in girls with different socioeconomic backgrounds. Another interpretation is that low statistical power coupled with a ceiling effect is creating a false interaction. More data points might reveal statistically significant relationships for the main effects of socioeconomic status and years in the program. Likewise, measures that emphasize the higher end of the scale, might yield more variance in responses, thus eliminating the ceiling effect, negating the interaction effect.

Overall, most measures point toward the expected relationships. Post-camp scores are higher than pre-camp scores. However, no inferences can be made given the lack of control group. The small number of statistically significant relationships and issues of non-normality of the data must temper any claims made about predicted relationships. These will be addressed in the discussion.

Qualitative data are largely consistent with extant research about science affinities in girls and identity and self-efficacy formation in general. Major themes in the data include girls' strong preference for participating in hands-on science, the important roles that teachers and mentors can play in engaging girls in science, and the ways in which girls' ideas about scientists can both support and undermine formation of strong science identities.

Component 3—Building Science Identity Theory

This chapter began with a quote from camper Alexandria, who referred to the SPICE campers as "little scientists." The title of this dissertation was taken from that quote and it gets to the heart of this research. How are little scientists made? What keeps them excited and engaged with science? Thus far this chapter has reported results of questions that can be answered through hypothesis testing. The analyses presented in components 1 and 2 go beyond questions of statistical significance to present a more nuanced understanding of the issues under examination. However, at their core, research questions 1 through 5 are designed to be answered in the affirmative or the negative. Yes, the program was implemented with fidelity. No, SPICE campers' interests in science do not increase following camp. Research question 6 moves into the realm of theory building. How do campers form science identities? What types of identities do they manifest?

The remainder of this chapter will focus on what kinds of science identities SPICE girls display and what these identities imply about how to support girls in science. Figure 19 details three emergent science identity archetypes, or flavors, and two nonscience identities. Based on the data collected in for this study, SPICE campers who demonstrate evidence of science identity formation fall into one of three categories: experts, experimentalists, and inventors. All three of these science identities are undergirded by a native curiosity about the natural world, an interest in learning, and a strong preference for hands-on science activities. How curiosity manifests in girls is somewhat different between types, however. The two nonscientist identities are divided in to enthusiasts—campers who are, as the name suggests, enthusiastic about science—and nonscientists, those who do not enjoy science. True nonscientists are uncommon at SPICE camp. The two campers who expressed an obvious dislike of science (based on observations) declined to participate in the research study, so their voices were not recorded. This category is defined by absence and little can be said about them, other than the fact that they do exist. Enthusiasts express a fondness for science and are highly engaged at camp, but reject an identity as a scientist.

The following sections will explore the three emerging science identity types and the enthusiasts through profiles of campers that fit each identity type. It is important to note that no camper hews cleanly to one archetype, in fact, all three archetypes appear to be present in girls evidencing science identities. However, girls tend to exhibit one archetype more strongly than others. Understanding these archetypes provides insight into how girls need to be supported as developing scientists.

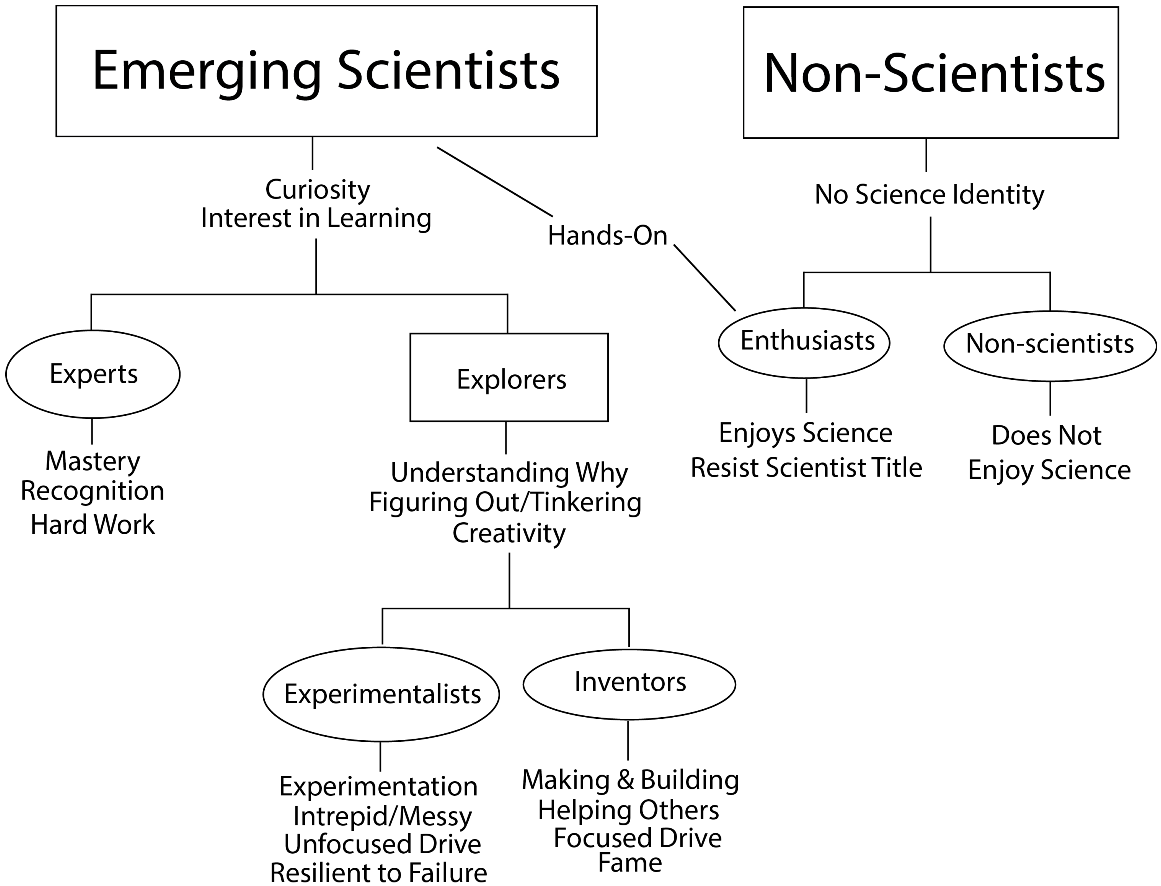


Figure 19. Archetypes of emergent and nonscience identities.

Table 34 shows all 11 campers who were interviewed and what identity types they fit based on interviews, focus groups, and observations. Several months after the interviews, the campers were sent a list of descriptions corresponding to the identity archetypes and asked to rank them according to which best fit their interest in science. This was used as a fidelity check on the researcher assessments. Five campers responded to the data request. Girls' top-ranked description matched researcher assignment in four of the five cases. The only camper who ranked the items differently was Tasha. Her rankings, however, make sense given her status as an enthusiast, which will be discussed more below. The sections in quotation marks are the statements girls were asked to rank in reference to their feelings about science.

Table 34

Camper self-identified science identity archetypes

Expert "In science, it is important to me to understand what I am learning and do well at it. It is important to me that teachers and classmates acknowledge my skills in science." *Campers:* Elaine*, Audrey*, Vidya, and Taylor
Experimentalist "In science, I really like figuring things out, experimenting and being creative." *Campers:* Matilda, Elizabeth*, Tasha**
Inventor "I want to use science to help others and make useful things or ideas. I would like to be known as someone who created something useful or solved an important problem." *Campers:* Becky & Alexandria
Enthusiast "I enjoy science, but I don't think of myself as someone who is serious about it." *Campers:* Tasha*, Saoirse

*Responded to classification request **Self-assignment different from researcher assignment

Experts. The name for this group derives not from girls who think they are experts at science, rather it derives from the ideas girls have about what scientists are (or should be) like. For these girls, scientists are highly knowledgeable, skillful practitioners of science who are recognized by peers for their mastery.

At the time of SPICE camp 2014, Audrey had just finished 7th grade at a local public middle school and was a participant in the Engineering and Computer Science camp. During her time at SPICE, Audrey formed a closed friendship with her partner Tasha. At Engineering camp the two built a functioning pinball table that was more complex than the instructor-designed example table. Observations of the engineering camp revealed that the pair dove into programming with a gusto not observed among any of the other campers. Even Amber, another Engineering camper who had prior experience with programming, was nowhere near as enthusiastic or ambitious in her coding as Audrey and Tasha.

Interestingly, Audrey presents a conundrum for classification. In focus groups and interviews she demurs from claiming the identity of scientist, but she is firmly set on studying as much math and science as possible and pursuing a career in marine biology. Many campers resisted outright claiming the title scientist, but most who were reluctant offered an alternative such as apprentice scientist, future scientist, or scientist-in-training. Audrey's reluctance to claim a science identity seems rooted in her already strongly developed identity as an athlete. She clarified this reluctance during a focus group conversation. "We can like it a lot. We're not like a mathematician, but we're either really good at math and we really like math or something like that. We would say, we really *like* math and I *am* a soccer player. That's how we would word it."

Soccer is something Audrey has invested time and effort in developing. She participates in it voluntarily outside of school and goes out of her way to find soccer opportunities. Science is something she enjoys and plans to make her career, but she does not feel that she has put in the requisite work to claim the identity.

> I feel like it's just how much time . . . we do this camp and we [do] some activities, but we're not like after school, that's what we're going to do. We're going home to hang out with friends and do a sport or something else, or play an instrument. I don't think any of us are going home doing science all day.

In this manner, Audrey, despite her demurral, is every bit an expert. Real scientists, to her, are people who have put in the time and have the expertise. To openly claim that identity would be an insult to scientists, just as someone who had played in a handful of casual games and claimed to be a soccer player would be an affront to Audrey. In discussion about her interests, Audrey consistently references understanding, effort, and skill.

> [I]t takes a lot of work to become a scientist. You have to really want to be it. And I think that takes a lot of determination. You're really interested in it and you have to be smart and willing to put in the effort. You can't be a good scientist if you don't ask questions or don't want to figure out why or what or how.

When asked about her feelings toward science, Audrey is enthusiastic. “I like it a lot. It's really interesting and I mean, I could spend all day with it just figuring out this one topic or going into it. Like you start in one place and you can go so many other ways.” Audrey applies these traits of determination, interest, and mastery to herself as a student. She wants to go beyond simply completing the tasks set before her. She wants to master the subject matter. “I like going in depth and figuring out why we're doing it and stuff and ask a lot of questions and I want to understand it, not just do it.”

Feedback from mentors is important to Audrey as well. In the fall she plays soccer five to six days a week and has a private lesson where she can perfect her technique. When asked about the importance of feedback from mentors and role models she emphasized how important it is to help “figure out what to work on and improve. [So] you actually know what you're doing.”

Audrey prefers mentors with a deep understanding of their subject. She finds most school science classes “boring,” consisting mostly of reading and routine question answering, but she enjoys visits from experts. “There are ones where people come give presentations. That's usually pretty cool because they usually know stuff and they can really explain in depth the topics.”

What does the expert archetype tell us about how girls build science identities? The expert, as the name suggests, wants to be an expert. She wants a deep understanding of the scientific topics she studies. She wants the opportunity to develop her skills and for those skills to be recognized. The expert most closely fits the standard conception of a “good” science student. She is more likely to comply with instruction and complete her assignments in school, as she is invested in grades and approval. She is also at risk of being turned off of science if she does not receive the recognition she seeks. The participants identified as experts in this study are all of the “A student” type. They succeed at all subjects they pursue in school, which means they have options. If they do not receive the fulfillment they crave in science, they may take their efforts to other disciplines where they will be encouraged.

Experts are also more likely to succumb to failure. Their need for mastery makes them more subject to frustration when their efforts do not succeed. Expert students are often observed in camp becoming upset with ambiguous activities. It is important to provide the expert with challenging “wins” and to help her work through frustration. Experts may succumb to a fixed-mindset mentality (Dweck, 2006, 2007) and retreat from science activities that disconfirm their belief in innate talent over hard work and perseverance.

Explorers. Two other closely related identity archetypes emerge from the data. These types are broadly classified as explorers. Both explorer types are characterized by an overriding interest in understanding how specific processes work. Where experts want to understand scientific principles in a deep manner, explorers want to dissect, disassemble, and probe. They prefer an inductive approach to science where they collect data hands-on through exploration without a predetermined hypothesis. Figuring out is a major component of explorer's approach to science. In focus groups, many girls expressed a strong preference for exploration. Madison expressed the explorer perspective while envisioning herself as a scientist: "If I were a scientist I'd probably have to use my brain a lot, because it's really challenging to be a scientist and it would just be really cool. You get to do hand-on experiments and you get to figure out things." The exploration types come in two flavors: experimenters and inventors.

Experimenters. At the end of every focus group and interview the researchers asked the students if they had any questions. A few asked logistical questions about camps and the possibility of volunteering as a junior instructor after graduation from the program. Most shrugged no and moved on. One student, Matilda, spent nearly ten minutes interviewing the researcher about camp, the research project, and the future of the pinball machine projects. Matilda was an Engineering camper working in a team of three girls who produced a superhero-themed pinball machine during camp. She was one of the few campers to take a table (measuring 18" x 2' x 4') home to continue tinkering with on her own.

Matilda has been described by SPICE instructors as "a firecracker," "sassy," and "the best kind of trouble." She does not hesitate to pronounce an activity boring if she is not enjoying it and will grill instructors about why she needs to follow prescribed rules. Matilda follows the mold of the class clown, entertaining her peers and disrupting activities when she is bored. When engaged, she is meticulous and focused. During the interview she explained why there are no longer any Lincoln Logs in her house.

> I thought it was the coolest thing to look up things to do with the Lincoln Logs. I would create Lincoln Log towns. Then my Lincoln Log towns were in a Lincoln Log kingdom, and then they took up the entire playroom. And so now I'm not allowed to have Lincoln Logs, because I slowly build them across the house, and then no one can step anywhere. I tried to create the Great Wall of China with Lincoln Logs.

Matilda’s parents are supportive of her explorations, up to the point where the Lincoln Logs took over the house. Her mother, a doctor, has taken Matilda and her sister to work where they once got to observe an operation. Matilda and her father work around the house on projects and tinker with electronics together.

> I got a tool kit when I was 10 for Christmas. I thought it was the coolest thing to take stuff apart. So me and my dad went to a St. Vincent de Paul and we got all the broken clocks that they have there and like one of those radio clocks. I took those apart and I would try to put them back together and we actually got one to work. That was fun. And broken lamps, we have kind of an old house so stuff just generally breaks in our house. The plumbing is really old. My dad used to live in this house when he was my age, so there's stuff in the basement that's dripping constantly. So I fix that sometimes. I watch while my dad fixes it and then when he leaves I get to fix stuff. I've replaced our sink in our bathroom, it was always leaking. It was dripping so we wanted to conserve water, so I got to connect all the pipes, and there was sawing of pipes. That was fun.

What Matilda describes here is the classic apprenticeship model of parenting often enacted by fathers and sons. One of the ways in which boys often have an advantage over girls in math, spatial reasoning, and applied technical skills is due to the time they spend with fathers and other adult males learning how to carry out home repairs, building projects, and automotive maintenance (Brickhouse et al., 2000).

Matilda is driven by a strong desire to understand what makes things tick—quite literally, in the case of a clock she found:

> It's just really interesting to me how things work. I tore apart a clock that I found, one of those mechanical ones that tick, so I could see how the second hand moved faster than the other hands, because I was really confused. So I just tore it apart until I could figure out how. And it's just satisfying to know how things work.

Girls with the experimenter identity archetype often engage in mechanical dissections like Matilda's clock. Girls of all archetypes express an interest in these activities, but experimenters prize these experiences above all others and credit them with fueling their interest in science. They also express a strong aversion to documentation and "busywork." When asked what she does not like about science, Matilda does not hesitate in her response: "The writing down. The writing part of science, the 'my hypothesis is,' now I'm going to write a very long hypothesis and then I'm going to watch something boring and then I'm going to write what happened. The writing part of science is not fun to me." Matilda embodies the explorer in her distain for documenting the scientific process, her willingness to make a mess and break things along the way, her resilience to failure, and her drive to understand. For Matilda, science is about a deeper understanding gained through experimentation. She describes how it began with a shallow interest in explosions and grew over time.

> I used to really like just watching stuff blow up. I would literally look up videos of things blowing up. Now, I'm more interested in why it's blowing up and what's going on. Like on a molecular level and stuff like that.

Matilda comes from a family where academic performance is highly valued, but she is not as concerned about performance and mastery as an expert type would be. Her interest is in engagement and learning.

> Grades are kind of a flexible thing. Like you can be having a lot of fun in the class, and learning a lot and still be getting a bad grade. So just as long as you're learning in a class, and you're having fun doing it, I think that then you've accomplished stuff in that class.

The experimenter is less interested in the acknowledgement that experts crave but values encouragement and support. The difference could be thought of as post hoc versus a priori. The expert wants confirmation of her accomplishments. The experimentalist wants support in her endeavors. Matilda describes it this way: "If someone encourages you, it makes you feel better and them feel better and if you're encouraged to do something you have more reason to do the stuff you want to do."

Another key trait of experimenters is resilience to failure. Failure and frustration are a threat to the formation of strong identities and self-efficacy. Matilda handles failure by recasting the meaning of failure as a failure to learn, rather than a failure in succeeding at a particular task. When asked what was most important in science, her response initially seems to favor a fixed-mindset view of success, but she then clarifies.

> To be successful in your experiments, sometimes your experiments go completely wrong. Like I read online that if you douse an apple in some cooking oil something spectacular was supposed to happen when you put it in an oven. I watched it for two hours and nothing happened. But even that was an experiment, because you learned that this doesn't react to that. So when your experiments fail, you still learn things. You just learn different things than what you expected.

What does the explorer archetype tell us about how girls engage with science? In the right circumstances, the explorer is self-driven to learn. She will seek out information and activities to carry out on her own. She values encouragement over acknowledgement. She views failure as a learning opportunity. These traits give the experimenter a strong foundation from which to build a science identity, when she is given freedom and support to try things out. Traditional gender expectations and classrooms environments, however, may prove problematic for experimenters. Prohibitions against making messes and taking up space that are often applied to girls may prevent the experimenter from engaging in the activities that she associates with science. Her resistance to writing and documenting makes classroom experiences tedious. Messages that reinforce the paperwork side of science may turn her off of pursuing formal science opportunities.

Inventers. Like their experimenter sisters, inventers like to get down and dirty with science. Unlike the experimenters, inventers have a focus to their innate curiosity. When they take a clock apart, it’s because they want to put it back together, or better yet, use the parts to build something new. Inventers have a purpose. They want to make something real that helps other people. They also would not mind being famous for their creation. Engineering camper Christy sees scientists as memorable figures.

> If they build something important that people will remember them by are what I think considered famous like the painters, like the one who painted *Starry Night*. And the person who made it. So with scientists, if they do something new or big or a different model of something is what I think it means to be a scientist.

Becky has good reason to want to help people. A lot of people, doctors and scientists, have helped her over the years. Becky has a spinal condition that makes it challenging for her to walk or stand for long periods of time. She spends most of the day in a wheelchair. She spends large parts of the summers recovering from surgeries to her neck and back. During SPICE camp 2014 she wore a high-collared brace to protect her fragile neck. Every day her mother dropped her off at camp with the handles to her chair installed, and every day, Becky took them off and handed them back. She would not permit anyone to push her around.

Becky flies to the East Coast most summers for surgeries. When she travels she sometimes gets to visit research labs and see scientists at work on mobility projects. When asked if she knew any scientists she talked about one of these visits.

> This one [scientist] I met is someone I know in Delaware at a hospital in the research part. They're working on something called WREX, and it's something to help with arms. I forget what it's called, but it’s when they can't lift up their arms very well. So it's made with Lego rubber bands and it just provides stability, so that way they can lift their arms up. And they're trying to develop it for like [a] suit.

Becky is interested in computers and programming. She builds Lego Mindstorms at home, and she and her mother volunteer at a local nonprofit taking apart computers for resale and recycling. Inventing is not just an interest for Becky, it is a practical concern:

> At our old house we invented a Wiffle ball hanging from a telephone wire that went up and like up to a hook across the door. So if I'm going down a ramp I can just pull it and it will close the door. So I don't have to reach behind me to close the door.

Many of the activities and interests Becky discusses relate to helping other people. She does not take gym in school (though she does participate in track after school), so instead she is a math assistant in the 4th and 5th grade classrooms. She does experiments with her preschool-aged cousins, and volunteers at the nonprofit. She enjoys sharing the science she has learned with others.

In her own learning, like the experimenters, Becky values actual learning over grades or getting the right answer. When asked what the most important part about doing science was she responded:

> Having fun and learning it probably. Not necessarily being good at it, but I think if you want to learn like trying to understand it, you don't need to but I think it's better to understand it and having fun is really important.

Becky is drawn to mathematics, coding, geometry, and engineering. While other campers focus on chemistry and explosions, Becky is more interested in building up rather than blowing up. Like the experimentalists, Becky enjoys taking things apart, but her focus is on creating. When asked what makes her interested in science she cites a desire to understand how things work.

> I'm just curious about a lot of things and I think it's fun to see how things work. It's like when I take apart a computer. It's fun because otherwise I wouldn't know anything about what's in the computer. Mostly dust <laughter erupts in the room>. So I guess curiosity and just seeing how things work, learning about the world. It's kind of fun.

Becky answers questions about science the way an engineer would. She focuses on process and understanding. When asked what it means to be good at science she responds, "I go through the thought process of how something works and just guess/wonder about it . . . and examine it and try and figure out how it works."

The difference between the experimenter's unfocused curiosity and the inventor's focused drive is subtle in this passage. Becky not only wants to know about how it works, but she has a process for understanding process. She is mentally walking through the how and why behind the process she is examining. Thinking of her building projects (coding, Legos, computers), this focus on the thought process gets back to the human connection. She understands the process through the lens of the humans who created the object. As a person who has had to rely on others more than usual, Becky is sensitive to the human side of science.

> I mean I [get] help from the people in my life. Like science they say that I'm good at it. They do encourage me, I mean they're not like you have to do science or anything but just "Science is fun. Try it." . . . So I guess that has helped, I mean it's kind of somewhat important to me, if someone was like "science is terrible" I might not enjoy it quite as much, but everyone is not like that.

What does the inventor archetype say about how girls form science identities? Inventors value the human connection to science. They are interested in a deep and specific understanding of processes, but unlike the experimenters, they are purpose driven. They want to make a contribution to society through science. Like the experimenters they need freedom and support in their explorations. Their creativity may be stifled by too much "paperwork," though their path as future engineers and builders will require a lot of just that kind of rigor. Inventors will gravitate toward scientific careers that have the lowest participation by women: engineering (be it physical, chemical, biological, or other) and computer science. They will need to receive explicit and implicit messages, often, that reinforce their belonging in science, and that their contributions are valued and needed.

Enthusiasts. Some girls have a blast at camp, enjoy science at school, and are encourage and supported by their parents to explore science, but reject any identity as a scientist or intentions toward a future in science. Tasha is one of these girls.

Tall and athletic, Tasha is a good student and a highly competitive cyclist, though she never mentions just how good she is at it. Her mother, not wanting to embarrass her, held back for a moment after Tasha's interview, while Tasha and a big group of the extended family headed off for a tour of the university campus. "Tasha won't tell you this, but she just won her last race in the women's category." In distance cycling this means that Tasha, at age 13, beat out women up to age 25, some with years of racing experience. Her mother is understandably proud. She goes on to talk about how serious Tasha is about cycling, how much fun she has had tinkering with the programming on her pinball machine, which is taking up a big section of the family room, and plans to get

Audrey and Tasha together before school started in September. It is clear that Tasha has a large and supportive family invested in keeping her interest in science high.

When asked to rank the statements relating to science archetypes as they related to her feelings about science, Tasha ranked the experimenter type highest. Enthusiast came in fourth. So why is Tasha listed as an enthusiast? In the interview and focus group, Tasha explicitly explained that despite her fondness for all aspects of science, she did not think of herself as a scientist because she does not feel she has the requisite experience to claim that identity. Tasha has another strongly developed identity as an athlete.

Audrey also resisted any science identity, on the grounds that she was not experienced enough to make that claim, but she is also planning for a career in marine biology. Tasha has a clear career path staked out in cycling and plans to go professional someday. In college, she plans to study sports medicine or physical therapy. These are careers that will require a healthy dose of science education, but are not generally considered part of the STEM disciplines. More importantly, Tasha does not consider them to be science careers.

Tasha enjoys talking about cycling with her dad and how he is teaching her to work on her bike. They also work together on household projects. In school she enjoys math because, as she says, “I like that there are right answers.” In science she gravitates toward engineering, building things, and figuring out how mechanical items work. As with the explorer types, she is not a fan of making hypotheses and writing things down. She is more interested in simply trying them out and seeing what happens.

Tasha is confident in her science abilities and enjoys science, but rejects a science identity. This is somewhat unusual in identity formation. People, especially children, tend to identify with things they are good at and enjoy. However, as Mattern and Shau (2002) showed with science interest and achievement among middle school girls, this is not always the case. It is likely that messages about the demanding, female-unfriendly nature of science careers make it less appealing as a career choice. There is also the fact that Tasha already has a strong identity as a successful athlete. “I think [of] a scientist as a kind of normal person who likes to do science so, I don't know. I don't do science as much as them. Because they like studying it and stuff.”

Not every girl who attends a program like SPICE is going to have dreams of being a scientist. Even among those that do, not all will pursue that goal as adults. Still, it is valuable to understand how the nonscientists relate to science, what they enjoy and what they dislike. Confident enthusiasts like Tasha may create spillover effects through their friendships by supporting and encouraging girls like Audrey.

Overview of Results

Analysis of fidelity reveals that the program was implemented with fidelity to the foundational theories and conceptual framework established in chapter II. Examination of the measures of science affinities shows that participants have higher starting science affinities than the comparison group. Participants’ science interests, efficacy, and attitudes were stable between the pre-camp and post-camp conditions. A statistically significant relationship between participant scholarship status and years in the program was found in the changes in science efficacy, attitudes toward science, and science identities. The model of science identity was statistically significant, indicating that camper science identities were predicted to change over time. The direction of the predicted change was dependent on the interaction between student scholarship status and years with the program. Non-scholarship students were predicted to experience increasing science identities. Scholarship students were predicted to experience decreasing science identities.

Participants reported that teachers had a substantial impact on their interests in science, though teachers were not perceived by most campers as actual science role models. SPICE girls reported a strong preference for engaging in science through hands-on activities. They expressed that hands-on exposure influenced their ability to understand and engage with science. Participants also identified science with danger, and valued the trust and responsibility given to them by SPICE instructors in handling potentially dangerous materials during camp activities.

SPICE girls' perceptions of gender and science focused on societal expectations for women. Many girls felt that traditional gender expectations and roles were hindering girls' engagement with science. The lack of female role models was cited as a reason girls do not feel welcomed into science. SPICE girls were divided in their perceptions of gendered interests in science. Their perceptions of the general engagement level of girls versus boys in science seemed to be influenced by the presence of other girls in their lives who enjoy and engage with science. As a minority in science, several girls expressed the desire to prove themselves better at science than their male peers.

Attitudes toward science among SPICE girls focused on the need for hard work and persistence necessary to be successful in science, the threats of failure and frustration in pursuing science education and careers, the requirement that scientists be highly knowledgeable, and the greater freedom scientists have in structuring their work. Girls' attitudes represented a mixture of positive and negative perceptions of science. The need to work very hard and persevere through failure loomed large in their minds. For some girls, the ability to succeed in spite of these requirements was viewed as a source of pride. For others there were concerns about the personal costs of a career in science. Girls appreciate the independence they perceived that scientists have in determining what, when, and how they would work. Generally, girls viewed a science career as challenging, but highly rewarding if science is your passion.

SPICE girls' discussions of their science identities was consistent with identity formation theory (Erikson, 1968). Girls' discussions of science identity focused on curiosity, symbolic acts, and doing science. For SPICE girls, curiosity and discovery are key elements of science identities that they relate to strongly. Scientists engage in exploration and discovery in a way that appeals to girls and their forming identities. Likewise, they are drawn to symbolic acts of inclusion. They place great value on the garb and implements of science and feel the most like scientists when engaged in science using these tools. Role enactment and dress make SPICE girls feel the most like scientists, but it is the act of doing science that they associate most with a science identity. Girls repeatedly linked the act of doing science with science identities, even to the point of disqualifying their teachers as "real" scientists, because they did not feel that teachers do "real science."

Nine of the 11 SPICE girls interviewed identified as scientists or scientists in training. Among these nine girls, three identity archetypes were observed: experts, experimenters, and inventers. These three archetypes are differentiated by the primary way in which girls identify as scientists. Experts view scientists as highly knowledgeable practitioners who are recognized for their skills in science. Experimenters see scientists as people who explore the way the world works through an inductive process of discovery. Inventors see scientists as people who contribute meaningfully to society through science. Identity archetypes provide a guide for how individual girls prefer to engage with science and what kinds of support they need.

The implications of the major findings reported in this chapter will be discussed in the next chapter. Particular emphasis will be placed on the interaction effect reported for the regression analyses of science affinities, the implications of girls science affinities as they map onto the SPICE program and on the predicted interaction of the theorized science identity archetypes and gender expectations.

CHAPTER V

DISCUSSION

Chapter V presents a summary of the study, significance of the study, and a discussion of the results. Study limitations and implications for practice are also discussed. Finally, recommendations for future research are presented.

Overview of the Study

Chapter I of this dissertation began with a discussion of the problem of gender disparities in STEM. Statistics representing the representation of women in various STEM disciplines were presented. A brief overview of the outreach intervention under study, the SPICE program was presented next, as was a brief summary of the results of a pilot study of the SPICE program conducted in 2013. Lastly, the research project and research questions were presented.

The purpose of this study was twofold. First, the study examined SPICE program participants' science affinities and their relationship to the program. Second, SPICE participants' reflections on science and their relationship to science were used to build theory about SPICE girls' science identity types. Information about girls' science affinities and the types of science identities they build were explored as they could provide valuable insight for educators and parents in how to better support girls in science. This information could also be used to improve outreach interventions like the SPICE program.

The study was divided into three components and six research questions. The components were: fidelity of implementation (research question 1), girls' science affinities (research questions 2–5), and science identity theory building (research question 6).

Chapter II presented literature addressing the explanations for gender disparities in STEM. The literature was organized by four chronological themes in thinking about gender disparities in STEM: equity, access, and preparation of girls for STEM careers; STEM curriculum and pedagogy that excludes girls from science; the exclusive culture of science; and science identity formation. The theoretical framework integrating Eriksonian identity theory, Bandura's self-efficacy theory, and work on mindsets by Dweck and colleagues was presented next. Finally, the conceptual framework integrating the three foundational theories with the theory of action from the SPICE program and the expected outcomes was presented.

Chapter III described the methods to be employed in the study including statistical analyses, instruments, and handling of qualitative data. A mixed-methods approach was used in the study, combining quantitative scale measures and qualitative data in the form of observations, focus group interviews, and individual interviews. Chapter III also presented the sample and research design for the quantitative portion of the study (pre-post measurement with a pre-treatment comparison group).

Chapter IV presented the results of the analyses by the three components described above. Analysis of fidelity measures showed that overall, implementation fidelity was high. Analysis of SPICE camper science affinities found that SPICE girls' science identities for campers were predicted to increase or decrease following camp depending on scholarship status. Chapter IV also presented SPICE girls' interest in and preferred ways of learning science (hands-on, deep understanding, and trust with dangerous activities), their perceptions of how gender influences girls' and women's science efficacy (societal messages, differences in interest by gender, the presence of female friends interested in science, and the need to prove oneself), their attitudes toward science (hard work, knowledgeability, and self-determination), and lastly, their sources of science identity (discovery, symbolic acts, doing science). Finally, new theory around girls' science identity types was presented. Three identity archetypes—experts, experimenters, and inventors—were described.

Significance of the Study

Gender diversity in STEM has been a national conversation for more than forty years (Corbett et al., 2008; Kelly, 1981). Educators, policy makers, scientists, and parents all have a stake in addressing this issue. Arguments for greater inclusivity in STEM range from the moral good of equal participation, to the economic benefits to women, to the greater good to society of a diverse STEM workforce. This study sought to better understand how middle-school-aged girls build science identities and efficacy and how an informal intervention might support that process.

The results of this study provide a bit more insight into how girls relate to science and what can be done to support girls' persistence in STEM. What follows is a discussion of the results reported in this study and their implications.

Discussion of the Results

This study explored girls' science efficacy and identity types on two levels. First the study sought to examine if the SPICE program was implemented with fidelity and to explore the relationships between the program and girls' science affinities. Put simply, was there a relationship between the SPICE experience and manifestations of girls developing science identities and self-efficacy? Girls who develop strong identities and efficacy around science were hypothesized to be more likely to persist in STEM. This is supported in the literature (Ahlqvist et al., 2013; Betz & Hackett, 1981; Blustein et al., 1989; Calabrese Barton & Brickhouse, 2006; Côté & Levine, 2002; Howes, 2002; Olitsky, 2007; Savickas, 1985; Tai et al., 2006). Second, the study looked more broadly at girls' science affinities and identity types. How did SPICE girls feel about science? How did they prefer to engage with science? How did they perceive the interaction of gender and science culture? What attitudes about science did they hold and how might those attitudes influence the development of strong science identities? What signs did SPICE girls show of developing identities as scientists? What types of identities were they forming and what do those types imply about how girls can be supported in science?

Discussion of the results is presented in three parts. First, a brief discussion of the results of component 1, implementation fidelity, is presented. Next, the results of components 2 and 3 as they map onto the SPICE intervention will be presented. Implications for improvements to the SPICE program, based on the results of this study, will also be discussed. Last, results of components 2 and 3 as they apply more broadly to the discussion of girls and STEM will be provided.

Implementation fidelity. The research design of this study does not permit causal inference, however, an investigation of the fidelity of implementation is an important check on both the program, and the meaning of the results reported. Fidelity evidence strengthens the limited claims that can be drawn from this study.

In a program like SPICE, evidence of fidelity is somewhat different from what educational researchers typically look for in a program. Fidelity measures did not examine the extent to which instructors covered material. They did not examine time spent on particular activities, the number of instructors present, or look at learning outcomes. Instead, fidelity was measured in terms of the operationalized elements of identity, self-efficacy, and mindsets. Raters looked at camper affect. Were students engaged and excited? They looked at how instructors encouraged students and provided feedback. Raters documented how much time was spent on hands-on activities versus passive learning. By these measures, the program was implemented with high fidelity. Camper evaluations (though limited to only the first week of two of the three camps) were consistently high. Camper affect was high in observations. Scores on the fidelity rubrics were also high.

SPICE is was a mature program in 2014 with 7 years of operation. There had been ample time for the administrators to develop the theoretical underpinnings and practice operationalizing and implementing those theories. Overall, fidelity of implementation was high. Therefore, results of the analysis of camper affinities were examined with reasonable certainty that the program was correctly implemented.

Mapping emergent themes in science affinities onto the SPICE program. How do the findings about girls' science affinities map on to the SPICE program and what do they tell us more generally about how interventions should be structured to support the building of science identities and self-efficacy? Figure 20 maps the four science affinities and their constituent elements as informed by observations, focus groups, and interviews with SPICE girls.

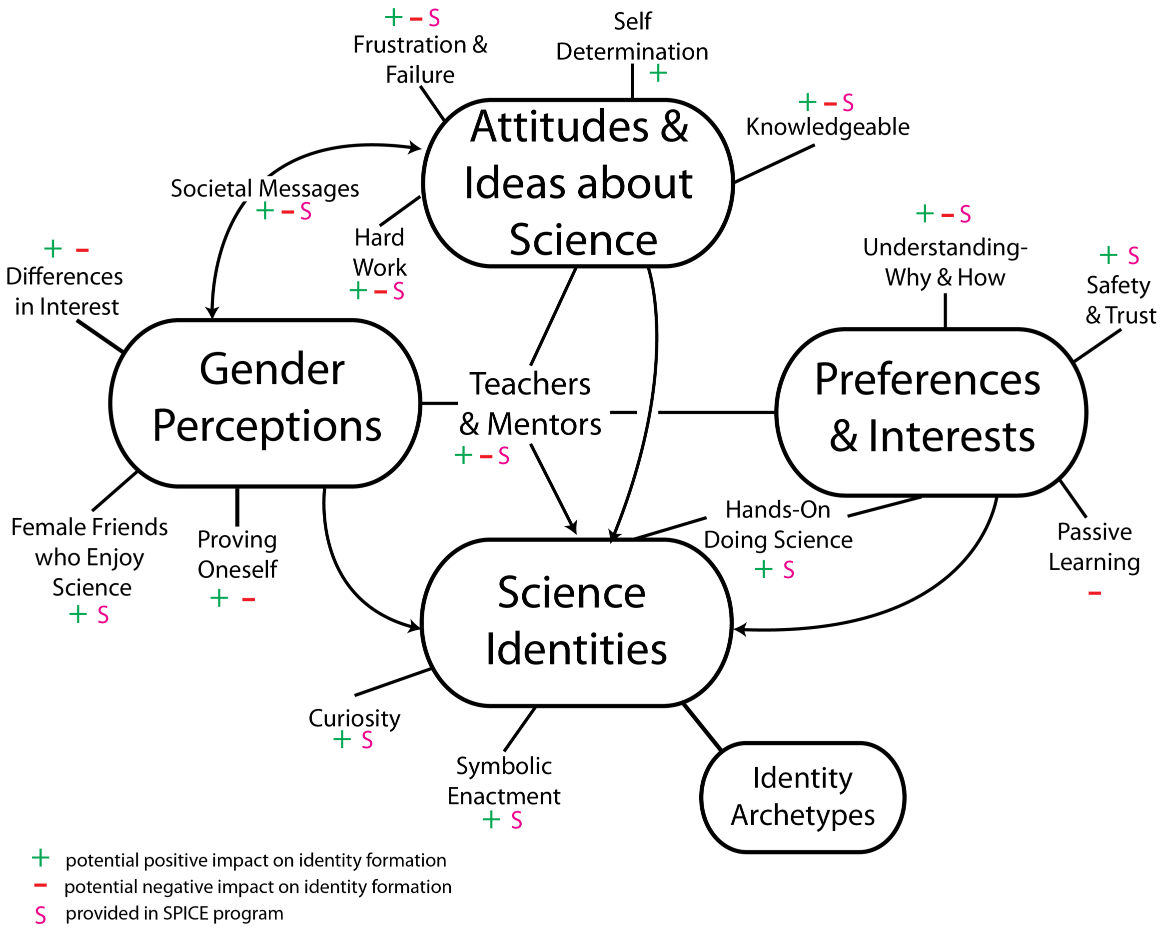


Figure 20. Emerging themes in girls' science identity formation.

Elements that have the potential to support identity and efficacy in science have been marked with a green plus symbol. Elements that have the potential to negatively impact identity and efficacy are marked with a red minus symbol. Elements addressed in the SPICE program are marked with a pink letter *S*. Though science affinities were explored through the SPICE program and the relevant elements were developed through observations and conversations with SPICE girls, not all elements are engaged in the SPICE program. Focus group and interview conversations focused on girls' science affinities more generally. Few questions in the conversations dwelt on the SPICE program. Girls were encouraged to provide a more holistic picture of their experiences and ideas about science above and beyond their SPICE participation.

The following sections briefly revisit SPICE girls' science affinities for the purpose of mapping those affinities onto the SPICE program and discussing how the program does or might support girls in these areas.

SPICE and girls' science preferences. The theme of girls' preferences and interests explores types of science experiences girls identify as potentially influencing their identities as scientists. Girls expressed a strong preference for hands-on activities over passive learning such as lectures, textbooks, and worksheets. Expert identity type girls find hands-on activities more engaging than passive learning (Billington et al., 2014; Pajares, 2005a; Trower & Chait, 2002). Experimenters and inventors find the ability to visualize and manipulate an aid to understanding and focusing on the subject. All three enjoy hands-on activities and feel more like scientists when carrying out experiments. In this way, SPICE is in alignment with girls' preferences for engaging with science, as almost every session is built around a hands-on activity.

SPICE girls express a desire for deeper learning and understanding of the subject matter. Experts are interested in developing an academic mastery of the subjects they study. Experimenters and inventors are focused on understanding the internal mechanisms of processes and tinkering with those processes. Both groups find surface learning unsatisfying. This is also consistent with research on girls' preferred learning styles (Hazari & Potvin, 2005; M. Schwartz et al., 2009). Expert types in particular do not care for the ambiguity of a casual understanding. For experimenters and inventers surface learning is frustrating for the lack of payout. SPICE provides mixed support in this area.

Campers are provided with access to expert scientists and given the chance to explore activities they enjoy in a deeper way. However, the limited nature of camp—just two weeks—and the need to switch activities frequently to keep all campers engaged may frustrate some students who wish to stick with a project longer than time allows. A possible improvement might include providing more extension resources for students who wish to continue investigations after camp.

The potentially dangerous nature of science experimentation, or at least the perception of danger, is attractive to SPICE girls. Though they have some concerns about causing harm, they are drawn to the potential chaos. This is consistent with findings by Archer et al. (2010). Experts crave the trust and responsibility that comes with potentially dangerous activities. To the expert, being permitted to take on a challenging task with the potential for damaging results is a sign that their mastery and skill have been recognized and rewarded. Experimenters take a certain glee in the potential for disaster, and the chance to learn from failure. Inventers see risk as an element of creation and failure as informing the creative process. Also, children's pleasure in the unexpected and explosions should not be deemphasized. SPICE camp provides a plethora of chemical reactions, explosions, and opportunities for experimentation, as noted in camper conversations.

Results of the analysis of the scale score of science interest show that SPICE girls enter the program with higher starting interest than the comparison group. Their interest in science does not change in a statistically significant manner following the SPICE camp intervention. SPICE provides access to the kinds of science opportunities for which girls express a preference. It remains unclear, however, if the program is helping to sustain or increase participants' preferences for science and what role socioeconomic status plays in their preferences.

Gender perceptions and SPICE. SPICE girls' gender perceptions were less cohesive than their science preferences, but some themes emerged. Many of them acknowledged traditional gender roles as an impediment to science careers, though they were defiant in the face of social restrictions. Experts, experimenters and inventors alike expressed a strong impulse to prove themselves as scientists in a male-dominated climate. Girls' perceptions of imbalances in interest in science seemed to be influenced heavily by the presence of science-engaged peers. Girls with friends who enjoyed science were more likely to cite girls as being more interested in science than boys. Girls who felt a dearth of female science peers observed more boys engaged with science. Relatable peers are an important component for both identity and self-efficacy (Bandura, 1997a, 1997b; S. Schwartz et al., 2011). Research has shown that students are more likely to identify with science if they have peers like themselves who also identify with science (Olitsky, 2007; Taconis & Kessels, 2009).

Analysis of the scale of science efficacy showed that SPICE girls had higher starting science affinities than the comparison group. No statistically significant change in science efficacy was found following SPICE camp. Participants who received scholarships were predicted to experience a slight bump in science efficacy following their first SPICE camp and decreasing science efficacy over time. Participants not receiving scholarships are predicted to increase science efficacy over time. The interaction between scholarship status and years with the program is troubling, though not surprising. A large body of research shows that low-income children have less access to all kinds of educational opportunities, particularly STEM opportunities (Chesler et al., 2010; Espinoza, 2011; Gandara, 2006; Maltese & Tai, 2011).

SPICE is particularly strong in addressing gendered perceptions of science. The program provides female role models and peers and many opportunities to try and share science activities. A more explicit discussion of how to cope with stereotypes and challenges might also be helpful to participating girls. The focus group that discussed disparities in depth seemed galvanized by the sharing and determined to proceed with their interest in science despite obstacles. SPICE alone may not be enough to overcome messages that undermine girls' science-efficacy.

Attitudes and SPICE. SPICE girls held a range of stereotypical ideas about scientists (fuzzy-haired, old, white, male chemists) but they also had more sophisticated ideas about scientists and science. The main attitudes that relate to SPICE girls' interest in science are: scientists as highly knowledgeable, scientists as hard workers, frustration and failure in science, and self-determination in science careers.

SPICE girls' ideas about scientists as highly knowledgeable and hard-working are closely interrelated. SPICE girls see scientists as people who spend long nights puzzling over research, perhaps at the cost of their social lives and families. Scientists work hard to become experts. SPICE girls are not particularly excited about the notion of hard work; however, they also believe that scientists choose to work hard because they are passionate about science. Girls with the expert archetype relate to the value of hard work in service of mastery. Experimenters relate to the notion of long nights in the lab puzzling out mysteries, and inventors appreciate scientists' dedication to creating works of value to others. SPICE provides opportunities to both confirm and mitigate girls' ideas about scientists as knowledgeable and hard-working. SPICE instructors are knowledgeable role models who share their experiences as students with the campers. The girls get to see that scientists do work hard because they enjoy science, but also that they are relatable human beings with social lives.

Girls see practicing science as a source of potential frustration and failure. Science is challenging and failure is common. Girls also see scientists as having more control over their work and more choices in what they do. Expert type girls are in more danger from frustration and failure. Their desire to be masterful and recognized as skilled may make them avoid challenges where failure is likely. Experimenter and inventor types are less susceptible to frustration and drawn to the idea of self-determination in work. Still no one enjoys constant failure and frustration. SPICE helps provide girls with context in defining failure. While an experiment may not turn out as expected, there is always room to learn from mistakes. Camp allows girls to fail in an environment where they can work through frustration with support and encouragement.

Results of the analyses of SPICE girls' science attitudes show that they have higher starting attitudes toward science than the comparison group. No statistically significant change in SPICE girls' attitudes was observed following camp. As above, the interaction between scholarship status and years with the program points to a larger underlying problem for fostering positive science attitudes in low-income girls.

Identities and SPICE. A number of factors influence the formation of science identities. For the girls in SPICE camp the major factors in identity formation were engaging in or doing science, freedom to explore (curiosity), and symbolically trying on scientific roles through the use of clothing (lab coats and goggles) and props (e.g., microscopes and chemicals).

Doing science was a major part of being a scientist for all girls, but was particularly salient for experts and enthusiasts. In fact, for some girls it was the dividing line between embracing or rejecting a science identity. Fundamentally, scientists are people who do science. A girl who does not feel experienced enough in science may reject a science identity, not from lack of interest, but on the basis of not having the right to claim the identity. For experimenters and inventors, doing science is where the joy in science resides. Tinkering and exploring are how they engage with science. SPICE provides ample opportunities for campers to try on the role of scientists by doing science. SPICE girls not only carry out science activities, but they are encouraged to innovate, reflect on why processes work, and relate them to real life.

Campers employ their curiosity through learning about subjects in greater depth utilizing hands-on activities (expert), time spent exploring activities by changing variables and trying different approaches (experimental), and plenty of building and tinkering (invention). Likewise, SPICE camp provides many opportunities to use the tools and garb of scientist during camp, something popular with all campers, even the nonscientists.

Results of the analyses of the scale of science identity show that SPICE campers have higher starting science identities. There was no statistically significant change in science identities following camp. However, results of the regression analysis of change in science identities did predict statistically significant variance in the model. As before, the interaction between scholarship status and years in the program was statistically significant. Once again, low-income girls are predicted to lose science identity over time while non-scholarship girls are expected to gain science identities. The pattern of statistically significant interactions between scholarship status and years in the program is discussed in more detail below.

Interpreting the results for the analysis of student science affinities. SPICE participants had statistically significant higher average scores in the pre-camp condition for all four of the identified scales of science affinities than the comparator group of SEP students. This provides evidence for the assumption that SPICE campers have higher-than-average science affinities compared with students of a similar age participating in a broader program. Given this high baseline, detecting any positive change in affinities in the post-camp condition may be difficult with such a small sample. Average scores for the same scales in the post-camp condition were consistently higher than in the pre-camp condition; however, only regression analysis of change in science identity explained statistically significant variance. This implies that overall, SPICE girls are sustaining the same high level of science affinities over time. However, the interaction effect found in the regression analyses suggests that some girls are increasing science affinities while others are decreasing science affinities. Whether or not SPICE camp plays a role in sustaining or changing science affinities cannot be assessed using this research design.

As was discussed at length in chapters I and II, middle school is the time when girls begin to loose interest in science. It is also a major life stage for identity building. Based on the literature, science affinities are expected to decline over time for girls in the same age group as the SPICE participants. The interaction effects between scholarship status and years in the program reported for the affinities of science efficacy, attitudes, and identities implies that the expected relationship may not be consistent across socioeconomic status groups, at least among the SPICE girls. This could be because the SPICE program did not provide enough, or the right kind of intervention for low-income girls. The interaction could be due to higher income girls who were already on an upward trajectory vis a vis science affinities prior to attending camp. Alternatively, as discussed before, the ceiling effect could be masking the main effects of socioeconomic status and years in the program. It is also possible, that SPICE participants receiving scholarships might have displayed even more pronounced predicted declines in science affinities with out the intervention. The consistency of the finding across three affinities scales suggests that the interaction effect is not simply an artifact of the data.

Ultimately, limitations of the research design and ceiling effects make it impossible to determine the true cause or meaning of the relationship between scholarship status and years in the program reported here. Recall, however, that in the first year of the program, scholarship students are predicted to increase their science affinities between one to three points. Each subsequent year, the gains are predicted to decrease and eventually reverse. For a time then, like the non-scholarship students, they are defying what is predicted in the literature. From this perspective, SPICE may be having a positive impact on both groups of girls', however; more emphasis should probably be placed on connecting scholarship girls with more identity building science opportunities.

Replication of the study with better measures and a control group may help clarify the source of the reported interaction effect. If scholarship status continues to predict declines in science affinities over time, new theory into the development of science identities that accounts for socioeconomic status would be indicated.

Considering all the results presented here, two questions come to mind, particularly in light of the disparate predicted outcomes for girls by scholarship status. First, just because girls prefer to learn science certain ways, does that mean those ways will support the formation of science identities and self-efficacy? The science affinities reported in chapter IV align closely with recommended best practice for engaging girls in STEM. Organizations like the National Science Foundation, the Girl Scouts of America, and the National Girls Collaborative all present best practice guidelines for engaging girls with science based in research (Billington et al., 2014; Modi, Schoenberg, & Salmond, 2012; National Science Foundation, 2007). One widely used and well-received set of guidelines is SciGirls Seven, a collaboration between the Corporation for Public Broadcasting and the National Girls Collaborative. The SciGirls Seven (Billington et al., 2014) are as follows:

1. Girls benefit from collaboration, especially when they can participate and communicate fairly.
2. Girls are motivated by projects they find personally relevant and meaningful.
3. Girls enjoy hands-on, open-ended projects and investigations.
4. Girls are motivated when they can approach projects in their own way, applying their creativity, unique talents, and preferred learning styles.

5. Girls' confidence and performance improves in response to specific, positive feedback on things they can control—such as effort, strategies, and behaviors.
6. Girls gain confidence and trust in their own reasoning when encouraged to think critically.
7. Girls benefit from relationships with role models and mentors.

SPICE girls perceive that women have not been permitted to fully participate in science (SciGirls #1) and note the dearth of relatable female science role models (SciGirls #7). SPICE girls strongly prefer exploratory hands-on science activities (SciGirls # 3). The presence of female peers who enjoy science is related to SPICE girls' science efficacy (SciGirls #1). SPICE girls want to use science to help other people, particularly inventor identity type girls (SciGirls #2). Discovery and curiosity are two of the principle defining elements of what makes someone a scientist for SPICE girls (SciGirls #4). SPICE girls show evidence of being susceptible to fixed mindsets, particularly expert types, when faced with failure, but respond enthusiastically to process-based praise during SPICE camp activities (SciGirls #5).

SPICE provides the type of science that is consistent with both best practice recommendations from experts (Billington et al., 2014) and the types of experience that girls prefer—that is, hands-on learning, focusing on depth over breadth, relatable instructors, the presence of peers who enjoy science, and feedback that is process-based. So yes, it is reasonable to expect that the affinities girls express will support the formation of science identities and efficacy and that programs like SPICE can facilitate this formation.

Second, if SPICE is providing activities in line with theory and recommended best practice, why is there no observed improvement in girls' science affinities as reported in chapter IV? Two factors need to be considered to answer this question. First, this study is underpowered, as will be discussed in more detail in the limitations section. Girls may in fact be experiencing increases in science affinities that are simply too small to measure due to the small sample size. There is also another explanation. Research shows that until about the age of 10 or 11 boys and girls both have strong interest and confidence in their science abilities (Archer et al., 2010). Research also shows that as early as second grade, boys and girls have internalized stereotypes associating science and math with boys and reading with girls (Cvencek et al., 2011). During the middle school years, girls begin losing interest in science at a faster rate than boys (Blickenstaff, 2005; Chesler et al., 2010; Cundiff et al., 2013; Watt, Eccles, & Durik, 2006). Research also shows that by the age of 14, most individuals have developed the level of interest in science that will persist throughout their lifetime. This level of interest can also predict the individual's likelihood of pursuing STEM education and careers (Cvencek et al., 2011).

Taken from this vantage point, simply sustaining these early high levels of science affinities is an improvement over what the literature predicts will happen to most girls, a steady decline and turn away from STEM. Given the research design and short time frame between the pre- and post-camp measurements, it is impossible to say if the SPICE program is sustaining girls' interest in science. Would these girls have lost a measureable amount of science affinity in that two-week period without the SPICE program? Not likely. However, it is important to note that the mean scores for all four science affinities were all higher in the post-camp time frame. They were not statistically significantly higher, but if the change in scores was completely random and girls' science affinities were truly unchanging, it would be expected that some of the averages would be slightly lower. Again, these results were not statistically significant—however, given the high likelihood of type II error, there is a sliver of evidence that something is going on. There is enough to merit further study, even if there are no additional conclusions about the efficacy of the program at this time.

What SPICE girls' affinities and identity types have to say about girls in STEM. As figure 20 showed, not all of the themes that emerged from the analysis of SPICE girls' science affinities and identity types relates directly to the SPICE program (self-determination, proving oneself, differences in science interest by gender, and passive learning). This section will discuss SPICE girls' science affinities in terms of their science interactions and aspirations outside of camp and how the different science identities are predicted to interact with gender expectations in the classroom.

One key takeaway from this study is that SPICE girls did not demonstrate one monolithic "girl" science identity. SPICE girls shared a lot in their preferences and attitudes toward science, but they also showed evidence of very different styles of science engagement. Often, when addressing the issue of girls in STEM, educators, researchers, and policy-makers approach the issue as though there is one problem, a girl problem. If they could only tease out the magic formula for cracking how to get girls interested in science, then the problem would be solved. Even guidance like the SciGirls Seven, which is founded on a host of peer-reviewed research (Calabrese Barton & Brickhouse, 2006; Halpern, Aronson, et al., 2007; L. H. Parker & Rennie, 2002), presents these guides as a key to science engagement for all girls. The research presented here points to a fundamental flaw in this approach. SPICE girls show no fewer than four identities related to science (and by deduction a fifth nonscience identity, or identity by absence of identity). The identity archetypes share a great deal in common. They all are driven by curiosity and a fundamental interest in science; however, how and why they pursue science is different in important ways.

Will the SciGirls Seven and other best practice guides support all of the identity types found among SPICE girls? For the most part yes, though practitioners would be well served by understanding which guidelines apply best to which girls. Experts, with their high levels of academic motivation and craving for acknowledgment, might not be so keen on the collaboration at the core of guideline #1. They might also become frustrated with projects that are too open-ended (guide #2). Experimenters will revel in science activities that follow guides #3 and #4, but may need help framing their freeform experiments into something coherent. Too much reliance on their own critical thinking without a little imposed structure (guide #6) may lead to pointless goofing off. Inventors will highly value activities that relate back to their own personal interests in subjects they find meaningful and helpful to others (guide #2). They will also need a lot of support from mentors and role models (guide #7), as their areas of interest will lead them toward disciplines where mentors are few and far between. The identity archetypes throw into relief the flawed thinking that there is one way to do science with girls, and problematizes any simple fixes. Indeed, part of the problem in addressing the problem of girls in STEM is framing the problem as a “girl problem” rather than a cultural STEM problem.

Another question surfaces when thinking of girls' science affinities and identity types. Do not most of the results reported here also apply to boys? With the exception of the noted absences of gender-appropriate role models and gendered societal messages, it seems that middle-school-aged boys might articulate many of the same science affinities and identities reported by SPICE girls. It seems likely that boys would also enjoy hands-on activities, process-based feedback, and relatable role models. Failure and worry about the hard work involved in a science career might also frustrate boys. So what is the difference? The difference is in how science plays out in the classroom and day-to-day life for boys and girls.

The remainder of the discussion of results will focus on the ways in which SPICE girls' affinities are likely different from boys' and the ways in which the SPICE girl affinities that are likely similar to boys' might result in different outcomes by gender.

It has already been noted multiple times in this dissertation that girls are less likely to engage in hands-on science than boys and have fewer science opportunities than boys unless they express a strong early interest in science (Alexander et al., 2012). Girls also have fewer relatable roles models given the far lower participation of women in sciences. The low levels of role models for girls signals that science careers are not viable options for women (Buck et al., 2008; Riegle-Crumb & Moore, 2013). Boys have access to a wide range of popular male science icons and are more likely to have personal science role models in their lives. Additionally, SPICE girls' science efficacy seemed to be influenced by the presence of female friends who were interested in science. Again, boys are more likely to be able to find friends who are interested in science at the middle school age range. SPICE girls also worried about the personal costs of the hard work required for science. Young boys may not be enamored of hard work, but gendered expectations do not often lead men to worry that careers will be incompatible with their personal lives.

SPICE girls expressed a need to prove themselves in science careers. Several SPICE campers expressed the belief that in order to succeed in science they would have to be better than all the men. This is a dangerous belief for retaining women in STEM. As research has shown, women are harsher in their judgments of their ability in science than men (Correll, 2001) and are susceptible to fixed mindsets toward disciplines presented as requiring brilliance (Leslie, Cimpian, Meyers, et al., 2015). Girls who think they need to be better than all the boys are setting a very high bar. Instead of striving to be skilled and competent scientists, they are framing success in terms of perfection that will not only be difficult to obtain, but nearly impossible to measure in a meaningful way as they progress in science. Science careers become increasingly specialized and success becomes more and more subjective over time. History also shows that women are less likely to be acknowledged for their accomplishments in science, further contributing to almost certain disappointment for a female scientist who feels that she must be the best in order to succeed.

The preceding summarizes the way SPICE girls' science affinities are likely different from boys. The following considers each of the three science identity types and how gender expectations may undermine girls' development as scientists.

The expert believes in mastery and expertise. She strives to be excellent, values knowledge and skill, and craves recognition from her peers and mentors. Experts will do well in school science classes. Their drive and organization will help them earn good grades and the respect of their teachers. They are also likely to be good in a number of subjects. Teachers will direct the expert toward the most challenging math and science classes, where she will excel. The diminished acknowledgement she is likely to receive will be a constant sticking point for her. An expert who has female role models and friends who enjoy science will likely stick with the subject for some time. The expert who does not have models and peers will likely turn her identity work to one of the other disciplines in which she achieves and also receives recognition. Like Sheela, in the Brickhouse et al. (2000) study, the expert will be encouraged in science, but may not receive the kind of recognition and academic challenge she requires to build an enduring identity as a scientist. Male experts are more likely to receive praise for their accomplishments, have relatable peers and role models, and simply to perceive science, with its masculine culture, as the right place to be.

The experimenter is not worried about recognition or academic challenges. She wants to know what makes the world go around and she will pursue her interests with reckless abandon. She will be resilient to setbacks, and thrive when teachers and parents give her freedom to explore science in all of its messy glory. If she overcomes the academic hurdles, the experimenter will make the transition to research with much less trauma than many of her classmates and will dive into research with the same gusto and resilience she has displayed all along. Typically, the most academically motivated students (including experts) are the ones who make it all the way to graduate school in the sciences. The transition from course-taker to research apprentice takes a toll on many students who previously excelled. As they move from the structured world of coursework into research with its self-direction, dead ends, and seemingly endless failures, doubt often sets in (Lovitts, 2005). Unfortunately, most female experimenters will not make it anywhere near that far in STEM. Experimenters are messy, inquisitive, and pushy, not characteristics expected from (or often tolerated in) girls. Like Tanisha in the Brickhouse et al. (2000) study, the experimenter will likely prove problematic to teachers and parents, who may, with the best of intentions, seek to curb her wild enthusiasm in the interests of keeping things neat and tidy, and fostering proper manners. The mess and pushy enthusiasm of the male experimenter is more likely to be tolerated by authority figures, as it is in line with gender expectations for boys. If he sticks through the hard academic work, the male experimenter is likely to be welcomed into science and thrive.

The inventor has a purpose. She does not simply wish to be good at science, and she is not messing around. She is on a mission. She wants to do something amazing. Most likely, she wants to do something amazing for people, or with dolphins, or for adorable small fuzzy animals. If she sticks with the biological sciences, the inventor will probably do well in science. She may become a doctor, a biologist, or a veterinarian, and find her place with other women who have excelled in science. She will become part of the minority as a woman scientist as she climbs higher up the career ladder, but she will never be alone. Like the experimenter, she may be chided for tearing things apart, but she has drive, so she may carry on with the mild disapproval. If the inventor leans toward the physical sciences or engineering, as she is likely to do given her passion for creation, she will have a much harder time. Invention and creation are hard work and often complicated. She needs peers and role models to encourage her, and she is not likely to find them. Most girls of her type will gravitate toward the biological sciences, as these are both more consistent with gender stereotypes and rich with female peers and role models. The physical, computer science, or engineering inventor will be lonely and most likely eventually leave science for friendlier climates.

Boys of the inventing type will likely be cherished and encouraged by parents and teachers. They will find groups of other boys who love to tinker and share their passion in maker circles or online communities. They will be praised for their ingenuity and encouraged to tackle challenging tasks. With hard work and creativity, the male inventor has a wide world of options before him.

The scenarios presented above are, of course, generalizations. Each child will take his or her own path. Some girls will find wonderful mentors and succeed in male-dominated fields. Many boys will lose interest in science and move on to something else. However, gender will almost certainly play a part in the experiences and choices these young scientists make. How science identity archetypes play out with regards to science will be heavily influenced by gender, and the deck is stacked against girl scientists of all types.

Beyond STEM careers. As was discussed above, women are more likely to leave STEM education and careers altogether than their male counterparts (Hewlett et al., 2008; National Science Board, 2014b, 2014c, 2014d). Does that mean that they are no using STEM skills? One weakness of the data currently available about women in STEM and STEM careers more generally, is that not much is known about what women who leave STEM do afterwards and if their STEM training plays a part in their careers. What about general STEM literacy and engagement? One central goal of informal science education is to engage non-science practitioners in science as citizens (Bell et al., 2009). Science literacy is valuable for people in every day lives and in their roles as voters and community members.

Perhaps it is a misrepresentation to assume that all women who leave STEM education and careers are lost to STEM entirely simply because they are not employed in a STEM identified career. Women with STEM degrees may move into areas like law, where they participate in the STEM discourse and economy by facilitating transfer of intellectual property or helping to define rules and regulations around ethical STEM research. The vast majority of science journal editors (though not editorial board members) are women (Bernstein, 2015; Woolston, 2015). Though journal editing is not a STEM career, it is a crucial part of the dissemination of STEM knowledge and requires technical STEM skills. These *science adjacent* careers are potential areas where women can (and do) contribute to STEM but are not measured.

Programs like SPICE might facilitate girls pursuing science adjacent careers that engage directly or indirectly with the scientific community and facilitate scientific knowledge. One of the stated goals of the SPICE program is to, "empower a generation of scientifically literate citizens (Todd, 2013)." Measuring these outcomes is scientifically challenging. However, the SPICE girls offer some indication that even if they do not pursue STEM careers, they do value science in their real lives. SPICE camper Alexandria summed it up this way:

> I mean I'm going to have to use science a lot in my life, and I don't think that just having the right answers for the test is going to help. I guess I really just need to understand it and be able to utilize that skill.

Regardless of their ultimate careers, SPICE campers value the role science will play in their lives. This broader role of science is missing from the discussion of gender disparities and STEM. A better understanding of what women do when they leave STEM or how girls who enjoy science pick careers outside of science would be valuable information for outreach programs like SPICE.

SPICE and systemic STEM gender disparities. In an ideal world, or even nations like Iceland where ideas about gender and STEM are more egalitarian (OECD, 2015), a program like SPICE would not be necessary or even logical. Gender disparities in STEM, however, remain a problem in many nations. School systems are not providing boys and girls with equitable experiences, as is evidenced by differential outcomes. Programs like SPICE address the problem external to schools, and in a fashion, this “lets schools off the hook” for addressing disparities. Rather than relying on external solutions like SPICE, schools can use research from outreach programs as models for identifying and removing systemic barriers to STEM engagement.

SPICE girls’ science affinities and identities point to a number of ways in which schools are not properly supporting girls STEM development. SPICE girls cite a lack of hands-on science, few peers interested in science, lack of relatable role models, and a need to “prove” themselves better at science than boys. Furthermore, girls are attracted to the discovery and curiosity elements of science, express a strong preference for symbolic science role enactment, and desire to be trusted with more complex, risky activities. Notably, SPICE girls with the most positive outlooks and strongest science identities spoke of passionate enthusiastic teachers who supported student interests in science. Specific recommendations for educators are presented below, however, it is important to note, that SPICE girls affinities do point both to ways that schools are failing girls and achievable ways in which schools can remove obstacles and support the development of science identities in female students.

Limitations

Limitations of the study are substantial and include the research design, low statistical power, normality of data, issues with the sample, imputation of missing data, and inter-rater reliability.

Research design. The goals of this study were twofold. First, the study sought to gain a better understanding of the impacts of the SPICE program on girls' science affinities, and second, to build theory around how girls develop identities as scientists. In order to determine the impact SPICE has on girls with any level of certainty, an experimental research design with a control group, random assignment to condition, and pre- and post- measurements of both groups would be necessary. Without these elements, no causal claims can be made about changes in participants' science affinities.

A comparison group was available for the pre-camp condition, however there was no random assignment and no post-condition measurement for the comparison group. It cannot be stated with any confidence that changes in girls' science affinities were due in part or whole to the SPICE intervention.

Sample. This study presents multiple problems with regard to the sample. Sample size for the experimental group is low (n = 51), which presents a problem for statistical power. There is self-selection bias among the participants, which relates back to the research design. In addition to being small and self-selected, the sample population is demographically homogeneous. Lastly, small sample size limits generalizability of the findings.

One of the goals of this study was to develop new theory about girls' science identities and to provide evidence confirming or refuting existing theory about girls' science affinities. The results reported for girls' science affinities are largely consistent with the literature. However, the theory of girls' science identities presented in the results is new and thus, no large body of research exists to support the results. Without a larger, more representative sample or other confirmatory studies, the results reported here are highly tentative. The resutls may be very accurate for SPICE girls and others like them, however, it is impossible to say that the identity archetypes will match the science identities of girls from other regions, backgrounds, and experiences. SPICE girls, overall, are not just demographically homogenous, they represent a specific subset of girls who (generally) already highly enjoy and relate to science. They have adults in their lives signed them up for a science camp and they have shared the SPICE experience. These commonalities make them unique among girls in ways that narrow the generalizability of the findings. Only further study with multiple groups of (preferably more diverse) girls will confirm the viability of broader application of these theories.

Looking more critically at the purpose of the SPICE program and this research, the sample presents another problem. Are the girls served by SPICE camp the most appropriate for intervention? As the results show, SPICE girls come to the program with high science affinities. These are girls who already enjoy science and have people in their lives willing and able to sign them up for a science summer camp. What about girls who do not have the connections or support to learn about or attend the camp? What about girls who do not enjoy science? Would the potential impact of the program not be greater if the girls served were more at risk of STEM attrition?

First, serving girls already more likely to persist with STEM limits the generalizability of the study. Elements that appear effective with the group of girls studied here may not be engaging with girls who do not have such high baseline science affinities. Girls from different backgrounds may have very different science affinities or may be looking for different elements in engaging science.

Do the girls in the SPICE program really need more support in science? Is SPICE adding any benefit and is that benefit substantive or marginal? It may be that the girls in SPICE are already so inclined toward science that SPICE is not having an impact. Results of the focus groups and interviews, however, would suggest otherwise. While some girls had fairly extensive opportunities to engage with science outside of SPICE. Many girls stated that they did not have these opportunities and expressed a strong value for the hands-on learning provided by SPICE. Many SPICE girls also expressed a desire for more peers interested in science and relatable role models in science, both of which were provided by SPICE. It is important to note, the earnestness and/or frustration many girls exhibited when discussing the lack of peers and role models. These were serious concerns, even among these highly science-engaged girls.

Would the program have greater impacts with girls more at risk of STEM attrition? Anecdotally, in the 2014 study and the pilot study in 2013, three girls who originally expressed ambivalence toward science early in camp explicitly expressed improved attitudes toward science. Instructors reported one specific case of a student saying that SPICE camp had given her a new appreciation of science and she would be seeking out more STEM opportunities in the future.

Each year there are one or two girls attending SPICE who clearly do not want to be part of a science camp. Typically these girls attend because a parent has signed them up against their will and they have no where else to go. Occasionally, these girls show interest in specific activities, however, they do not show signs of developing positive science affinities. Sometimes these girls leave camp within the first week. Others complete the camp but do not return the next year.

These limited examples suggest that SPICE camp might be beneficial to girls who are undecided about science, or who might have had some negative science experiences, but have not developed an active dislike for STEM in general. Attracting girls on the edge of abandoning STEM as an area of engagement and interest might be a way to improve the impact of the program and retain more girls in STEM.

Statistical power. Prospective power analysis shows that the study is underpowered. The effect sizes (Cohen's *d*) calculated using the results of the *t*-tests ranged from .04 to .82. A minimum sample size of 156 was calculated to detect an effect size of .20 with alpha set to .05 and power of .8. Prospective power analysis showed that an effect size of .4 with alpha at .05 and power .8 would be detectible with a sample size as low as 78. This study is therefore highly susceptible to type II error. The results of the *t*-tests between the SPICE camper and SEP camper science affinities suggests that this is the case. Results of the comparisons of means between the two groups were all statistically significant. The effect sizes ranged between .11 and .82 with a sample size of 125. The comparisons of means within the SPICE camp group before and after camp yielded no statistically significant results with a sample size of 51. However, it is not possible to definitively say if the lack of significant effects detected was due to low power or a true lack of any change in camper science affinities.

As discussed in the results, ceiling effects may also be masking what would otherwise have been statistically significant main effects for scholarship status and years with the program. Simply increasing the sample size alone may not be enough to illuminate the true underlying relationships. It may also be necessary to reformulate the scales used in the science affinities factors to emphasize the higher end of the spectrum.

Self-selection bias and homogeneity. Girls attending SPICE camp are typically already highly interested in science and/or have strong parental support for science education. This was borne out by the comparison to the SEP participants, who had lower average science affinities. Selection bias impacts both generalizability of results to the large population of middle-school-aged girls and makes it more challenging to detect changes in preferences for science. Ideally, the study would include multiple years of data and have a control group of girls with a wider range of initial science engagement.

In terms of race, ethnicity, and socioeconomic status, the composition of SPICE participants was close to the demographics of the state and county. Oregon and Lane County are not diverse areas. SPICE campers are overwhelmingly white and from modest income families. The relative homogeneity of campers limits generalizability of the findings when examining more diverse populations.

Non-normal data. The science affinity scales for efficacy, attitudes, and identity showed signs of non-normality in the area of kurtosis, which violates the assumptions for parametric tests of statistical inference such as *t*-tests and multiple regression analysis. In the cases of the difference scores for efficacy and attitudes the kurtosis was not severe, just above the standard 2.0 cutoff. For the scale of change in science identities the kurtosis statistic was 4.34. Inspection of histograms showed that non-normality stemmed from a few outliers and a general clumping of the scores at the high end of the distribution. As has been noted before, SPICE campers have high starting science affinities. Nonparametric tests were employed in the comparisons of means and yielded the same results. Regression analysis has been shown to be fairly robust to violations of normality (Pedhazur, 1982). Examination of the residual plots and statistics measuring unduly influential cases did not reveal any problem cases. Some caution should be taken in interpreting the results of these analyses; however, non-normality is not likely a serious issue for the analyses reported in this dissertation.

Imputation of data. Data points were missing in eight SPICE camp cases and 12 SEP cases. Overall, 16% of SPICE cases contained some missing data. Of the cases with missing data 15 were missing only one or two items and five were missing three or more items. Items appear to have been missed through oversight, not through any systematic choice on the part of respondents. Missing data were imputed using mean scores, which is not an effective or desirable method for handling missing data (Donders, ven der Heijden, Stijnen, & Moons, 2006). However, given the small sample size, other methods were not an option. Imputing the mean reduces variability and biases standard errors downward. If campers were losing interest in science, imputing the mean would make it appear that their interest was sustained. Likewise, if they were gaining interest those results would be masked.

Inter-rater reliability. Inter-rater reliability scores all fell within the "excellent" range (Hallgren, 2012). However, overlap between raters was inconsistent. Two raters never shared observations and three other pairings shared only one observation. Lack of overlap between raters undermines confidence in the assessment of inter-rater reliability and diminishes the reliability of the fidelity rubrics in assessing implementation fidelity of the operationalized elements of identity, self-efficacy, and mindsets around which camp activities are built.

Reflection on limitations. The limitations of this study largely stem from research design and sample size. Ideally, this study would have employed a randomized controlled trial; however, such a design was not possible in this circumstance. The inclusion of a control group was dependent on the number of applicants to the program, which was not high enough to form a control group. Likewise, sample size is a function of the number of girls who have applied to the program. Repeating the study in future years and collecting longitudinal data will help correct for the issue of sample size. Likewise, as the program grows the inclusion of a control group will be possible, and in fact in the summer of 2015 a randomly assigned control group was achieved.

Issues of non-normal data and imputation of missing data can also be improved in future years. As the data set grows, non-normality will likely disappear and more sophisticated methods of data imputation that result in less bias can be employed. Mistakes were made in the data collection process for this study. More careful coordination with the SEP program would have yielded sufficient post-program data to include the SEP participants in the regression model, which would have increased sample size and statistical power. Likewise, more careful screening of survey responses at the time of submission would have permitted the researchers to collect the missing data from campers right away, thereby reducing overall missing data.

Generalizability is major flaw of the study. All the limitations discussed above ultimately make broad claims about the implications of the study problematic. Results of both the quantitative and qualitative analyses might be due to idiosyncrasies in the sample population that do not apply to girls more generally. Further study will help illuminate if these results are indeed indicative of girls' science affinities and identity archetypes, or if the study is highly specific to the participants.

Implications for Practice

SPICE is a specific and targeted program, however, SPICE girls science affinities and identities have implications for a broader range of settings. Implications for other outreach programs and formal classroom settings are discussed next. Recommendations for various stakeholders follow.

SPICE girls show evidence of a variety of identities and affinities; however, these affinities share common elements that are likely present in the wider population of middle and elementary school children. The elements of SPICE operationalized from the theories of identity, self-efficacy, and mindsets, could be adapted to other outreach programs. Where SPICE is more general in subject matter, often, outreach programs focus on a particular discipline or career area. This is most commonly the case with programs sponsored by professional organizations (ACS, 2015; APS, 2015; SWE, 2015). One advantage of the SPICE program emphasis on engagement and psychosocial development is the broader applicability of the techniques employed. SPICE has adapted a wide range of material across many disciplines over the years. It is the approach that has remained constant. Other programs can adapt the SPICE camp approach to their specific subject matter. SPICE girls science affinities support the use of hands-on activities, symbolic acts, relatable role models, and the presence of similar peers as important elements for engagement

Furthermore, girls' reflections on SPICE and classroom study suggest a number of improvements for classroom science curriculum delivery. Girls' engagement at SPICE camp is high. Girls directly attribute their engagement and interest in learning to the operationalized elements of hands-on science engagement, use of tools, language, and garb of science, access to relatable experts, and engaged peers. Though providing hands-on science in school classrooms can be challenging and cost more than textbooks and worksheets, the potential for increasing engagement by students traditionally disengaged in science class may outweigh the challenge. Some simple changes that could increase engagement in science classrooms could involve inviting diverse expert guests into the classroom, highlighting the accomplishments of underrepresented scientific trailblazers, discussing science careers, acknowledging the accomplishments of students, and engaging in process-based feedback and emphasizing hard work over innate talent. In cases where hands-on activities for all students are not possible, including students directly in front of the classroom demonstration would provide engaging vicarious learning opportunities, while signaling that students are both trusted and capable of conducting scientific experiments.

Taking into account the above limitations, this study does point to some possible ways in which parents and educators can better support girls in developing strong science identities. Recommendations for girls are also presented.

Recommendations for parents. SPICE girls who thought of themselves as scientists universally reported support from their parents. Interviews and focus groups also revealed ways in which parents supported girls. First and foremost, parents enrolled their daughters in a science camp. Beyond this, though, parents permitted girls to take home large, awkward pinball tables with wires sticking out them. Many parents attended the girls' presentations on the last day of camp. Girls spoke of parents helping them find devices to take apart, encouraging them to enroll in hard classes, and taking them to museums and workplaces where science was carried out. Based on girls' reports of parent support and their science affinities, the following are recommended for parents:

- Seek out science opportunities for daughters, and encourage their friends to join in as well. Coordinate with other parents to enroll groups of friends in programs, or host science activities at home.
- Talk about science career options and point out successful women in science. Let girls know that science is a viable area of study for girls.
- Let girls get messy with science.
- Invite daughters to join in on home repairs and automotive maintenance. Invite them into traditionally male domains of practical and scientific activities.

Recommendations for teachers and outreach programs. Teachers are often the first science role models girls encounter. SPICE girls report that teachers have a powerful impact on their interests in science, and yet, they often do not see their teachers as scientists.

- Teach through hands-on activities whenever possible.

- Share your passion for science with your students. Enthusiasm is contagious.
- Highlight your own scientific background and the experience you have as a scientist.
- Focus on a deep understanding in learning.
- Show your students you trust them as scientists by letting them try out more advanced activities.
- Try to support all types of science identities by recognizing student accomplishments, creating room to explore, and providing a supportive community of learners.
- Bring diverse experts into the classroom and identify diverse role models to students.

Recommendations for girls. Girls can and do advocate for themselves in science. Some ways girls can help their parents and teachers to be more supportive include:

- Let the adults in your life know how you learn best.
- Ask for more opportunities to engage with science.
- Explore, tinker, and investigate on your own. A screwdriver and a defunct electronic device can be a learning experience.
- Build a circle of friends who enjoy science and explore together.
- Abandon the notion that you have to be the best or better than others. Focus on enjoying science and learning new things.

Future Directions

Results of the study suggest two areas for future inquiry. First replication of the study in subsequent years with a control group, and improved science affinities measures will strengthen the findings and help clarify the relationship between scholarship status and years in the program. Second, collecting data from a broader sample of middle-school-aged children to further elaborate on the science archetypes described here will help determine if the archetypes are generalizable to the larger population.

Replication of the study with future years of SPICE campers will provide a larger data set with repeated measures. A longitudinal model with a control group and multiple years of data collection will strengthen causal inference and compensate for most of the limitations noted above (research design, sample size, statistical power, non-normal distribution of data). Repeated measures over several years would also provide the opportunity to track changes in girls' science affinities over time. Changing the scale of the science affinities items to include greater variance in at the high end of science affinities might reveal subtle changes in the affinities of already highly science-engaged girls.

The identity archetypes identified in this study might have possible applications for teachers, parents, and science outreach programs. Conducting interviews with a larger pool of students beyond the SPICE program would provide insight into identity types, perhaps revealing more archetypes, or modifying the archetypes identified here. Further research on these archetypes could also involve the development of instruments that measure characteristics that underlie the identities to confirm the theoretical constructs. Development of scales would help in identifying student preferences and priorities in science learning, which could guide instruction and mentoring. Developing such instruments with a larger population might identify more or different strains of scientific identities as well.

APPENDIX A

SPICE CAMP 2014 SCHEDULES

Discovery Camp Week 1				
	TUESDAY 7/8 **Scavenger Hunt**	WEDNESDAY 7/9 **Ballistics**	THURSDAY 7/10 **Hot and Cold**	FRIDAY 7/11 **Collections & Light**
9:30-10:20	Introduction	Black Box	Brain Waves	Plant collection/Tree Walk
10:20-11:10	Science Scavenger Hunt	Water Balloons	GAMES	Proscope Collection
11:20-12:00	Science Scavenger Hunt	Water Balloons	Cold and Density - Dry Ice Bubble	Lasers
12:00-1:00	Lunch	Lunch	Lunch	Lunch
1:00-2:20	Scavenger Hunt	Catapults	Freeze -BBQ	Light Spectra
2:20-3:10	Scavenger Hunt	Catapults	Freeze - BBQ	Light Spectra
3:10-4:00	Scrapbook	Scrapbook	Scrapbook	T-Shirts

Discovery Camp Week 2					
	MONDAY 7/14 **Aerodynamics**	TUESDAY 7/15 **Chemistry**	WEDNESDAY 7/16 **Fish & Bees**	THURSDAY 7/17 **Amazing Race**	FRIDAY 7/18 **Wrap Up**
9:30-10:20	Airplanes	Elephant's Toothpaste Ooblek	Urban Farm	Amazing Race	Slideshow
10:20-11:10	Egg Drop	Flubber	Bee Dance Barn game	Amazing Race	Slideshow
11:20-12:00	Egg Drop	Proscope	Sharks and Zebra Fish	Amazing Race	Cyclops Party T-shirt Signing
12:00-1:00	Lunch	Lunch	Lunch	Lunch	Lunch
1:00-2:20	Rockets	Creature Classification	Traits	Amazing Race	Presentation
2:20-3:10	Rockets	T-shirts	Life Cycle of A Plant	Amazing Race	Presentation
3:10-4:00	Scrapbook	Scrapbook	Bee making	Scrapbook	Ice Cream Party

Forensics Camp

Week 1

	TUESDAY 7/8 **Scavenger Hunt**	WEDNESDAY 7/9 **Ballistics**	THURSDAY 7/10 **Hot and Cold**	FRIDAY 7/11 **Collections & Light**
9:00-10:00	Intro/Safety	Witness Reliability	Accident Reconstruction “Tread Lightly”	Hair Analysis “Hairy Cat Capers”
10:00-11:00	Critical Thinking & Observation Mini-Mock Crime Scene	Fingerprint Analysis	Dental Analysis “Take a Bite Out of Crime”	Fiber Analysis "Picking Up The Pieces"
11:00-12:00	CSI: Fact or Fiction?			
Lunch				
1:00-2:00	Deductive Reasoning "The Deadly Picnic"	Toxicology	Impression Evidence "Casting for Evidence"	Pollen Analysis
2:00-3:00	Lie Detection - YouTube Video and "Two Truths and a Lie"		Stride Length Analysis Computer Lab Klamath B26	Flame Test
3:00-4:00	Graveyard Candy	Fingerprint Pendant Decoration		Mugshot Silhouettes

Forensics Camp

Week 2

	MONDAY 7/14 **Blood!**	TUESDAY 7/15 **Analysis**	WEDNESDAY 7/16 **Crime Scenes!**	THURSDAY 7/17 **Evidence**	THURSDAY 7/17 **Presentations**
9:00-10:00	Blood Detection	Handwriting Analysis	Evidence Gathering Preview	Evidence Processing Stations	Presentation Practice
10:00-11:00		DNA Extraction			
11:00-12:00	Blood Typing "The Case of the High Tech Lab"		Crime Scene Evidence Gathering		
Lunch					
1:00-2:00	Blood Drop Analysis "Cold Blood"	Chromatography	Witness Profiles Witness Interviews	Presentation Preparation	Last Minute Prep
2:00-3:00					Camp Presentations
3:00-4:00	Crime Scene Cookies	Decryption	Guess Who		

Engineering Camp

Week 1

<table>
<tr><th></th><th>TUESDAY 7/8</th><th>WEDNESDAY 7/9</th><th>THURSDAY 7/10</th><th>Friday 7/11</th></tr>
<tr><td>9:00-10:00</td><td>Introductions, icebreakers, PBJ robot.</td><td rowspan="3">LEDs, Transistors & Switches</td><td rowspan="3">RGB Mixer, IR Detectors with inputs</td><td rowspan="3">Jukebox: Shift Registers, LED Score Boards & Patterned Lights</td></tr>
<tr><td>10:00-11:00</td><td rowspan="2">Pinball Overview</td></tr>
<tr><td>11:00-12:00</td></tr>
<tr><td colspan="5">Lunch</td></tr>
<tr><td>1:00-2:00</td><td>Brainstorming</td><td>Reset button and drain mini project</td><td rowspan="3">Mechanical Elements – flipper, launcher & custom Elements</td><td rowspan="2">Scoreboard and Patterned light mini Project</td></tr>
<tr><td>2:00-3:00</td><td rowspan="2">Blair Alley Field trip</td><td rowspan="2">Draft Proposal/Mechanics Proposal</td></tr>
<tr><td>3:00-4:00</td><td>Revisit skeleton Program</td></tr>
</table>

Engineering Camp

Week 2

	MONDAY 7/14	TUESDAY 7/15	WEDNESDAY 7/16	THURSDAY 7/17	THURSDAY 7/17
9:00-10:00 10:00-11:00 11:00-12:00	CD Drive Dismantling/Motor Extraction	Electronic Prototyping & Programming	Electronic Prototyping & Programming	Final Assembly & Programming Consultation	Arcade Prep
Lunch					
1:00-2:00	Blue Prints, Flipper & Launcher building	Proposal Updates/Building	Electronic Assembly	Decoration and Presentation Prep	Arcade Prep
2:00-3:00 3:00-4:00					Final Presentations

APPENDIX B

THE SPICE PROGRAM

The SPICE Intervention

The Science Program to Inspire Creativity and Excellence (SPICE) is a cohort-based, university-run science outreach program targeting middle school girls. The goal of the program is to encourage more young girls to pursue science, technology, engineering, and mathematics (STEM) education and careers. The program was founded in 2008 as a pilot summer camp supported by the Oregon Center for Optics at the University of Oregon. The pilot camp included 15 participants (8 female, 7 male) ages 11 to 16 recruited through newspaper advertisements and the informal social networks of participating faculty and staff. Recruiting efforts focused on targeting female participants. Activities focused on optical science and included a mixture of simple activities using household supplies and more advanced projects in the UO undergraduate optics laboratory.

In 2009 the program received funds from the Office of Equity and Inclusion to support expanding the camp to include academic year activities in addition to the summer program. The program was refocused to specifically girls ages 11 and up. Seventeen girls were recruited for the 2009 camp, which also focused on optical science. The program was popular with participants, many of who requested to return to the program for the following year. Camp offerings were expanded into a cohort-based program in 2010. The 2009 participants returned to a new crime scene investigation themed camp and a new cohort was recruited into the optics camp.

In 2011, a third camp with an engineering focus was added. The age range of participants was adjusted to girls entering 6th, 7th, and 8th grades. The introductory camp was renamed the Discovery camp and designated for rising 6th grade girls. The second camp was renamed the Forensic Investigation camp and designated for rising 7th graders. The third camp was named Engineering camp and designated for rising 8th graders. In 2012 a computer science element was added to the Engineering camp and the name was changed to the Engineering and Computer Science camp. The program name was officially changed to SPICE in 2011.

SPICE provides outreach activities and summer camps built on the principles of identity formation, utilizing relatable near-peer mentors (Singh, 2010), positive reinforcement, and hands-on, student-centered activities. The program is cohort-based with students progressing to a new camp each summer as a group. Campers are admitted to the program in summer following the 5th grade academic year and attend the Discovery Camp. They return the following summer to attend the Forensic Investigation camp and the summer after that they attend the Computer Science and Engineering camp. All three camps run for two weeks concurrently in the month of July from 9 a.m. to 4 p.m. The 2014 Camp ran from July 8 to 18. Wrap-around care was available before and after camp to accommodate working parents. Appendix A includes complete schedules for all three 2014 camps.

Discovery camp. The first camp combines activities from a variety of disciplines (e.g., physics, biology, optics, and chemistry) with a focus on data collection and analysis. Campers spend the first day on a science scavenger hunt, travelling in small groups to a number of sites on the University of Oregon campus to complete tasks and collect data. Activities include identifying and measuring relative campus tree circumferences using improvised measuring tools (arms, hands, and feet), calculating average travel times of rubber duck toys from the top of the Cascade Charlie waterfall to the fountain basin through repeated trials, and using maps and clues to locate headstones in the pioneer graveyard. Campers are required to collect and compile data using multiple measurements and to compute averages. Data are then reported to instructors who supply clues to a larger puzzle based on the accuracy of camper data. The more accurate the camper reports are, the more data they receive for the final puzzle. At the end of the day, the campers come together to pool their data and solve a final logic puzzle.

Each day of camp has a theme, such as ballistics, heat and density, biological discovery, and all about waves. Campers participate in four to six self-contained activities around the theme of the day. Throughout the day, participants document their activities in lab notebooks for use at the end of the camp. On the penultimate day campers apply what they learned previously to complete the Amazing Science Race. Small teams (2–3 campers) engage in a series of challenges based on the previous activities. Race activities take place around campus and require campers to use skills and data they collected throughout the week to complete each challenge and earn prizes.

Forensic Investigation camp. Forensics camp focuses on activities that help the girls to piece together events that occur before scientists arrive on scene. Events may be mass extinctions that took place millions of years ago or a lab accident that took place the night before. Activities focus on analytical techniques for explaining mysteries including activities in the areas of geology and paleontology, neuroscience, chemistry, and taxonomy.

For the Forensics camp capstone project, teams of 4 to 5 campers solve a mini mystery. Past mysteries have included simulated thefts, murders, archeological excavations, and vandalism. Campers collect evidence from the crime scene, interview witnesses, analyze evidence—using techniques learned earlier in the camp—and create a presentation of their findings.

Engineering and Computer Science camp. The final camp combines simple mechanical engineering principles along with elementary coding exercises. Students complete a series of small activities such as writing code that controls sensors and building devices using simple machines. Final projects build on the smaller activities to produce a larger device. Past final projects have included Rube Goldberg Machines and working pinball tables.

In 2013 and 2014, campers built fully functional pinball machines. Completing the pinball machines required campers to plan the machine design as a group, build the machine frames, construct obstacles, and wire and program electronic components. Campers are required to submit drawings, specifications, and supply lists to the camp instructors at each phase of construction. The final machines include all the requisite mechanical components (launchers, flippers, and obstacles) as well as sensors and programming that keep score and track the number of "lives" the player has remaining.

Presentations. Instructors and campers document activities throughout the two weeks using tablets, scrapbooks, and lab notebooks. On the last day of camp, all three groups come together to share out what they learned. Parents and friends are invited in the afternoon to watch the camper presentations. The Discovery campers put together slideshows that present their favorite activities from the Amazing Science Race. The

Forensics campers build electronic “murder boards” using presentation software and walk the audience through the mystery they solved earlier in the week. An element of drama is added by having the individuals who role-played as witnesses to the crime attend the presentation. The campers then “arrest” the guilty party in front of the audience. After presentations from the first two camps, parents, instructors, and campers move into the arcade where the Engineering campers demonstrate their functioning pinball machines, while everyone enjoys liquid nitrogen ice cream made by camp staff.

APPENDIX C

RESULTS FROM PREVIOUS RESEARCH

Results from Previous Research

In the summer of 2013, the author conducted a pilot study of SPICE camper science attitudes and career preferences. Study subjects included 53 6th, 7th, and 8th graders attending the SPICE summer camps. Measurements were taken on the first day of camp, near the end of camp, and again several months later. Research activities that campers participated in included an implicit association test (IAT) of the relationship between gender and science (Greenwald, McGhee, & Schwartz, 1998; Greenwald, Nosek, & Banaji, 2003; B.A. Nosek et al., 2002), a booklet of matched study/career preferences, and a focus group discussions of science attitudes. Additionally, parents completed two questionnaires about their child's engagement with science.

Results of the pilot study show that the girls who attended SPICE camp have stronger associations of women with science than national averages as reported by Project Implicit (B. A. Nosek et al., 2009). National data show that 72% percent of respondents associate science slightly to strongly with males, 18% have no automatic preference between gender and science, 9% associate science slightly to moderately with females, and only 1% associate science strongly with women. SPICE camper responses were more normally distributed with 38% of girls associating science slightly or moderately with males, 27% have no association of science with gender, and 35% associate science slightly or moderately with females. No SPICE campers associated science strongly with either gender. Figure 21 shows the data graphically.

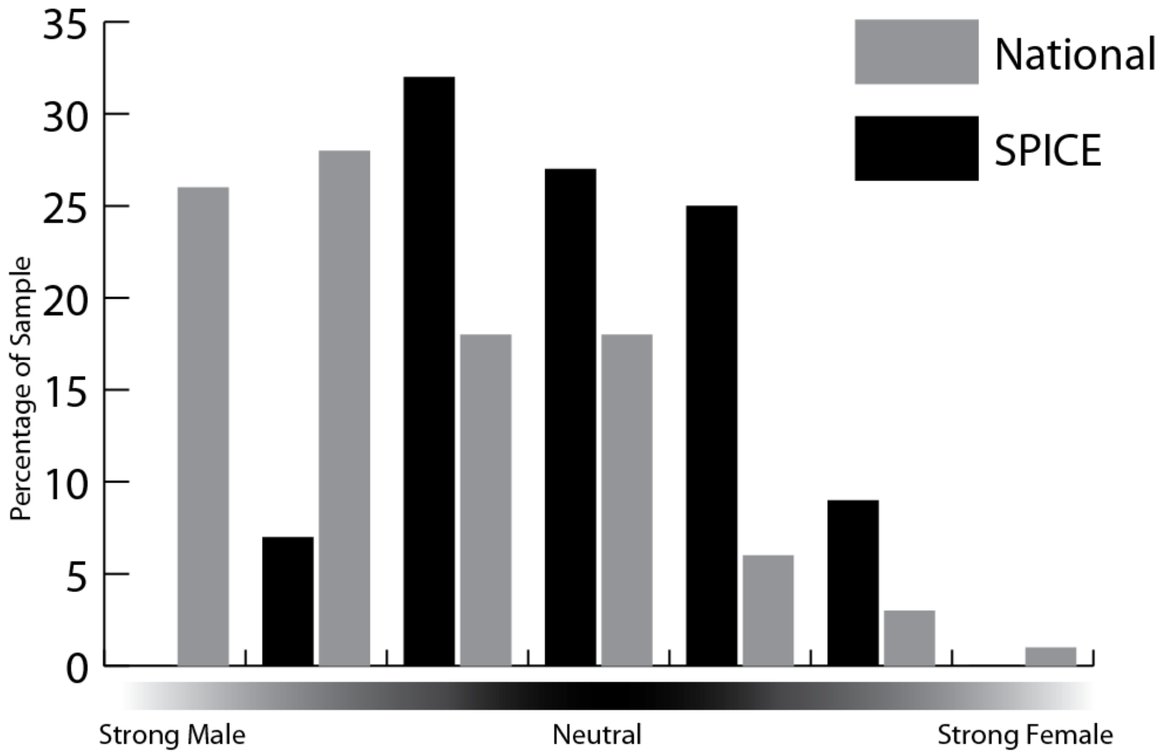


Figure 21. SPICE camper implicit associations of science and gender as compared to large national data set of responses to the Project Implicit test of Gender and Science (Nosek et al., 2009).

The majority (43 of 47) of SPICE participants reported moderately or highly enjoying science. In surveys the 36 of 47 (77%) reported feeling supported in their interest in science, and 38 of 47 (81%) campers selected “agree” to “strongly agree” with the statement, “I think of myself as a scientist.” Campers also expressed preferences for science careers over nonscience careers both through their responses to the career preference booklets and in statements during focus group conversations. These data suggest that SPICE participants are already highly engaged with and interested in science when they arrive at camp.

In the focus group conversation, SPICE girls were highly critical of how science is presented in school and emphasized the importance of inspiring, passionate science teachers in encouraging them to enjoy STEM. They were also aware of the underrepresentation of women in science and the social messages that science is not for girls. Campers respond enthusiastically to the diverse mentors and role models they encounter in camp, voluntarily comparing SPICE instructors to their schoolteachers and citing ways in which SPICE instructors were interesting science role models.

SPICE girls participating in the pilot study also displayed nuanced but compartmentalized views of science. They drew distinct boundaries between the science they do at school and that done at SPICE camp. In focus group discussions they consistently expressed a desire for school science that was more hands-on, conceptual, and related to their lives and interests.

Many girls resisted claiming identities as scientists, but endorsed science and exhibited characteristics of nascent science identities. Three types, or flavors, of nascent science identities emerged from their responses to questions about science identity. The first theme focused on the informal, exploratory aspects of science. Girls expressing the exploratory science identity emphasized the importance of friends and peers who also identified as "nerds" or "geeks." The second flavor focused on the creative and inventive aspects of science. Girls in the creative category were interested in science careers that involved the creation of new technology or knowledge. SPICE participants also expressed strong interest in doing science that helps other people. The last group identified as scientists in training. For girls with the creative type, it was important to demonstrate skill as scientists and to gain the approval of science mentors.

The implications of the findings of the pilot study for this proposal are threefold:

- Girls entering the SPICE program already enjoy and relate to science.

- Girls have different associations and identities with regard to science that emphasize different aspects of scientific inquiry (exploration, creativity, mastery).
- Girls crave relatable role models as a means of boosting confidence and feeling welcomed into the culture of science.

APPENDIX D

SUMMER ENRICHMENT PROGRAM 2015 SCHEDULE

Week 1						
Sunday	Monday **A Classes**	Tuesday **B Classes**	Wednesday **A classes**	Thursday **B Classes**	Friday **A & B Classes**	Saturday August
Welcome!	Breakfast and Morning Announcements 7-7:50 am					
Check-in Students Arrive Parent Orientation Reception 2:00-3:00 pm Orientation and Campus Tour Welcome BBQ Dinner 5:00-6:30 pm	**Period 1-** 8-9:50 am				**Period 1A** 8-8:50 am	Floor Game Time 9:00-12:00pm
	Red, White, and Blue		Verlan Francais			
	Contemporary Dance		Anthropology of Movement			
	*How to Blow Things Up		Activism, Human Rights, and Gender		**Period 1B** 9-9:50 am	
	Who gets the Money		*Alien Abductions			
	Period 2-10-11:00 am					
	*Monster Hunting 101		*Tangled Webs: Science in Literature		**Period 2A** 10-11 am	
	Body and Mind Wellness		Stand and Deliver: Improv			
	Trekking Through Italy		Grimm Reality: Fairy Tales			
	Undercover Scientist: Ethnography		Tribal Oregon			
	Lunch 11:00-11:50 am					
	Period 2 12:00-12:50 pm				**Period 2B** 12-12:50 pm	Saturday Market 1:00-4:30 pm
	Period 3 1:00-2:50 pm					
	*Combinatorics		Dance Improv & Choreography		**Period 3A** 1-1:50 pm	
	Food in Italian Cinema		Ritual, Festival, Humor, and Chaos			
	Movie Musicals		Theatrical Production &Design		**Period 3B** 2-2:50 pm	
	*Not-So-Fictional Sci-Fi		Big Brother is Watching			
	Floor Meeting 3-3:30 pm					
	Open Recreation 3:30-5:30 pm					
	Outdoor BBQ 5-6:30 pm		Dinner 5 pm-6:30 pm			
	Dorm Floor Night		Special Events		Staff Follies	Costume Dance

<table>
<tr><th colspan="7">Week 2</th></tr>
<tr><th>Sunday</th><th>Monday
A Classes</th><th>Tuesday
B Classes</th><th>Wednesday
A classes</th><th>Thursday
B Classes</th><th>Friday
A & B Classes</th><th>Saturday</th></tr>
<tr><td colspan="7">Breakfast and Morning Announcements 7-7:50 am</td></tr>
<tr><td rowspan="21">Parent Visitation Day!

Dinner
5-6:30 pm

Camp Movie Night
6:45-8:45 pm</td><td colspan="4">Period 1- 8-9:50 am</td><td rowspan="3">Period 1A
8-8:50 am</td><td rowspan="21">Parent Pick Up</td></tr>
<tr><td colspan="2">Red, White, and Blue</td><td colspan="2">Verlan Francais</td></tr>
<tr><td colspan="2">Contemporary Dance</td><td colspan="2">Anthropology of Movement</td></tr>
<tr><td colspan="2">How to Blow Things Up</td><td colspan="2">Activism, Human Rights, and Gender</td><td rowspan="3">Period 1B 9-9:50 am</td></tr>
<tr><td colspan="2">Who gets the Money</td><td colspan="2">Alien Abductions</td></tr>
<tr><td colspan="4">Period 2-10-11:00 am</td></tr>
<tr><td colspan="2">Monster Hunting 101</td><td colspan="2">Tangled Webs: Science in Literature</td><td rowspan="4">Period 2A 10-11 am</td></tr>
<tr><td colspan="2">Body and Mind Wellness</td><td colspan="2">Stand and Deliver: Improv</td></tr>
<tr><td colspan="2">Trekking Through Italy</td><td colspan="2">Grimm Reality: Fairy Tales</td></tr>
<tr><td colspan="2">Undercover Scientist: Ethnography</td><td colspan="2">Tribal Oregon</td></tr>
<tr><td colspan="5">Lunch 11:00-11:50 am</td></tr>
<tr><td colspan="4">Period 2 12:00-12:50 pm</td><td rowspan="2">Period 2B 12-12:50 pm</td></tr>
<tr><td colspan="4">Period 3 1:00-2:50 pm</td></tr>
<tr><td colspan="2">Combinatorics</td><td colspan="2">Dance Improv & Choreography</td><td rowspan="2">Period 3A 1-1:50 pm</td></tr>
<tr><td colspan="2">Food in Italian Cinema</td><td colspan="2">Ritual, Festival, Humor, and Chaos</td></tr>
<tr><td colspan="2">Movie Musicals</td><td colspan="2">Theatrical Production &Design</td><td rowspan="2">Period 3B 2-2:50 pm</td></tr>
<tr><td colspan="2">Not-So-Fictional Sci-Fi</td><td colspan="2">Big Brother is Watching</td></tr>
<tr><td colspan="5">Floor Meeting 3-3:30 pm</td></tr>
<tr><td colspan="5">Open Recreation 3:30-5:30 pm</td></tr>
<tr><td colspan="2">Outdoor BBQ
5-6:30 pm</td><td colspan="3">Dinner
5 pm-6:30 pm</td></tr>
<tr><td colspan="2">Photo Scavenger Hunt
6:45-8:45</td><td colspan="2">Special Events
6:45-8:45</td><td>Graduation & Dance</td></tr>
</table>

APPENDIX E

PARENT SURVEY

1) What, if any, SPICE activities has your child participated in in the last 12 months?

- ☐ SPICE Summer Camp - June 2013
- ☐ SLUG Queen Contest/Eugene Celebration Parade – August/September 2013
- ☐ UO Science Open House – September 2013
- ☐ Girls Science Adventure – Egg Drop – April 2014
- ☐ Girls Rule event at LCC – DNA Extraction Workshop – March 2014
- ☐ Science Project Development Workshops (at school) -2014
- ☐ Science Project Development Workshop (at UO) - 2014
- ☐ UO Science and Invention Fair
- ☐ Girls Science After School Club at Roosevelt Middle School
- ☐ Monster Genetics Workshop at Springfield Library – May 22, 2014
- ☐ Waves and Light – Adoptive Parent's Association Meeting – May 19th, 2014
- ☐ Under the Microscope/El dia de los ninos at the Springfield Library – April 26th, 2014
- ☐ Other SPICE or Science on Demand Event

2) What if any other science enrichment opportunities has your child participated in in the last 12 months?

- ☐ Meet a Scientist at the Science Factory
- ☐ Girls Science Adventure with the Science Factory (other than Egg Drop)
  Number of workshops attended _______
- ☐ Workshops/Camps at the Science Factory
  Number of days participated ________
- ☐ Workshops/Camps at the UO Museum of Natural and Cultural History
  Number of days participated ________
- ☐ Workshops/Camps at Nearby Nature
  Number of days participated ________
- ☐ Other science related workshops/camps
  Program name: _________________________
  Number of days participated ________
- ☐ Visits to science museums or exhibits (Science Factory/OMSI/etc)
  Number of visits ________
- ☐ After school clubs
  How often? ______________
- ☐ Other science related clubs
  How often? _____________
- ☐ Other (describe)

3) What other forms of science enrichment does you child regularly view/participate in?

- ☐ TV shows like Mythbusters, Sid the Science Kid, NOVA, or National Geographic Programs?
  How many days a week does your child watch shows like these? ___________

- ☐ Web sites like How Stuff Works, Bill Nye the Science Guy, Steve Spangler Science and others?
  How many days a week does your child visit sites like these? ____________

- ☐ Watch science videos on YouTube and other sites?
  How many days a week does your child watch science videos? __________

- ☐ Play science board games, video games, science toys or other?
  How many days a week does your child play science? ___________

- ☐ Other?
  How many days a week? __________

4) Please select which best describes your child.

	Strongly Disagree	Disagree	Agree	Strongly Agree
My child enjoys studying science in school	☐	☐	☐	☐
My child enjoys guided science activities outside of school	☐	☐	☐	☐
My child does science activities on her own	☐	☐	☐	☐
My child is encouraged to do science by teachers	☐	☐	☐	☐
My child is encouraged to do science by friends and family	☐	☐	☐	☐
My child is confident in her science abilities	☐	☐	☐	☐
My child identifies as a scientist	☐	☐	☐	☐

APPENDIX F

SCIENCE AFFINITY SCALES

Scales from Pilot Study	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
My teachers encourage me to do science	1	2	3	4	5
My family and friends encourage me to do science	1	2	3	4	5
I am good at science	1	2	3	4	5
I think of myself as a scientist	1	2	3	4	5

Colorado Learning Attitudes about Science Survey

Personal Interest Scale	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I think about the science I experience in everyday life	1	2	3	4	5
I am not satisfied until I understand why something works the way it does	1	2	3	4	5
I study science to learn knowledge that will be useful in my life outside of school	1	2	3	4	5
I enjoy solving science problems	1	2	3	4	5
Learning science changes my ideas about how the world works	1	2	3	4	5
Reasoning skills used to understand science can be useful in my everyday life.	1	2	3	4	5

Other Scales

Self-Concept of Ability	Not Very Good	Not Good	Neutral	Good	Very Good
How good at science are you?	1	2	3	4	5
If you were to rank all the students in your science class from the worst to the best in science, where would you put yourself?	1	2	3	4	5
Compared to most of your other school subjects, how good are you at math [science]?	1	2	3	4	5

Task Value

	Not Very Imp.	Not Imp.	Neutral	Imp.	Very Imp.
How important is it that you learn science?	1	2	3	4	5
How interesting is science to you?	1	2	3	4	5
How important do you think math [science] will be to you in the future?	1	2	3	4	5

Attitudes Toward Science

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Science is Fun	1	2	3	4	5
I do not like science and it bothers me to have to study it.	1	2	3	4	5
During science class, I usually am interested	1	2	3	4	5
I would like to learn more about science.	1	2	3	4	5
If I knew I would never got to science class again, I would fee sad.	1	2	3	4	5
Science is interesting to me and I enjoy it.	1	2	3	4	5
Science makes me feel uncomfortable, restless, irritable, and impatient.	1	2	3	4	5
Science is fascinating and fun	1	2	3	4	5
The feeling that I have towards science is a good feeling.	1	2	3	4	5
When I hear the word science, I have a feeling of dislike.	1	2	3	4	5
Science is a topic which I enjoy studying.	1	2	3	4	5
I feel at ease with science and I like it very much.	1	2	3	4	5
I feel a definite positive reaction to science.	1	2	3	4	5
Science is boring.	1	2	3	4	5

APPENDIX G

FOCUS GROUP SCRIPT

Focus Group

What do you think of when you think of scientists?

Do you personally know any scientists outside of camp? Who?

What do you think it's like to be a scientist?

Is it hard?

Is it fun?

Has meeting the your teachers here at camp who are scientists changed any ideas you have about scientists?

How?

How do you feel when you are doing science activities? At camp? At school? Somewhere else?

What does it mean to be a scientist?

What does it take to be considered a scientist?

Who decides if you are a scientist?

Do you think of yourselves as scientists?

What do you think you would like about being a scientist?

What do you think you would <u>not</u> like about being a scientist?

Do you think you would enjoy being a scientist?

Do you think you would be a good scientist?

What do you think makes a good scientist?

Thinking back on your experiences with science, what experiences (if any) made you feel the most like a scientist?

Which (if any) discouraged your from wanting to do science?

APPENDIX H

INTERVIEW SCRIPT

Interview Script

<<I am doing research on how girls think about science and what they like and don't like about science. I want to talk with you about your thoughts about science. You can skip any question you don't want to answer and you can ask me questions at any time.>>

General Activities and Interests

What are your favorite activities or hobbies or other things you like to do for fun (doesn't have to be science)?

What about XX activities is interesting to you?

How important is it to you to be good at activities that interest you?

How important is it to you to share those activities with others?

How important is it to you to get feedback and/or praise for activities you enjoy?

Does anyone else in your family have an interesting hobby, like your parents or siblings?

What kinds of toys or stuff do you play with at home?

Do you ever help your parents or other adults in doing chores around the house or in the community that involve technical skill like, fixing a broken lamp, working on a car, or home repairs?

Do you participate in any clubs or extra activities at school?

Which ones?

What are those like?

What, if any, sorts of science activities do you participate in outside of school?

Do you enjoy those activities?

What do you like/not like about them?

(If any, ask about activities, also ask who initiated activity – parents, camper, other)

School Interests

What are your favorite subjects at school?

What about those subjects do you like?

How important is it to you to be knowledgeable about the subjects you like at school?

How important is it to you to get good grades in the subjects you like?

Do you ever seek out extra information about the school subjects you like on your own time, or try to do activities related to those subjects outside of school? (books, youtube videos, Wikipedia, etc)

What electives have you/do you plan to take in middle school?

In your science classes at school, what kinds of activities do you do?

Is there an activity or project in science that really sticks out in your memory?

What about it did you like/dislike?

If you could get your school to offer a class or program or project with a science theme, what would it be? Why is that interesting to you?

Which do you think is more important to you when you're doing science:

Being good at/understanding science well

Getting good grades

Having fun while you are doing it?

Science Interests

How would you describe your feelings toward science?

What kinds of science (or technology and math) are you most interested in?

What makes you interested in science?

What kind of science activities do you like to do?

What about those activities do you like?

Because it's new/novel/something you didn't know?

Or do you find it useful?

Or you are good at it?

Have you ever searched/or Googled about science you were curious about on your own?

Or Have you ever tried some scientific activities that you did at school or camps at your home by yourself?

What science activities that you don't do now would you do if you had the chance?

What kinds of science activities do you not like to do?

What do you think would make science (in or out of school) more interesting to you?

Have your feelings toward science changed over time? How?

Science Perceptions

What do you think of when you think of science?

Do your ideas about science come from personal experience?

If not, where do they come from?

What do you think of when you think of scientists?

Do your ideas about scientists come from personal experience?

If not, where do they come from?

Do you think of scientists as someone like you?

How are you like/unlink scientists?

Do you think of yourself as some one who is good at science?

What does it mean to you to be good at science?

Better understanding?

Better grades?

Success in experimentation?

Do theses things matter to you when you pursue science?

How would other people who know you, like your friends, teachers and parents describe your interest and skill in science?

How important is it to you for the people in your life (friends, family, teachers) to encourage you to do science?

Do people in your life encourage you to do science?

Has anyone ever discouraged you in science? What happened?

Science and Peers

How do your friends and classmates feel about science?

Do you and your friends do science together?

If yes, what sorts of science do you do?

Do you ever pretend not to like science?

Do many girls you know like science?

Do many boys you know like science?

Have you noticed if more girls or boys like science?

Why do you think that is?

Have you ever decided not to do a science activity you were interested in because no other girls were participating?

Science Intentions

What science classes do you plan to take in middle/high school?

Do you plan to take more than just the required courses in science?

Do you plan to take more than just the required courses in math?

What kind of job do you want to do when you grow up?

Have you considered a job in science?

What do you think makes a good job?

What do you think a job in science would be like?

Would you be comfortable doing a job without many other women around?

Do you plan to go to college or some other kind of school/training after high school?

What do you want to study there?

What do you think has most impact on your pursuing science/doing science?

Your personal interest?

Encouragement from people around you?

Because you think it's useful?

To get better grades at all subject?

Because you are good at it?

Or any external resources or information (Media, textbook..) saying science is important?

Conclusion

Is there anything else I should know about you and science?

Do you have any questions for us?

APPENDIX I

CODE BOOK DEVELOPMENT

Initial Codes—Book 1

Fidelity
Attitudes Toward Science
Disparities
Girls
Ideas about Science
Math
Scientists
Stereotypes
Women and Science
Engagement
Perceptions by Others
SPICE Camp
Identity
Enjoying Science
School
Understanding Science
Teachers
Parents
Careers

Thematically Organized Codes—Book 2

Attitudes & Stereotypes
- Attitudes Toward Science
- Change in Attitude
- Collaboration in Science
- Disparities
- Feelings About Science
- Girls
- Gross
- Hard Work
- Ideas about Science
- Knowledgeable
- Math
- Safety
- Scientists
- Stereotypes
- Women and Science

Fidelity
- Camper Engagement
- Camper Interactions
- Teachers

Learning
- Academics

Memorable Quotes

Perception by Others

SPICE Camp

Identity & Self-Efficacy
- *Confidence and Self-Esteem*
  - Enjoying Science
  - Frustration-Failure
  - Intentions
  - Interest in Science
  - Leadership
  - Mentoring
  - Perception of Self
  - Traits
- *Experience & Mastery*
  - Engagement
  - Experimentation
  - Figuring Out-Creativity
  - Hands-on
  - Independent Activities
  - Other Science Learning
  - Passive Learning
  - School
  - Understanding-Mastery
- *Feedback & Social Persuasion*
  - Friends & Peers
  - Mentors
  - Parents
  - Pressure
  - Role Models
  - Teachers
- *Identity*
- *Vicarious Learning*
  - Sharing Science

Final Code Book—Book 3

Fidelity

Attributes & Other Codes
- Memorable Quotes
- Interviewer
- Perceptions by Others
- Observation
- SPICE Camp

Attitudes & Stereotypes
- Attitudes Toward Science
- Collaboration in Science
- Gender & Disparities
- Gross
- Hard Work & Persistence
- Knowledgeable
- Math
- Safety
- Scientists
- Self-Determination
- Stereotypes

Identity & Self-Efficacy
- *Confidence and Self-Esteem*
  - Enjoying Science
  - Frustration-Failure
  - Intentions
  - Interest in Science
  - Perception of Self
- *Experience & Mastery*
  - Academics
  - Bored-Engaged
  - Discovery
  - Experimentation
  - Figuring Out-Creativity
  - Hands-on vs Passive
  - Independent Activities
  - Learning
  - Other Science Learning
  - School
  - Understanding-Mastery
- *Feedback & Social Persuasion*
  - Enc/Discourage
  - Friends & Peers
  - Mentors & Role Models
  - Parents
  - Pressure
  - Recognition
  - Teachers
- *Identity*
- *Vicarious Learning*
  - Exclusion
  - Sharing Science
  - Teamwork

REFERENCES CITED

Abdi, H. (2010). Holm's sequential Bonferroni procedure. In N. Salkind (Ed.), *Encylopedia of Research Design* (pp. 8). Thousand Oaks, CA: SAGE.

ACS. (2015) American Chemical Society: Community Outreach. Retrieved from http://www.acs.org/content/acs/en/education/outreach.html

Adams, W. K., Perkins, K. K., Podolefsky, N. S., Dubson, M., Finkelstein, N. D., & Wieman, C. E. (2006). New instrument for measuring student beliefs about physics and learning physics: The Colorado Learning Attitudes about Science Survey. *Physical Review Special Topics-Physics Education Research, 2*(1). Retrieved from <Go to ISI>://WOS:000204838600001

Ahlqvist, S., London, B., & Rosenthal, L. (2013). Unstable identity compatibility how gender rejection sensitivity undermines the success of women in science, technology, engineering, and mathematics fields. *Psychological Science, 24*(9), 1644-1652. Retrieved from <Go to ISI>://WOS:000324403000004

Alexander, J. M., Johnson, K. E., & Kelley, K. (2012). Longitudinal Analysis of the Relations Between Opportunities to Learn About Science and the Development of Interests Related to Science. *Science Education, 96*(5), 763–786.

Alper, J. (1993). The pipeline is leaking women all the way along. *Science, 260*(5106), 409–411.

Ambady, N., Shih, M., Kim, A., & Pittinsky, T. (2001). Stereotype susceptibility in children: Effects of identity activation on quantitative performance. *Psychological Science, 12*(5), 385–390.

American Academy for the Advancement of Science. (2013). Women's international science.

Andrew, T., Whigham, M., Hendrickson, A., & Chambers, S. (1999). Competency Beliefs, Positive Affect, and Gender Stereotypes of Elementary Students and Their Parents about Science versus Other School Subjects. *Journal of Research in Science Teaching, 36*(6), 719–747.

APS (2015) American Physical Society: Physics outreach. Retrieved from http://www.aps.org/programs/outreach/

Archer, L., Dewitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2010). "Doing" science versus "Being" a scientist: Examining 10/11-year-old schoolchildren's constructions of science through the lens of identity. *Science Education, 94*(4), 617-639. Retrieved from <Go to ISI>://000278957200002

Archer, L., Dewitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2012). “Balancing acts”: Elementary school girls’ negotiations of femininity, achievement, and science. *Science Education, 80*(1), 967–989.

Archer, L., Dewitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2013). 'Not girly, not sexy, not glamorous': primary school girls' and parents' constructions of science aspirations. *Pedagogy, Culture & Society, 21*(1), 171–194.

Armstrong, R. (2014). When to use the Bonferroni correction. *Ophthalmic & Physiological Optics, 34*, 502–508.

August, L., & Waltman, J. (2004). Culture, climate, and contribution: Career satisfaction among female faculty. *Research in Higher Education, 45*(2), 177–192. Retrieved from <Go to ISI>://000222616800004

Baker, D., Krause, S., Yasar, S., Roberts, C., & Robinson-Kurpius, S. (2007). An intervention to address gender issues in a course on design, engineering, and technology for science educators. *Journal of Engineering Education, 96*(3), 213–226.

Bandura, A. (1976). *Social Learning Theory* (1 ed.). Upper Saddle River, NJ: Prentice Hall.

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review, 84*(2), 191–215.

Bandura, A. (1997a). *Self-efficacy in changing societies*. Cambridge, MA: Cambridge University Press.

Bandura, A. (1997b). *Self-efficacy: The exercise of control*. New York, NY: W.H. Freeman and Company.

Bandura, A., Ross, D., & Ross, S. (1961). Transmission of aggression through the imitation of agressive models. *Journal of Abnormal and Social Psychology, 63*, 575–582.

Barbera, J., Adams, W. K., Wieman, C. E., & Perkins, K. K. (2008). Modifying and validating the Colorado learning attitudes about science survey for use in chemistry. *Chemical Education Research, 85*(10), 1435–1439.

Barton, A. C. (1997). Liberatory Science Education: Weaving Connections Between Feminist Theory and Science Education. *Teaching Journal, 27*(2), 141–163.

Barton, A. C., & Osborne, M. D. (2001). Marginalized discourses and pedagogies: Constructively confronting science fo all in classroom practice. *Counterpoints, 150*, 7–32.

Battle, A., & Wigfield, A. (2003). College women's value orientations toward family, career, and graduate school. *Journal of Vocational Behavior, 62*(1), 56–75. Retrieved from <Go to ISI>://WOS:000182021600005

Baumeister, R., Bratslavsky, E., Finkenauer, C., & Vohs, K. (2001). Bad is stronger than good. *Review of General Psychology, 5*(4), 323–370.

Bayer Corporation. (2010). *Bayer facts of science education XIV: Female and minority chemists and chemical engineers speak about diversity and underrepresentation in STEM*. Retrieved from http://bayerfactsofscience.online-pressroom.com/

Bell, P., Lewenstein, B., Shouse, A. W., & Feder, M. A. (2009). *Learning science in informal environments*. Washington, D.C.: The National Academies Press.

Benson, N. (2003). Erick Erikson's theory of identity development *Psychology: A graphic guide* (4th ed.). Cambridge, UK: totem Books.

Bergen, D. (2002). The role of pretend play in children's cognitive development. *Early Childhood Research & Practice, 4*(1), 13.

Bernstein, R. (2015). PLOS ONE ousts reviewer, editor after sexist peer-review storm. *ScienceInsider*.

Betz, N. E., & Hackett, G. (1981). The relationship of career-related self-efficacy expectations to perceived career options in college women and men. *Journal of Counseling Psychology, 28*(5), 399–410.

Bianchini, J., Johnston, C., Oram, S., & Cavazos, L. (2003). Learning to teach science in contemporary and equitable ways: The successes and struggles of first-year science teachers. *Science Education, 87*(3), 419–443.

Billington, B., Britsch, B., Karl, R., Carter, S., Freese, J., & Regalla, L. (2014). *SciGirls Seven: How to engage girls in STEM*. Retrieved from

Blank, R., Langesen, D., & Petermann, A. (2007). *State Indicators of Science and Mathematics Education: Appendicies*. Retrieved from Washington, DC:

Blickenstaff, J. C. (2005). Women and science careers: Leaky pipeline or gender filter? *Gender and Education, 17*(4), 369–386. Retrieved from <Go to ISI>://000230456500002

Bloom, B. (1976). *Human characteristics of school learning*. New York, NY: McGraw-Hill.

Blumenfeld, P., Marx, R., Patrick, H., Krajcik, H., & Soloway, E. (1997). Teaching for understanding. In I. h. o. t. a. teaching (Ed.), *International handbook of of teachers and teaching* (Vol. 2, pp. 819–878). Dordrecht: The Netherlands: Kluwer.

Blustein, D., Devenis, L., & Kidney, B. (1989). Relationship between the identity formation process and career development. *Journal of Counseling Psychology, 36*(2), 196–202.

Brainard, S. G., & Carlin, L. (1998). A six-year longitudinal study of undergraduate women in engineering and science. *Journal of Engineering Education, 87*, 369–375.

Bransford, J., Brown, A., & Cocking, R. (2000). *How*

People Learn: Brain, Mind, Experience, and School: National Academy Press.

Brickhouse, N. W. (1998). Femism(s) and science education. In K. Tobin & B. Fraser (Eds.), *International handbook of science education* (pp. 1067–1082). New York, NY: Kluwer.

Brickhouse, N. W. (2001). Embodying science: A feminist perspective on learning. *Journal of Research in Science Teaching, 38*(3), 282–295. Retrieved from <Go to ISI>://000167159800002

Brickhouse, N. W., Lowery, P., & Schultz, K. (2000). What kind of a girl does science? The construction of school science identities. *Journal of Research in Science Teaching, 37*(5), 441–458. Retrieved from <Go to ISI>://000086819000004

Brones, A. (2013). 5 Women scientists whose amazing discoveries were stolen by a man. Retrieved from http://news.nationalgeographic.com/news/2013/13/130519-women-scientists-overlooked-dna-history-science/

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. Retrieved from <Go to ISI>://000260589600001

Buchmann, C., Diprete, T., & McDaniel, A. (2007). *Gender Inequalities in Education*. Retrieved from New York: NY:

Buck, G. A., Plano Clark, V. L., Leslie-Pelecky, D., Lu, Y., & Cerda-Lizarrage, P. (2008). Examining the Cognitive Processes Used by Adolescent Girls and Women Scientists in Identifying Science Role Models: A Feminist Approach. *Science Education, 92*(4), 21.

Burning Glass. (2014). *Real-time insight into the market for entry-level STEM jobs*. Retrieved from

Byrne, E. (1993). *Women and science: The snark syndrome*. London: Falmer Press.

Calabrese Barton, A., & Brickhouse, N. W. (2006). Engaging girls in science. In C. Skelton, B. Fracis, & L. Smulyan (Eds.), *The SAGE Handbook of Gender and Education*. London: Sage.

Carlone, H. (2004). The cultural production of science in reform-based physics: Girls' access, participation, and resistance. *Journal of Research in Science Teaching, 41*(4), 392–414.

Carrell, S. E., Page, M. E., & West, J. E. (2010). Sex and science: How professor gender perpetuates the gender gap. *Quarterly Journal of Economics, 125*(3), 1101–1144. Retrieved from <Go to ISI>://000281353500006

Chambers, D. W. (2006). Stereotypic Images of the scientist: The draw a scientist test. *Science Education, 67*(2), 255–265.

Chen, X., & Soldner, M. (2013). *STEM Attrition: College students' paths into and out of STEM fields*. Retrieved from Washington, D.C.:

Chesler, N., Barabino, G., Bhatia, S., & Richards-Kortum, R. (2010). The pipeline still leaks and more than you think: A status report on gender diversity in biomedical engineering. *Annals of Biomedical Engineering, 38*(5), 1928–1935. doi:DOI 10.1007/s10439-010-9958-9

Christidou, V. (2011). Interest, attitudes and images related to science: Combining students' voices with the voices of school Science, teachers, and popular science. *International Journal of Environmental & Science Education, 6*(2), 141–159.

Cicchetti, D. (1994). Guidelines, criteria, and rules of thumb for evaluating normed and standardized

assessment instruments in psychology. *Psychological Assessment, 6*(4), 284–290.

CollegeBoard. (2014). *The 10th annual AP report to the nation*. Retrieved from

Colvin, W., Lyden, S., & Leon de la Barra, B. (2013). Attracting girls to civil engineering through hands-on activities that reveal the communal goals and values of the profession. *Leadership and Management in Engineering, 13*(1), 35–41.

Corbett, C., & Hill, C. (2015). *Solving the equations: The variables for women's success in engineering and computing*. Retrieved from Washington, DC:

Corbett, C., Hill, C., & St. Rose, A. (2008). *Where the girls are: The facts about gender equity in education*. Retrieved from Washington, D.C.:

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

Correll, S. J. (2004). Constraints into preferences: Gender, status, and emerging career aspirations. *American Sociological Review, 69*(1), 93–113.

Côté, J. E., & Levine, C. G. (2002). *Identity, Formation, Agency, and Culture: A Social Psychological Synthesis [*Mahwah, N.J.: Psychology Press.

Crowley, K., Callanan, M. A., Tenenbaum, H. R., & Allen, E. (2001). Parents explain more often to boys than to girls during shared scientific thinking. *Psychological Science, 12*(3), 258–261. Retrieved from <Go to ISI>://000169288000014

Cundiff, J. L., Vescio, T. K., Loken, E., & Lo, L. (2013). Do gender-science stereotypes predict science identification and science career aspirations among undergraduate science majors? *Social Psychology of Education, 16*(4), 541–554. Retrieved from <Go to ISI>://WOS:000328264200001

Cvencek, D., Meltzoff, A., & Greenwald, A. (2011). Math-gender stereotypes in elementary school children. *Child Development, 82*(3), 766–779. doi:DOI 10.1111/j.1467-8624.2010.01529.x

Dawson, C. (2000). Upper primary boys' and girls' interests in science: have they changed since 1980?,. *International Journal of Science Education, 22*(6), 557–570.

DeBoer, G. E. (1991). *A history of ideas in science education: Implications for practice*. New York, NY: Teachers College Press.

DeNeef, A. (2002). *The preparing future faculty program: what difference does it make?* Retrieved from Washington, DC:

Devine, P. G., Forscher, P. S., Austin, A. J., & Cox, W. T. L. (2012). Long-term reduction in implict race bias: A prejudice habit-breaking intevention. *Journal of Experimental Social Psychology, 48*(5), 1267–1278.

DiStefano, C., Zhu, M., & Mindrila, D. (2009). Understanding and using factor scores: Consideration for the applied researcher. *Practical Assessment, Research & Evaluation, 14*(20), 11.

Donders, A., van der Heijden, G., Stijnen, T., & Moons, K. (2006). Review: A gentle introduction to imputation of missing values. *Journal of Clinical Epidemiology, 59*(10), 1087–1091.

Dougherty, C., Mellor, L., & Jian, S. (2006). *The relationship between Advanced Placement and college graduation*. Retrieved from

Duffy, J., Warren, K., & Walsh, M. (2001). Classroom interactions: Gender of teacher, gender of student, and classroom subject. *Sex Roles, 45.9*(10), 579–593.

Dukeshire, E. (2014). How I came to study, teach, and love science.

Duschl, R., Schweingruber, H., & Shouse, A. (2007). *Taking science to school: Learning and teaching science in grades K-8*. Washington, DC: The National Academies Press.

Dweck, C. S. (2006). Is math a gift? Beliefs that put females at risk. In S. J. Ceci & W. M. Williams (Eds.), *Why aren't moe women in science? Top researchers debate the evidence* (pp. 47–55). Washington, D.C.: American Psychological Association.

Dweck, C. S. (2007). *Mindset: The new psychology of success*. New York, NY: Ballantine Books.

Dweck, C. S. (2008). *Mindsets and Math/Science Achievement*. Retrieved from New York, NY:

Eccles, J., & Blumenfeld, P. (1985). Classroom experiences and student gender: Are there differences and do they matter. In L. Wilkinson & C. Marrett (Eds.), *Gender influences in classroom interaction* (pp. 79–114). New York, NY: Academic Press Inc.

Eccles, J. S., Adler, T., & Meece, J. L. (1984). Sex differences in achievement: A test of alternate theories. *Journal of Personality and Social Psychology, 46*, 26–43.

Eccles, J. S., & Wigfield, A. (1995). In the Mind of the Actor - the Structure of Adolescents Achievement Task Values and Expectancy-Related Beliefs. *Personality and Social Psychology Bulletin, 21*(3), 215–225. Retrieved from <Go to ISI>://WOS:A1995QH31200003

Eisenhart, M. (2008). *We can’t get there from here: High school girls consider engineering*. Paper presented at the Presentation for a Women in Engineering ProActive Network (WEPAN) national webcast.

Ellis, P. D. (2010). *The essential guide to effect sizes: Statistical power, meta-analysis, and the interpretation of research results*. Cambridge, MA: Cambridge University Press.

Else-Quest, N. M., Mineo, C. C., & Higgins, A. (2013). Math and science attitudes and achievement at the intersection of gender and ethnicity. *Psychology of Women Quarterly, 37*(3), 293–309. Retrieved from <Go to ISI>://WOS:000329574900002

Erikson, E. (1968). *Identity, youth and crisis*. Oxford: W.W. Norton & Company.

Espinoza, L. L. (2011). Pipelines and pathways: Women of color in undergraduate STEM majors and the college experiences that contribute to persistence. *Harvard Educational Review, 81*(2), 209–240.

Evans, M. A., & Whigham, M. (1995). The effect of a role model project upon the attitudes of ninth-grade science students. *Journal of Research in Science Teaching, 32*(2), 195–204.

Falk, J. H., Storksdieck, M., & Dierking, L. D. (2007). Investigating public science interest and understanding: evidence for the importance of free-choice learning. *Public Understanding of Science, 16*(4), 455–469. Retrieved from <Go to ISI>://000250624200006

Farenga, S. J., & Joyce, B. A. (1999). Intentions of young students to enroll in science courses in the future: An examination of gender differences. *Science Education, 83*(1), 55–76.

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*(2), 175–191.

Fencl, H., & Scheel, K. (2006). Making sens of retention: An examiniation of undergraduate women's participation in physics courses. In J. M. Bystydzienski & S. R. Bird (Eds.), *Removing barriers: Women in academic science, technology, engineering and mathematics* (pp. 287–302). Bloomington, IN: Indiana University Press.

Fenichel, M., & Schweingruber, H. (2010). *Surrounded by science: Learning science in informal environments.* Washington, DC: National Research Council.

Fensham, P., & Harlen, W. (1999). School science and public understanding of science. *International Journal of Science Education, 21*(7), 755–763.

Ferrieira, M. (2001). Building Communities Through Role Models, Mentors, and Hands-on Science. *School Community Journal, 11*(2), 27–38.

Files, J. A., Blair, J. E., Mayer, A. P., & Ko, M. G. (2008). Facilitated peer mentorship: A pilot program for academic advancement of female medical faculty. *Journal of Womens Health, 17*(6), 1009–1015. Retrieved from <Go to ISI>://000258897000014

Fouad, N. A., & Guillen, A. (2006). Outcome expectations: Looking to the past and potential future. *Journal of Career Assessment, 14*(1), 130–142. Retrieved from <Go to ISI>://000235060800008

Fouad, N. A., & Smith, P. L. (1996). A test of a social cognitive model for middle school students: Math and science. *Journal of Counseling Psychology, 43*(3), 338–346. Retrieved from <Go to ISI>://A1996UY34600011

Fredricks, J. A., & Eccles, J. S. (2002). Children's competence and value beliefs from childhood through adolescence: Growth trajectories in two male-sex-typed domains. *Developmental Psychology, 38*, 519–533.

Gandara, P. (2001). *Paving the way to postsecondary education: K-12 intervention programs for underrepresented youth*. Retrieved from Washington, D.C.:

Gandara, P. (2006). Strengthening the academic pipeline leader to careers in math, science, and technology for latino students. *Journal of Hispanic Higher Education, 5*(3), 222–237.

Geiser, S., & Santelices, V. (2004). *The Role Of Advanced Placement And Honors Courses In College Admissions*. Retrieved from

Gennep, A. V. (1909). *The rites of passage*. Chicago: Chicago University Press.

Germann, P. J. (1988). Development of the attitude toward science in school assessment and its use to investigate the relationship between science achievement and attitude toward science in school. *Journal of Research in Science Teaching, 25*(8), 689–703.

Gibbs, G. (2011). *Analyzing Qualitative Data*. Thousand Oaks, CA: SAGE.

Gilbert, J. (2001). Science and its 'other': Looking underneath 'woman' and 'science' for new directions in research on gender and science education. *Gender and Education, 13*(3), 291–305.

Gilbert, J., & Calvert, S. (2003). Challenging accepted wisdom: Looking at the gender and science education question through a difference lens. *International Journal of Science Education, 25*(7), 861–878.

Glass, J. L., Sassler, S., Levitte, Y., & Michelmore, K. M. (2013). What's so special about STEM? A comparison of women's retention in STEM and professional occupations. *Social Forces, 92*(2), 723–756.

Gleim, J., & Gliem, R. (2003). *Calculating, interpreting, and reporting Cronbach's alpha reliability coefficient for Likert-type scales*. Paper presented at the Midwest research to practice conference in adult, continuing, and community education, Columbus, OH.

Good, C., Aronson, J., & Harder, J. A. (2008). Problems in the pipeline: Sterotype threat and women's achievement in high-level math courses. *Journal of Applied Developmental Psychology, 29*(1), 17–28.

Greenwald, A. G., McGhee, D. E., & Schwartz, J. L. K. (1998). Measuring individual differences in implicit cognition: The implicit association test. *Journal of Personality and Social Psychology, 74*(6), 1464–1480.

Greenwald, A. G., Nosek, B. A., & Banaji, M. R. (2003). Understanding and using the implicit association test: I. An improved scoring algorithm. *Journal of Personality and Social Psychology, 85*(2), 197–216.

Hackett, G., & Betz, N. E. (1989). An exploration of the mathematics self-efficacy/mathematics performance correspondence. *Journal for Research in Mathematics Education, 20*(3), 261–273.

Hallgren, K. (2012). Computing Inter-Rater Reliability for Observational Data: An Overview and Tutorial. *Tutorial Quantitative Methods for Psychology, 8*(1), 23–34.

Halpern, D. F., Aronson, J., Reimer, N., Simpkins, S., Star, J. R., & Wentzel, K. (2007). *Encouraging girls in math and science*. Retrieved from Washington, DC:

Halpern, D. F., Benbow, C. P., Geary, D. C., Gur, R. C., Hyde, J. S., & Gernsbacker, M. A. (2007). The science of sex differences in science and mathematics. *Psychological Science in the Public Interest, 8*(1), 1–51.

Halvorson, H. G. (2011). The trouble with bright girls. Retrieved from https://www.psychologytoday.com/blog/the-science-success/201101/the-trouble-bright-girls

Haraway, D. (1991). *Simians, cyborgs, and women: The reinvention of nature*. New York, NY: Routledge.

Harding, S. (1991). *Whose science? Whose knowledge? Thinking from women's lives*. Ithaca, NY: Cornell University Press.

Haslette, B. B., & Lipman, S. (1997). Micro inequities: Up close and personal. In N. V. Benokraitis (Ed.), *Subtle sexism: Current practice and prospects for change*. Sage Publications, Inc.: Thousand Oaks, CA.

Hattie, J. (2003). *Teachers make a difference: what is the research evidence?* Retrieved from Melbourne:

Haussler, P., & Hoffman, L. (2002). An Intervention Study to Enhance Girls' Interest, Self-Concept, and Achievement in Physics Classes. *Journal of Research in Science Teaching, 39*(9), 870–888.

Hazari, Z., & Potvin, G. (2005). Views on Female Under-Representation in Physics: Retraining Women or Reinventing Physics? *Electronic Journal of Science Education, 10*(1), 33.

Hazari, Z., Sonnert, G., Sadler, P., & Shanahan, M. (2010). Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: A gender study. *Journal of Research in Science Teaching, 47*(8), 978–1003. doi:DOI 10.1002/tea.20363

Hessling, R., Traxel, N., & Schmidt, T. (2004). Ceiling Effect. In M. Lewis-Beck, A. Bryman & T. Lia (Eds.), *Encyclopedia of Social Science Research Methods* (pp. 1528). Thousand Oaks, CA: SAGE.

Hewlett, S. A., Buck Luce, C., Servon, L. J., Sherbin, L., shiller, P., Sosnovich, E., & Sumberg, K. (2008). *The Athena factor: Reversign the brain drain in science, engineering and technology*. Retrieved from Boston:

Hill, C., Corbett, C., & St.Rose, A. (2010). *Why so few? Women in science, technology, engineering and mathematics*. Retrieved from Washington, D.C.:

Holmes, M. (2011). Does gender bias influence awards given by societies. *Eos, Transactions American Geophysical Union, 92*(47), 421–422.

Holmes, R. (2010, 20 November 2010). The Royal Societie's lost women. *The Observer*. Retrieved from http://www.guardian.co.uk/science/2010/nov/21/royal-society-lost-women-scientists

Horn, M. L. (1997). *Girls in science: The effect role models have on student interest.* (Masters of Education), University of Lethbridge, Lethbridge, Alberta.

Howes, E. (1998). Connecting girls and science: A feminist teacher research study of a high school prenatal testing unit. *Journal of Research in Science Teaching, 35*(8), 877–896.

Howes, E. (2002). *Connecting girls and science: Constructivism, feminism, and science education reform*. New York, NY: Teachers College Press.

Huttenlocher, P. R. (2009). *Neural plasticity*. Cambridge, MA: Harvard University Press.

Hyde, J. S. (1996). Meta-analysis and the psychology of gender differences. In B. Laslett, S. G. Kohlstedt, H. Longino, & E. Hammonds (Eds.), *Gender and scientific authority* (pp. 450). Chicago, IL: University of Chicago Press.

Hyun, T. E. (2014). *Middle school girls: Perceptions and experiences with robotics.* (Ph.D.), California University, Fullerton, CA.

Ing, M., Aschbacher, P., & Tsai, S. M. (2014). Gender differences in the consistency of middle school students' interests in engineering and science careers. *Journal of Pre-College Engineering Education Research, 4*(2), 1010.

Jayaratne, T. E., Thomas, N. G., & Trautmann, M. (2003). Intervention program to keep girls in the science pipeline: Outcome differences by ethnic status. *Journal of Research in Science Teaching, 40*(4), 393–414.

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

Jones, M. G., & Wheatley, J. (1990). Gender differences in teacher-student interactions in science classrooms. *Journal of Research in Science Teaching, 27*(9), 861–874.

Jones, S. M., & Dindia, K. (2004). A meta-analytic perspective on sex equity in the classroom. *Review of Educational Research, 74*(4), 443–471.

Jovanovic, J., & King, S. S. (1998). Boys and girls in the performance-based science classroom: Who's doing the performing? *American Educational Research Journal, 35*(3), 477–496. Retrieved from <Go to ISI>://000076547900005

Kaku, M. (2010). A Brief History of Sexism in Science (video).

Kanter, R. M. (1977). Some effects of proportions on group life - Skewed sex-ratios and responses to token women. *American Journal of Sociology, 82*(5), 965–990. Retrieved from <Go to ISI>://A1977DA15400002

Kelly, A. (1981). *The missing half: Girls and science education*. Manchester, UK: Manchester University Press.

Kerpelman, J. L., Pittman, J. F., & Lamke, L. K. (1997). Toward a microprocess perspective on adolescent identity development. *Journal of Adolescent Research, 12*(3), 325–346.

Kitts, K. (2009). The paradox of middle and high school students' attitudes towards science versus their attitudes about science as a career. *Journal of Geoscience Education, 57*(2), 159–164.

Kleinman, S. S. (1998). Overview of feminist perspectives on the ideology of science. *Journal of Research in Science Teaching, 35*(8), 837–844.

Klofpenstein, K., & Kathleen, T. M. (2009). A link between advanced placement experience and early college success. *Southern Economic Journal, 75*(3), 873–891.

Kulis, S., Sicotte, D., & Collins, S. (2002). More than a pipeline problem: Labor supply constraints and gender stratification across academic science disciplines. *Research in Higher Education, 43*(6), 657–691.

Lagoke, B., Jegede, O., & Oyebanji, P. (1997). Towards and elminiation of the gender gulf in science concept attainment through the use of environmental analogs. *International Journal of Science Education, 19*(4), 365–380.

Laursen, S., Liston, C., Thiry, H., & Graf, J. (2007). What good is a scientist in the classroom? Participant outcomes and program design features for a short-duration science outreach intervention in K-12 classrooms. *CBE Life Science Education, 6*(1), 49–64.

Lavy, V., & Sand, E. (2015). *On the origins of gender human capital gaps: Short and long term consequences of teachers' stereotypical biases*. Retrieved from

Leaper, C., Farkas, T., & Spears Brown, C. (2012). Adolescent girls' experiences and gender-related beliefs in relation to their motivation in math/science and English. *Journal of Youth and Adolescence, 41*(3), 268–282.

Lee, J. A. (2008). Gender equity issues in technology education: A qualitative approach to uncovering barriers. 326.

Leslie, S.-J., Cimpian, A., Meyer, M., & Freeland, E. (2015). Expectations of brilliance underlie gender distributions across academic disciplines. *Science, 347*(6219), 262–265.

Leslie, S.-J., Cimpian, A., Meyers, M., & Feeland, E. (2015). Expectations of brilliance underlie gender distribution across academic disciplines. *Nature, 347*(6219), 262–265.

Lewis, C. J. (2012). *I need to see you to be you: examining the relevance of role modeling on female STEM career choice.* (M.A.), California State University, Sacramento, Sacramento, CA.

Lincoln, A., Pincus, S., Koster, J., & Leboy, P. (2012). The Matilda effect in science: Awards and prizes in the United States, 1990 and 2000s. *Social Studies of Science, 42*(2), 307–320.

Longino, H. (1990). *Science as social knowledge: Values and objectivity in science inquiry*. Princeton, NJ: Princeton University Press.

Lovitts, B. E. (2005). Being a good course-taker is not enough: a theoretical perspective on the transition to independent research. *Studies in Higher Education, 30*(2), 137–154. Retrieved from <Go to ISI>://000227676300003

Low, K. S. D., Yoon, M., Roberts, B. W., & Rounds, J. (2005). The stability of vocational interests from early adolescence to middle adulthood: A quantitative review of longitudinal studies. *Psychological Bulletin, 131*(5), 713–737.

Lubinksi, D., & Benbow, C. P. (2006). Study of mathematically precocious youth after 35 years: Uncovering antecedents for the development of math-science expertise. *Perspectives on Psychological Science, 1*(4), 316–319.

MacDonald, T. L. (2000). *Junior high female role model intervention improves science persistence and attitudes in girls over time.* Paper presented at the Proceedings of the 8th CCWESTT Conference, St. John's, NF.

Malone, K. R., & Barabino, G. (2009). Narrations of race in STEM research settings: Identity formation and its discontents. *Science Education, 93*(3), 485–510. Retrieved from <Go to ISI>://000265327400004

Maltese, A. V., & Tai, R. H. (2011). Pipeline persistence: Examining the association of educational experience with earned degrees in STEM among U.S. students. *Science Education Policy, 95*(5), 877–907.

Maranto, C. L., & Griffin, A. E. C. (2011). The antecedents of a 'chilly climate' for women faculty in higher education. *Human Relations, 64*(2), 139–159. Retrieved from <Go to ISI>://000287803200001

Marcia, J. (1966). Development and validation of ego-identity status. *Journal of Personality and Social Psychology, 3*(5), 551–558.

Markowitz, L., & Puchner, L. (2014). Troubling the ontological bubble: Middle school students challenging gender stereotypes. *Journal of Gender Studies*, 1–14. doi:http://dx.doi.org/10.1080/09589236.2014.987657

Marschke, R., Laursen, S., McCarl Nielsen, J., & Rankin, P. (2007). Demographic inertia revisited: An immodest proposal to achieve equitable gender representation among faculty in higher education. *Journal of Higher Education, 78*(1), 1–27.

Mastern, A. (2001). Ordinary magic: Resilience processes in development. *American Psychologist, 56*, 227–238.

Matsui, T., Mastsui, K., & Ohnishi, R. (1990). Mechanism underlying math self-efficacy learning of college students. *Journal of Vocational Behavior, 37*(225–238), 225.

Mattern, N., & Schau, C. (2002). Gender differences in science attitude-achievement relationships over time among white middle-school students. *Journal of Research in Science Teaching, 39*(4), 324–340. doi:DOI 10.1002/tea.10024

McGinnis, J., & Pearsall, M. (1998). Teaching elementary science methods to women: A male professor's experience from two perspectives. *Journal of Research in Science Teaching, 35*(8), 919–949.

McKinney, K. (2010). Identity formation *Corsini Encyclopedia of Psychology* (pp. 1–2).

Merolla, D. M., & Serpe, R. T. (2013). STEM enrichment programs and graduate school matriculation: the role of science identity salience. *Social Psychology of Education, 16*(4), 575–597. Retrieved from <Go to ISI>://WOS:000328264200003

Merriam, S. (2009). *Qualitative research: A guide to design and implementation* (3rd ed.). San Francisco, CA: Jossey-Bass.

Milam, J. (2012). *Girls and STEM education: A Literature Review*. Georgia Institute of Technology. Atlanta, GA.

Miles, M., Huberman, A., & Saldaña, J. (2015). *Qualitative data analysis: A methods sourcebook* (3rd ed.): Sage Publications, Inc.

Miller, P. H., Blessing, J. S., & Schwartz, S. (2006). Gender differences in high-school students' views about science. *International Journal of Science Education, 28*(4), 363–381. Retrieved from <Go to ISI>://000234121000003

Minnesota State Colleges and Universities. (2015). Science, Technology, Engineering, and Math (STEM) Careers: Which STEM careers are in demand? Retrieved from http://www.iseek.org/careers/stemcareers

Modi, K., Schoenberg, J., & Salmond, K. (2012). *Generation STEM: What girls say about science, technology, engineering, and math*. Retrieved from New York, NY:

Munro, M., & Elsom, D. (2000). *Choosing science at 16: The influences of science teachers and careers advisors on students' decisions about science subjects and science and technology careers.* Retrieved from

National Center for Education Statistics. (2010). Table 197. Total fall enrollment in degree-granting institutions, by attendance status, sex of student, and control of institution: Selected years, 1947 through 2009 *Digest of Education Statistics*.

National Science Board. (2014a). *Science and Engineering Indicators*. Retrieved from

National Science Board. (2014b). TABLE 2-17. Earned bachelor's degrees, by sex and field: 2000–11. In National Science Foundation (Ed.), *Science & Engineering Indicators* (pp. 1). Washingto, DC.

National Science Board. (2014c). TABLE 7-2. Doctoral degrees awarded to women, by field: 2002–12 In National Science Foundation (Ed.), *Science & Engineering Indicators*. Washingto, DC.

National Science Board. (2014d). TABLE 8-1. S&E postdoctoral fellows in academic institutions, by field, citizenship, and sex: 2012. In National Science Foundation (Ed.), *Science & Engineering Indicators* (pp. 1). Washingto, DC.

National Science Foundation. (2007). Five myths about girls and science [Press release]

National Science Foundation. (2010). ADVANCE: Increasing the participation and advancement of women in academic science and engineering careers (ADVANCE) NSF-10593. *2011*(10/13/2011), Funding Solicitation. Retrieved from http://www.nsf.gov/publications/pub_summ.jsp?WT.z_pims_id=5383&ods_key=nsf10593

National Science Foundation. (2011a). *Table 9-24. S&E doctorate holders employed in universities and 4-year colleges, by occupation, sex, years since doctorate, and tenure status: 2008*. Retrieved from Arlington, VA: http://www.nsf.gov/statistics/wmpd/

National Science Foundation. (2011b). *Women, minorities, and persons with disabilities in science and engineering: 2011*. Retrieved from Arlington, VA: http://www.nsf.gov/statistics/wmpd/

National Science Foundation. (2014). *ADVANCE: Increasing the Participation and Advancement of Women in Academic Science and Engineering Careers (ADVANCE)* Retrieved from Washington, DC:

National Science Foundation, & Directorate for Social, B., and Economic Sciences,. (2011). *Women, minorities, and persons with disabilities in science and engineering: 2011*. Retrieved from Arlington, VA: http://www.nsf.gov/statistics/wmpd/

National Science Foundation, & Division of Science Resources and Statistics. (2008). *Science and engineering degrees: 1966-2006*. Retrieved from Arlington, VA: http://www.nsf.gov/statistics/wmpd/

Neal, H. A., Smith, T. L., & McCormick, J. B. (2001). *Beyond Sputnik: U.S. science policy in the 21st century*. Ann Arbor, MI: University of Chicago Pres.

Nolan, S. (2014, June 18, 2014). [Summer Enrichment Program Administration].

Nolan, S., Buckner, J., Marzabadi, C., & Kuck, V. (2008). Training and mentoring of chemists: A study of gender disparity. *Sex Roles, 58*(3–4), 235–250. doi:DOI 10.1007/s11199-007-9310-5

Nord, C., Roey, S., Perkins, R., Lyons, M., Lemanski, N., Bronw, J., & Schuknecht, J. (2011). *The Nation's Report Card: America's High School Graduates (NCES 2011-462).* Retrieved from Washington, D.C.: U.S. Government Printing Office.:

Nosek, B. A., Banaji, M. R., & Greenwald, A. G. (2002). Harvesting implicit group attitudes and beliefs from a demonstration web site. *Group Dynamics: Theory, Research, and Practice, 6*(1), 101–115.

Nosek, B. A., Banaji, M. R., & Greenwald, A. G. (2002b). Math = male, me = female, therefore math ≠ me. *Journal of Personality and Social Psychology, 83*(1), 44–59.

Nosek, B. A., Smyth, F. L., Sriram, N., Lindner, N. M., Devos, T., Ayala, A., . . . Greenwald, A. G. (2009). National differences in gender-science stereotypes predict national sex differences in science and math achievement. *Proceedings of the National Academy of Sciences of the United States of America, 106*(26), 10593–10597. Retrieved from <Go to ISI>://WOS:000267564300038

Nyquist, J., & Wulff, D. (2000). Re-envisioning the Ph.D.   Retrieved from http://depts.washington.edu/envision/project_resources/

O'Connor, B. P. (2000). SPSS and SAS programs for determining the number of components using parallel analysis and Vlicer's MAP test. *Behavior Research Methods, Instruments & Computers, 32*(2), 396–402.

OECD. (2015). The ABC of gender equality in education: Aptitude, behavior, confidence (pp. 180): PISA, OECD Pubclishing.

O'Rourke, E. O., Haimovitz, K., Ballwebber, C., Dweck, C. S., & Popovic, Z. (2014). *Brain points: a growth mindset incentive structure boosts persistence in an educational game.* Paper presented at the CHI'14 Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, New York, NY.

Olitsky, S. (2007). Facilitating identity formation, group membership, and learning in science classrooms: What can be learned from out-of-field teaching in an urban school? *Science Education, 91*(2), 201–221. Retrieved from <Go to ISI>://000244832100001

Oregon Department of Education. (2009). *Science standards by grade level*. Retrieved from Salem,OR:

Oregon Department of Education. (2014). Students eligible for free and reduced lunch. Retrieved from http://www.ode.state.or.us/sfda/reports/r0061Select2.asp

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. doi:DOI 10.1080/0950069032000032199

Pajares, F. (1996). Self-efficacy beliefs and mathematical problem-solving of gifted students. *Contemporary Educational Psychology, 21*(4), 325–344.

Pajares, F. (1997). Current directions in self-efficacy research. In M. Maehr & P. R. Pintrich (Eds.), *Advances in motivation and achivement* (Vol. 10). Greenwich, CT: JAI.

Pajares, F. (2005a). Gender differences in mathematics self-efficacy beliefs. In A. M. Gallagher & J. C. Kaufman (Eds.), *Gender differences in mathematics: An integrative psychological approach* Boston: Cambridge University Press.

Pajares, F. (2005b). Gender differences in mathematics self-efficacy beliefs. In A. M. Gallagher & J. C. Kaufman (Eds.), *Gender differences in mathematics: An integrative psychological*

approach (pp. 294–315). Boston: Cambridge University Press.

Parker, L. H., & Rennie, L. J. (2002). Teachers' implementation of gender-inclusive instructional strategies in single-sex and mixed-sex science classrooms. *International Journal of Science Education, 29*(9), 881–897.

Parker, V. (2000). Effects of a science intervention program on middle-grade student achievement and attitudes. *School Science and Mathematics, 100*(5), 236–242.

Paulsen, C. A., & Bransfield, C. P. (2010). Evaluation of the engineer your life initiative. *Science and Technology, 2*(2), 263–273.

Pedhazur, E. J. (1982). *Multiple Regression in Behavioral Research: Explanation and Prediction*. New York, NY: Holt, Rinehart and Winston.

Perneger, T. V. (1998). What's wrong with Bonferroni adjustmens. *BMJ, 316*, 1236–1238.

Phillips, K. A., Barow, L. H., & Chandrasekhar, M. (2002). Science career interests among high school girls one year after participation in a summer science program. *Journal of Women and Minorities in Science and Engineering, 8*, 235–247.

Piaget, J., & Inhelder, B. (1969). *The psychology of the child* (2nd ed.). New York, NY: Basci Books.

Plant, E. A., Baylor, A. L., Doeer, C. E., & Rosenberg-Kima, R. B. (2009). Changing middleschool students' attitudes and performance regarding engineering with computerbased social models. *Computers & Education, 53*(2), 209–215.

Plucker, J. (1996). Secondary science an mathematics teachers and gender equity: Attitudes and attempted interventions. *Journal of Research in Science Teaching, 33*(7), 737–751.

Powers, D. A., & Xie, Y. (2008). *Statistical methods for categorical data analysis* (2nd ed.). San Diego, CA: Academic Press.

Rabenberg, T. A. (2013). *Middle School Girls' STEM Education: Using Teacher Influences, Parent Encouragement, Peer Influences, And Self Efficacy To Predict Confidence And Interest In Math And Science.* (Ph.D. Dissertation), Drake University, Des Moines, Iowa.

Rennie, L. J. (2003). "Pirates can be male or femal": Investigating gender-inclusivity in a years 2/3 classroom. *Research in Science Education, 33*(4), 515–528.

Ride, S. (2012). Great Education Starts with Inspired Teachers.

Riegle-Crumb, C., & King, B. (2010). Questioning a white male advantage in STEM: Examining disparities in college major by gender and race/ethnicity. *Educational Research, 39*(9), 656–664.

Riegle-Crumb, C., & Moore, C. (2013). The gender gap in high school physics: Considerign the context of local communities. *Social Science Quarterly, 95*(1), 253–268.

Robinson, J., & Lubienski, S. (2011). The Development of Gender Achievement Gaps in Mathematics and Reading During Elementary and Middle School: Examining Direct Cognitive Assessments and Teacher Ratings. *American Educational Research Journal, 48*(2), 268–302. doi:DOI 10.3102/0002831210372249

Rosser, S. (2012). *Breaking into the lab*. New York, NY: New York University Press.

Rosser, S. V. (2004). *The science glass ceiling: Academic women scientists and the struggle to succeed*. New York, New York: Routledge.

Roychoudhury, A., Tippins, D., & Nichols, S. (1995). Gender-inclusive science teaching: A feminist-constructivist approach. *Journal of Research in Science Teaching, 32*(9), 897–924.

Rudman, L. A., Ashmore, R. D., & Gary, M. L. (2001). "Unlearning" automatic biases: The maleability of implicit prejudice and stereotypes. *Journal of Personality and Social Psychology, 81*(5), 856–868.

Rudolph, J. L. (2002). *Scientists in the Classroom: The cold war reconstruction of American science education*. New York, NY: Palgrave Macmillan.

Sadker, M., & Sadker, D. (1981). *Failing at fairness: How our schools cheat girls*. New York, NY: Simon and Schuster.

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.

Saldaña, J. (2013). *The coding manual for qualitative researchers* (2nd Ed.). Thousand Oaks, CA: SAGE.

Saraga, E., & Griffiths, D. (1981). Biological inevitabilities or political choices? The future for girls in science. In A. Kelly (Ed.), *The missing half: girls and science education* (pp. 85–97). Manchester: Manchester University Press.

Savickas, M. (1985). Identity in vocational development. *Journal of Vocational Behavior, 27*(3), 329–337.

Scalise, K. (2012). Analysis of teaching and learning (graduate course). Eugene, OR.

Schwartz, M., Sadler, P. M., Sonnert, G., & Tai, R. (2009). Depth versus breadth: How content coverage in high school science courses relates to later success in college science coursework. *Science Education, 93*(5), 798–826.

Schwartz, S., Luyckx, K., & Vignoles, V. (2011). *Handbook of identity theory and research*. New York, NY: Springer.

Schwartz, S. J. (2001). The evolution of Eriksonian and neo-Eriksonian identity theorty and research: A review and integration. *Identity: An international Journal of Theory and Research, 1*(1), 7–58.

Schwartz, S. J., Zamboanga, B. L., Luyckzx, K., Meca, A., & Ritchie, R. A. (2013). Identity in emerging adulthood: Reviewing the field and looking forward. *Emerging Adulthood, 1*(2), 96–113.

Scott, A., & Martin, A. (2014). *Perceived barriers and endorsement of stereotypes among adolescent girls of color in STEM*. Retrieved from Oakland, CA:

Semsar, K., Knight, J. K., Birol, G., & Smith, M. K. (2011). The Colorado learning attitudes about science survey (CLASS) for use in biology. *CBE-Life Sciences Education, 10*, 268–278.

Seymour, E. (1995). The loss of women from science, mathematics and engineering undergraduate majors: An explanatory account. *Science Education, 79*(4), 437–473.

Seymour, E., & Hewitt, N. M. (1997). *Talking about leaving: Why undergraduates leave the sciences*. Boulder, Co: Westview.

Shoffner, M. F., & Newson, D. W. (2001). Identity development of gifted female adolescents: The influence of career development, age, and life-role salience. *Journal of Secondary Gifted Education, 12*, 201–211.

Simard, C., Henderson, A. D., Gilmartin, S. K., Scheibinger, L., & Whitney, T. (2008). *Climbing the technical ladder: Obstacles and solutions for mid-level women in technology*. Retrieved from Stanford, CA:

Smith, S., Pedersen-Gallegos, L., & Riegle-Crumb, C. (2002). The training, careers, and work of Ph.D. physical scientists: not simply academic. *American Journal of Physics, 70*(11), 1081–1092.

Sokol, J. T. (2009). Identity development throughout the lifetime: An examination of Eriksonian theory. *Graduate Journal of Counseling Psychology, 1*(2), 139–148.

Sorge, C. (2007). What Happens? Relationship of Age and Gender with Science Attitudes from Elementary to Middle School. *Science Educator, 16*(2), 33–37.

Spear, M. (1987). The biasing influence of pupil sex in a science marking exercise. In A. Kelly (Ed.), *Science for girls* (pp. 46–51). Milton Keynes: Open University Press.

Spelke, E. S. (2005). Sex differences in intrinsic aptitude for mathematics and science? A critical review. *American Psychologist, 60*(9), 950–958.

Stake, J. E. (2003). Understanding male bias against girls and women in science. *Journal of Applied Social Psychology, 33*(4), 667–682.

Stake, J. E. (2006). The critical mediating role of social encouragement for science motivation and confidence among high school girls and boys. *Journal of Applied Social Psychology, 36*(4), 1017–1045.

Stake, J. E., & Mares, K. R. (2001). Science Enrichment Programs for Gifted High School Girls and Boys: Predictors of Program Impact on Science Con®dence and Motivation. *Journal of Research in Science Teaching, 38*(10), 1065–1088.

Stake, J. E., & Nickens, S. D. (2005). Adolescent girls' and boys' science peer relationships and perceptions of the possible self as scientist. *Sex Roles, 52*(1–2), 1–11.

Stead, D., & Kelly, L. (2015). *Inspiring science in the early years: Exploring good practice*. Berkshire, UK: McGraw Hill Education.

Steele, C. M., & Aronson, J. (1995). Stereotype threat and the intellectual test performance of African Americans. *Journal of Personality and Social Psychology, 69*(5), 797–811.

Steinke, J., Lapinski, M. K., Crocker, N., Zietsman-Thomas, A., Williams, Y., Evergreen, S. H., & Kuchibhotla, S. (2007). Assessing media influences on middle school-aged children's perceptions of women in science using the Draw-A-Scientist Test (DAST). *Science Communication, 29*(1), 35–64. Retrieved from <Go to ISI>://000248851100003

Stevens, J. P. (2009). *Applied multivariate statistics for the social sciences* (5th ed.). New York, NY: Routledge.

Swail, W. S., & Perna, L. W. (2002). Pre-College Outreach Programs. *Increasing access to college*, 250.

SWE. (2015) Society of Women Engineers: K-12 outreach. Retrieved from http://societyofwomenengineers.swe.org/k-12-outreach

Taconis, R., & Kessels, U. (2009). How choosing science depends on students' individual fit to 'science culture'. *International Journal of Science Education, 31*(8), 1115–1132. doi:DOI 10.1080/09500690802050876PII 793170196

Tai, R., Qi Liu, C., Maltese, A., & Fan, X. (2006). Planning early for caeers in science. *Science, 312*, 1143–1145.

Tai, R., & Sadler, P. (2001). Gender differences in introductory undergraduate physics performance: University physics in the USA. *International Journal of Science Education, 23*(10), 1017–1037.

Tasca, C., Rapetti, M., Giovanni Carta, M., & Fadda, B. (2012). Women and hysteria in the history of mental health. *Clinical Practice and Epidemiology in Mental Health, 8*, 110–119.

Thorne, B. (1993). *Gender play: Girls and boys in school*. Chapel Hill, SC: Rutgers University Press.

Todd, B. (2012). *Gender and science course taking in the High School Transcript Study*. Paper presented at the HSTS Database Training Seminar, Alexandria, VA.

Todd, B. (2013). The Science Program to Inspire Creativity and Excellence.

Tolley, K. (2002). *The science education of american girls: A historical perspective*. New York, NY: Routledge.

Tracey, T. J. G. (2002). Development of interests and competency beliefs: A 1-year longitudinal study of fifth-to eighth-grade students using the ICA-R and structural equation modeling. *Journal of Counseling Psychology, 49*(2), 148–163.

Trower, C. A., & Chait, R. P. (2002). Faculty diversity: Too little for too long. *Harvard Magazine*.

Turk-Bicakci, L., Berger, A., & Hazton, C. (2014). *The nonacadmic careers of STEM PhD holders*. Retrieved from

U.S. Depatment of Labor. Bureau of Labor Statistics. (2014). *Women in the labor force: A databook*. Retrieved from Wasington, DC:

Ulriksen, L., Madsen, L., & Holmegaard, H. (2010). What do we know about explanations for drop out/opt out among young people from STM higher education programmes? *Studies in Science Education, 46*(2), 209–244. doi:DOI 10.1080/03057267.2010.504549

United States Census Bureau. (2011a). Table 231. educationanal attainment by selected characteristics. *The 2012 Statistical Abstract*.

United States Census Bureau. (2011b). Table 299. Degrees earned by level and sex: 1960 to 2009. *The 2012 Statiscical Abstract*.

United States Census Bureau. (2014). State & County Quick Facts. Retrieved from http://quickfacts.census.gov/qfd/states/41000.html

Varma, R., & Hahn, H. (2008). Gender and the pipeline metaphor in computing. *European Journal of Engineering Education, 33*(1), 3–11.

Vygotsky, L. (1978). *Mind in society: The development of higher psychological processes*. United States: Harvard University Press.

Walford, G. (1981). Tracking down sexism in physics textbooks. *Physics Education, 16*(5), 261–265.

Watson, J. (1930). *Behaviorism*. New York, NY: Norton.

Watt, H. M. G., Eccles, J. S., & Durik, A. M. (2006). The leaky mathematics pipeline for girls: A motivational analysis of high school enrollments in Austrailia and the USA. *Equal Opportunities International, 25*(8), 642–659.

Weisgram, E. S., & Bigler, R. S. (2007). Effects of learning about gender discrimination on adolescent girls' attitudes toward and interest in science. *Psychology of Women Quarterly, 31*(3), 262–269. Retrieved from <Go to ISI>://000248849300004

Wieman, C. (2007). Why not try a scientific approach to science education. *Change, 39*(5), 5–9.

Wigfield, A., & Eccles, J. S. (2000). Expectancy-value theory of achievement motivation. *Contemporary Educational Psychology, 25*(1), 68–81. Retrieved from <Go to ISI>://WOS:000084720200004

Wilkinson, L., & Marrett, C. (1985). *Gender influences in classroom interaction*. New York: NY: Academic Press.

Wimberly, G. L., & Noeth, R. J. (2005). *College readiness begins in middle school: ACT Policy Report*. Retrieved from http://www.act.org/research/policymakers/pdf/CollegeReadiness.pdf

Woolston, C. (2015). Sexist review causes Twitter storm, *Nature Research Highlights*.

Xu, Y. (2008). Gender disparity in STEM disciplines: A study of faculty attrition and turnover intentions. *Research in Higher Education, 49*(7), 607–624. doi:DOI 10.1007/s11162-008-9097-4

Yeager, D. S., & Dweck, C. S. (2012). Mindsets that promote resilience: When students believe that personal characteristics can be developed. *Educational Psychologist, 47*(4), 302–312.

Yeager, D. S., Purdie-Vaughns, V., Garcia, J., Apfel, N., Brzustoski, P., Hessert, W., . . . Cohen, G. (2014). Breaking the cycle of mistrust: Wise interventions to provide critical feedback across the racial divide. . *Journal of Experimental Psychology, 143*(2), 804–824.

Youth Enrichment Talented and Gifted. (2014). *Summer Enrichment Program*. University of Oregon. Eugene, OR.

Zeldin, A. L., & Pajares, F. (2000). Against the odds: Self-efficacy beliefs of women in mathematical, scientific, and technological careers. *American Educational Research Journal, 37*(1), 215.

Zohar, A., & Bronshtein, B. (2005). Physics teachers' knowledge and beliefs regarding girls' low participation rates in advanced physics classes. *International Journal of Science Education, 27*(1), 61–77.