INFLUENCES ON

ENGAGEMENT FOR FEMALES IN SECONDARY SCIENCE

by

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I wish to thank the many trailblazing women who paved the way for me to attain higher education. By continually standing up and speaking out, the feminist movement and its allies have made great gains toward the goal of women's equal achievement in the modern Western world. This paper presents a science educator's perspective on the obstacles faced by female adolescents in the secondary science setting. I hope to shed light on areas of darkness in classrooms, curriculums, and communities, which still impede the path to success for young women in the sciences.

I would like to thank my family for supporting my journey in many ways. I am here because of my grandparents and great-grandparents who were teachers and who encouraged their daughters and granddaughter to attend college and to pursue their interests.

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ABSTRACT

Historically, women have been underrepresented in the fields of science, technology, engineering, and mathematics (STEM). Within the last few decades however, the percentage of women seeking advanced degrees in science has grown to levels equitable with their male counterparts. “Hard” science fields such as technology development and engineering, still evidence a minority of women professionals and educators. While women comprise half of the people seeking degrees in higher education, they remain a minority in positions of leadership. This paper reviewed research to explain the decrease in interest for women in science education and careers, which is first measured during adolescence. Research directed at female secondary students’ biology, self-perceptions, pedagogy, and goal orientations was reviewed in order to create an understanding of the gap in interest from a multidimensional perspective. The research implicated students’ socialization, experiences of gender discrimination, self-concepts, and pedagogy as either supporting or creating barriers for girls’ engagement in science. Pedagogy that is differentiated and which challenges discrimination and gender biases was supported by the research literature as being ameliorative for adolescent females’ gap in interest in science.

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CHAPTER ONE: INTRODUCTION

Introduction

Gender equity has been a major social issue in the Western world throughout the last half-century. As there have been many gains in the area of women inclusion in a variety of career fields, women obtaining careers in the sciences are still not equitable with men (Page, Bailey, & Van Delinder, 2009). A lack of interest in science courses and careers for adolescent females is evident starting in secondary school. This trend continues into college and the workforce. In order to remain competitive in the global economy, science fields need to be occupied by a variety of voices and innovative thinkers. Women's equal engagement in Science, Technology, Engineering and Math (STEM) fields, is vital for the national economy and technological innovation. The need to resolve the gap in engagement for women in STEM drives researchers to seek the factors that influence adolescent female students to lose interest during their formative, secondary science education.

Research to explain the gender gap in the sciences has been approached from biological, motivational, self-perceptive, and pedagogical frameworks. While no one area of research completely explains the complexity of the issue of females lacking engagement in STEM, all of these areas of research are informative for teachers, parents, and community members to pave a way forward toward greater equity among genders in science career fields.

Rationale

Educators have a primary responsibility to address and ameliorate the gender gap in science education and career fields. There remains a significant difference between the attainment of careers in many science fields for males and females. In 2004, for example, women earned 33% of the doctoral degrees granted in chemistry, computer science, math, physics and engineering. An emerging picture from the research points to the gap in science engagement for female adolescents which becomes more pronounced as students move through secondary education and into higher education (Ma, 2008).

While females attain as much academically as males- in 2008 for example, women earned 59% of all bachelor degrees and 58% of all master's degrees (Halpern, Aronson, Reimer, Simpkins, Star, & Wentzel, 2007)- there remains a minority of women in positions of prominence in most professional fields. Women make up 30% of tenured or tenure-track professors at doctoral granting institutions (Page et al., 2009). While women are attending undergraduate and graduate schools at rates meeting and exceeding the population of men in higher education, STEM fields remain underrepresented by women. Women represent half of the workforce, but only 26% of people working in science and engineering (Halpern et al., 2007).

Women's under-representation in STEM fields evidences a gender imbalance in these fields in higher education and the workforce. An equal representation of both genders in the STEM workforce is especially desirable in an age where technological innovation and economic competition in the world market is of paramount importance to society. On a practical level, a gender imbalance in STEM fields means that a disproportionate amount of research is produced from a male perspective and is therefore has a degree of gender bias. Unequal gender representation in STEM careers also means that opportunities for collaboration among a variety of voices and perspectives is missed (Page et al., 2009). This is also true of the underrepresentation of racial and ethnic minorities in STEM fields. In order to tackle complex societal and global issues in education, the economy and the environment, a variety of collaborating viewpoints is required and is desperately needed (Sterling, 2005).

The difference in science interest between girls and boys has been shown to arise in early adolescence. Up until that developmental period, boys and girls achieve and engage equally in science. The achievement disparity comes at the same time as other landmarks of development and identity formation (Miller, 2011). Riegle-Crumb, Moore, and Ramos-Wada (2010) found that interest in science decreased significantly for female students between fourth and eighth grade. This research indicates that pedagogy aimed at closing the gap in science achievement should begin during early adolescence.

Research is aimed at biology, self-perception, pedagogy, and goal orientation to explain gender differences in engagement in the sciences. This paper examines research on the influences of the gender engagement gap in science by highlighting each of these areas of research. The intent is show that that are many facets of the gap in engagement in science for adolescent girls, and solutions must therefore be multifaceted to close the gap.

Historical Background

A gender gap in STEM fields can be traced to the beginnings of the industries of science and technology in western society. A patriarchal scientific paradigm arose in parallel with the cultural stigma that males are more intelligent and capable in the fields of math, science, and technology, and woman are not interested and competent in math and science (Page et al., 2009).

Parker and Rosenthal (2011) delineated the 1890s as the period when pedagogy for boys and girls diverged. During and after industrialization in the United States, male students were encouraged in the sciences of mining and engineering, which were seen as growing business fields. Female students were largely not offered science courses in secondary school and were filtered into Latin, and the arts. Pressure to conform to societal gender roles discouraged women from pursuing careers in science at the cost of being stigmatized as lesbians. Males were similarly discouraged from fields that were not seen as masculine (Parker & Rosenthal, 2011). After the Second World War, boys were increasingly pushed into careers in woodworking and automobile repair, in order to increase global competition in technology and defense. Correspondingly, girls were required to take home economics classes during which they were taught how to use and consume a multitude of newly manufactured goods (Parker & Rosenthal, 2011). Powerful social stigmatization prevented individuals from entering careers that were typically assigned to the opposite gender.

Female scientists who did make it through their education and conducted research during the early nineteenth century were often overshadowed and diminished in importance beside their male counterparts. By the 1920’s there were thousands of women working in the sciences, a great step toward equal participation, however positions of leadership and power remained unobtainable for female scientists (Rossiter, 1984).

The mid-nineteenth century saw increasing gains for women in science, as they filled faculty positions at women’s colleges and remained the predominant gender of educators in primary school institutions. Societal pressures for women to conform to gender roles still remained strong and prevented women scientists from receiving equal representation in institutions of research and influence in the sciences (Behringer, 1985).

Since the women’s rights movement, many societal structures have shifted to allow women to have more opportunities and positions of power in society. Women now comprise 50% of the workforce in the Unites States, and are exceeding male educational achievement (Halpern et al., 2007). In many science fields and leadership positions in the sciences, however, women remain a minority. Interest and perceived ability in science has been shown to decrease for girls as they enter high school, and this lack of confidence increases as women go through schooling from that point onward (Brownlow, Rogers & Jacobi, 2000). Currently, federal and non-profit organizations promoting engaging STEM curriculum are diligently working to increase female and minority groups' involvement in the STEM workforce.

Definitions

Gender in this paper is used to denote identified gender and is limited to including female and male identified individuals. I do not make a distinction between biological or socialized females, and transgendered females and am therefore not addressing possible differences in science achievement among sexual minority groups. This is also noted in the paper's limitations section. Further, gender typing is the assignment of gender stereotypes to individuals based on perceived gender (Browning et al., 2000). Gender roles are behaviors that are associated with stereotypical gender behavior (Pajares et al., 2001); and gender biases are beliefs about gender issues that are based on stereotypes (Pajares et al., 2001).

Socio-cultural and socio-psychological factors are terms that are used in this paper synonymously. These are factors that are impressed upon an individual within the context of her society and culture.

Sexism is discrimination based on biological sex norms.

Biological factors are innate. For the purpose of this paper, biological factors relate to processes of cognition and neurological structure (Weiss et al., 2002).

Motivational factors derive from an individual's desire to act and the reasoning behind choices for action. They are often described using multi-variant models and take into consideration interacting variables (Meece, Anderman, and Anderman, 2006).

Adolescence is considered to be between the ages of twelve and eighteen.

Secondary school includes middle and high school education, and any grade level catering to adolescent children.

Limitations

This paper is limited to analyzing the attributes of achievement in science based on identified male and female gender. It therefore does not address science achievement of sexual minorities or individuals who are not identified by male or female gender.

This literature review is limited to research conducted in English speaking countries in Western modern society. The purpose of this limited scope on the research is to limit the impact of different socialization and cultural frameworks on findings.

The studies reviewed focused on middle and high school aged adolescents (ages 12-18). The purpose of this limitation is to explore the issues of female adolescent engagement in the sciences in order to provide pedagogical strategies to ameliorate the identified issues.

Statement of Purpose

This paper is a critical review of the literature from the fields of education, social science, and psychology, addressing the gender gap in science engagement, which begins during adolescence in secondary school. Women are underrepresented in occupations and leadership positions in science fields, with research showing that self-confidence, engagement, and achievement in science starts to decline for girls during adolescence (Brownlow et al., 2000).

Interventions in science education, teacher practice, and public education are necessary to bridge the gap for equal engagement across genders in the sciences. This paper offers an analysis of current research on the influences of the gender gap in engagement in science and ideas for teaching practice to ameliorate the gender inequalities that remain in science education and careers.

Summary

This research paper traces the historical background of the gender gap in adolescent girls' science interest as it is influenced by a web of factors: biological, self-perception, goal orientations, and pedagogy. Chapter One explored the historical background of the gender differences engagement in the sciences while discussing the definitions, and limitations of this thesis paper. Chapter Two reviews peer reviewed literature from the fields of education, social sciences and psychology addressing engagement in the sciences. Chapter

Three summarizes the findings, presents classroom implications and provides suggestions for future research on engaging female adolescents in science education and careers. This paper draws the conclusion that contextualized, engaging, and non-discriminatory pedagogy is foundational for addressing the gender divide in science achievement.

CHAPTER TWO: CRITICAL REVIEW OF THE LITERATURE

Introduction

Chapter one introduced the history of the gap in engagement for female secondary science students. Engaging female students' interest in science education and careers is of great concern in Western society, as women remain a minority in many science and technology professions today. This chapter examines current research identifying factors that influence the gap in engagement for female science students. In particular, research will be presented by theme to examine the biological, self-perception, pedagogy, and goal orientation factors that have been shown to influence the lack of engagement for women in the sciences.

Biological factors

The first three studies presented explain the gap in engagement for female students in science in terms of biological influencers. Historically, gender differences in performance and achievement in the sciences have been attributed to biological differences between the sexes, with women being considered less capable biologically to study and practice as professional scientists. More recent research dispels the contention that women are less intelligent, or have lower achievement than men in science education and careers. Weiss, Kemmler, Deisenhammer, Fleischhacker, and Delazer (2003) investigated sex differences in 97 university students using a battery of neurophysiological tests and found differences in verbal fluency and visual-spatial tests between genders. Other gender differences among adolescents were found by Gregory, Haüsermann, Rijsdijk, and Eley (2009) in a longitudinal study of twin pairs. Adolescent females were reported to be significantly more pro-social than male peers based on self and parent reported measures among 1160 adolescent twin pairs. Zeyer and Wolf (2010) investigated the influence of sex and brain type on the motivation to learn science in a quantitative correlational analysis of 77 upper secondary students in Switzerland.

Weiss, Kemmler, Deisenhammer, Fleischhacker, and Delazer (2007) showed that cognitive processing differs between men and women with women performing better than men in verbal and memory tasks, and men performing better on visual-spatial tasks. In a correlational quantitative study, Weiss et al. gave 97 university students a battery of neuropsychological tests to investigate whether or not there were sex differences in cognitive functions. The researchers found that women performed at a significantly higher level than men on the Warrington Memory Test ($p=0.048$), in the Lexical Fluency Task ($p=0.020$), and on the digit symbol test ($p=0.029$). Men performed at a higher level than women on a visual-spatial test ($p=0.05$), and marginally higher on the three-dimensional cube test ($p=0.064$).

This research is consistent with other studies showing higher performance for males on spatial rotations tasks (Karnovsky, 1974). While researchers demonstrated a difference that could be attributed to biological factors, they were explicit about not attributing their significant findings to biological factors alone. There are socio-psychological implications for Weiss et al.'s (2007) findings on gender differences that could be attributed to differences in gender socialization.

In their study, Gregory, Haüsermann, Rijsdijk, and Eley (2009) collected data from 1160 twin pairs and their parents. Pro-social behavior was assessed by self-report and parent-report measures using a pro-social strengths and weaknesses questionnaire. Researchers found significantly higher pro-social behavior in females than males as reported by both participants and their parents ($p<0.001$). Genetic and non-shared environmental influences had the greatest impact on participants pro-sociability. This suggests that an interaction of genes and the environment is responsible for pro-social behavior in adolescents. Strengths of Gregory et al.'s (2009) research and findings are the large sample size and the data collected from a variety of rating sources; self and parent reporters. A weakness of the study is the limited generalizability of the findings to non-twin populations.

Zeyer and Wolf (2010) investigated the influence of sex on the motivation to learn science and the impact of brain type on the motivation to learn science. Participants were 77 upper secondary students (43 women and 33 men) from 15 to 20 years old at a science learning center in Switzerland. A little over 36% were science students and 63.3% were non-science students. Researchers visited four classes during their one-day course at the learning center. Students completed a questionnaire which asked 60 forced choice questions targeted at assessing students’ empathizing quotient (EQ) and their systemizing quotient (SQ) in order to determine their brain type. A second questionnaire asked 30 forced response questions to measure students’ motivation toward science learning (SMQ).

Cronbach’s alpha coefficients were 0.849 for the SMQ (30 items), 0.877 for the SQ (40 items) and .899 for the EQ (40 items). Researchers found no significant difference in the SMQ of students across genders. Female students’ EQs (43.81, SD = 10.14) were found to be significantly higher than male students’ EQs (35.22, SD = 11.17; $p < .001$). The average SQ of male students (30.41, SD =13.39) was found to be significantly higher than the average SQ for female students (22.40, SD = 8.67; $p < .001$). Researchers found a significant difference between brain quotients by gender with female students on average having an empathizing brain quotient and male students on average having a systemizing brain quotient ($p < .001$).

A strength of Zeyer and Wolf’s (2010) study, was their explicitness about the theoretical underpinnings of their research questions and design. Zeyer and Wolf (2010) also assessed and were transparent about the statistical analysis of their testing measures. However, Zeyer and Wolf (2010) explained differences in terms of biology without confronting socialization differences and their own schemas about gender. This lack of reflection could impact the internal validity of their research.

The previous research evidenced some differences in the cognitive processing of male and female students. Weiss et al. (2003) found that female students performed significantly better at memory and verbal tasks than male students, who in turn performed significantly better at visual and spatial reasoning tasks. This finding can be connected to other findings indicating that female adolescent students are more pro-social (Gregory et al., 2009), and empathizing than their male counterparts (Zeyer and Wolf, 2010). Interestingly, no significant difference was found across genders in measures of motivation to learn science (Zeyer and Wolf, 2010). This is consistent with findings discussed in future chapters. Historically, biological differences have been cited as a way to explain the disparity between men and women working in the sciences. The current research literature suggests rather an interaction between pedagogical, biological, and sociological factors that evidences differences in science interest between the sexes.

Self-Perception

Self-perception and self-efficacy have been shown to play a part in effort, self-confidence, and belief in one's ability to meet goals and overcome obstacles (Pajaras, 1996; Bandura, 1997). Low self-efficacy has been correlated with lower performance for adolescent females. This section addresses research on female science students' self-perception and its influence on science engagement and ability in school. Self-perception in this paper refers to self-concepts, theories of intelligence, self-efficacy, beliefs about possible-selves, and sexual discrimination experiences. In a correlational quantitative research design, He and Freeman

(2010) investigated the effect of gender on the development of computer self-efficacy in a study of 243 undergraduate business students in the US. Fouad, Hackett, Kantamneni, Fitzpatrick, Haag, and Spencer, (2010) researched the effect of perceived experiences that hindered or advanced choices to continue in math or science education and careers, in a quantitative correlational study of 323 eighth grade students, 600 tenth grade students, and 628 college students in the Mid and Southwest, US. Buday, Stake, and Peterson (2011) investigated the effect and importance of support from others on science career-related possible selves as a function of gender in a quantitative correlational research design of 88 former members of a science enrichment program. Leaper and Brown (2008) found that 52 percent of 600 adolescent females experienced discriminating remarks about their abilities in math, science and computer science in a study of students from Georgia and California. In a quantitative longitudinal study of differences in beliefs by gender, Simpkins, Davis-Kean, and Eccles (2006) found significant differences between genders in measures of grades, activity participation, expectancy values, and course enrollment, in a group of 227 children from three school districts in Michigan. In a study on self-regulatory efficacy beliefs of 263 middle school students in the Southeastern U.S. Usher, and Pajares (2006) found that girls reported stronger vicarious experience and social persuasions than boys who participated in the study.

In a correlational quantitative research design, He and Freeman (2010) investigated the effect of gender on the development of computer self-efficacy. The analysis was performed using data from 243 undergraduate business students from two MIS computing courses at a medium sized public university. Participants consisted of 127 female and 116 male students, the majority of which (71.6%) were between the ages of 17-20.

Zero-order correlation found that gender can be a strong predictor for general Computer Self-Efficacy ($r = 0.263$, $p < 0.001$). However, after controlling for the effects of computer knowledge and current computer experience, researchers found an insignificant difference between genders on CSE measures. A strength of He and Freeman's (2010) study is their inclusion of reliability and validity assessments for their research measures. A weakness of their findings is that they cannot be extrapolated to other populations because of the narrow demographics of participants. Results therefore lack external validity outside of computer science undergraduate settings.

Buday, Stake, and Peterson (2011) investigated the effect and importance of support from others on science career-related possible selves as a function of gender. Participants in this correlational quantitative study were contacted based on their membership in a science enrichment camp between 1995 and 1998. Individuals who agreed to participate in the survey returned questionnaires measuring family support, peer support, professor support, romantic partner support, scientific setting environment and scientific setting sex discrimination, future career self and future personal self, measured perceptions of self as scientist, science career perceptions, motivation for a science career scale, and current job category.

Buday et al. (2011) found no significant gender differences for measures of interest. Beliefs about one's future career as a scientist mediated the relationship between perceived supportive environment and science career perceptions ($Z = 3.84$, $p < .0001$). Their finding is incongruent with previous research suggesting that females are discouraged from entering science career fields. Buday et al. (2011) discussion suggests this is because the women in their study had been participants in a voluntary science summer enrichment program and likely already felt an aptitude for science and were supported in their interest.

A strength of Buday et al.'s research was the high significance level that they used in performing their data analysis. The current research was also explicit about the outcomes of all of their measures; those that yielded a significant result, and those that did not. A related weakness of the study was in the small sample size that likely led to the failure to reject the null hypothesis on research findings.

Leaper and Brown (2008) showed that 52 percent of adolescent girls had experienced discouraging remarks about their abilities in math, science, and computer science classes. In a study of 600 female students surveyed from middle and high school classrooms, school related programs, and summer camps in Georgia and California, ranging in age from 12 to 18, Leaper and Brown examined the influences of perceived experiences of sexism using a correlational quantitative research design. Researchers used Klonoff and Landrine's (1995) Schedule of Sexist Events inventory to find out about participants' experiences with sexual harassment. This measure asked participants to rank experiences of sexual harassment on a four-point scale of the frequency of experiences of sexual harassment in specific contexts.

Leaper and Brown (2008) found that 90 percent of the study's participants reported experiencing sexual harassment at some point in their lives. Academic sexism was correlated with participants' background variables, age, socialization variables, and individual variables ($F(31,568) = 4.17$, $R2= .19$, $p<.01$). Fifty-two percent of girls reported hearing discouraging remarks about their math, science, and computer abilities. Researchers also found that male peers were the most common perpetrators of sexism; 31.8% of participants reported sexual harassment by male peers at least once in their lives.

The strengths of the study are the wide range or correlated measures; researchers investigated a web of possible interacting factors that could increase perceived sexism for adolescent girls. Researchers also looked at girls from a wide range of socioeconomic and ethnic backgrounds, demonstrating greater reliability that the findings would be replicated in other populations. A weakness of Leaper and Brown's (2008) study is that researchers did not discuss the implications of different cultural definitions of sexual harassment. They did not elaborate on their finding that culture impacts perceived sexism. Further research is therefore needed in order to fully understand this finding.

In a quantitative longitudinal correlational study of differences in beliefs by gender, Simpkins, Davis-Kean, and Eccles (2006) examined the relationship between science ability beliefs and class choice in a group of 227 children from three school districts in Michigan. Simpkins et al. (2006) used data from the Michigan Childhood and Beyond study, collected from schools during the spring when study participants were in fifth and sixth grades, and again after they had finished twelfth grade. Several questionnaires were administered to students, examining expectancy values, self-concepts, interest, perception of importance in science, grades, and high school courses chosen. MANOVA analysis found a significant difference between the genders in measures of grades, activity participation, expectancy values, and course enrollment ($F(20,27)=2.27$, $p< 0.01$). In addition, the number of science courses taken in high school was positively correlated with youths' grades in 5th and 10th grades, which were related to self-concepts and beliefs.

The strength of Simpkins et al.'s (2006) research is the relationship that it demonstrated between self-concept, grades, expectancy beliefs in middle school, and choice for science courses in high school. This research offered a long view of the development of science engagement for adolescents, while providing evidence that gender plays a role in self-concept, expectancy beliefs, grades, and further, science course choice in high school. A weakness of Simpkins et al.'s research is the racially limited demographics of participants. The findings therefore are not reliable across all racial, ethnic, and socioeconomic populations. The study would need to be replicated with a more diverse participant population to resolve this issue.

Usher and Pajares (2006) explored gender differences in sources of self-efficacy in a study of 263 sixth grade students from a public urban middle school in the Southeastern US. In their study, Usher and Pajares examined the relationship between sources of self-efficacy and gender. Instruments were group administered in a reading class during the first semester of students' academic year. Participants were given the Sources of Self-Efficacy, a 24-item scale assessing students' evaluations of sources which inform self-efficacy beliefs. Exploratory factor analysis was used to identify constructs underlying the items. Analysis was conducted with SAS system's FACTOR procedure. Separate ANOVA tests were conducted to determine gender, race/ethnicity, and reading ability level differences in academic self-efficacy, self-efficacy for self-regulation, and reading grade.

Boys and girls did not differ in academic self-efficacy or self-efficacy for self-regulation. Students reading above grade level (Mean = 5.0) reported stronger self-mastery experiences than did students reading below level (Mean = 3.9, < .007). Students reading below level (Mean = 3.3) reported greater physiological arousal than did above-level students (Mean = 2.5, $\alpha < .007$). Mastery experiences ($\beta = .343$ for academic self-efficacy; $\beta =.354$ for self-regulatory self-efficacy) and social persuasions ($\beta = .376$ for academic self-efficacy; $\beta = .286$ for self-regulatory self-efficacy) predicted girlsÕ academic and self-regulatory self-efficacy, whereas mastery experiences ($\beta = .343$ for academic self-efficacy; $\beta =.354$ for self-regulatory self-efficacy) and vicarious experiences predicted academic self-efficacy ($\beta = .180$) and self-regulatory self-efficacy ($\beta = .175$) for boys. Usher and Pajares found that girls and boys differed significantly on measures of vicarious experience (Boys mean = 4.9, Girls mean = 5.3, $\alpha <.007$), and social persuasion (boys mean= 4.3, girls mean= 4.8, $\alpha <.007$)

A strength of Usher and PajaresÕs (2006) study is the high significance level used in their statistical analysis, in order to avoid a type I error. A weakness of the study is the lack of diversity in the participant population (68% Caucasian), which decreases the reliability of the study's findings.

Fouad, Hackett, Kantamneni, Fitzpatrick, Haag, and Spencer, (2010) researched the effect of perceived experiences that hindered or advanced choices to continue in math or science education and careers in a quantitative correlational study. This study consisted of 323 eighth graders from three educational levels (8th grade, 10th grade, and college) from the Midwest and Southwest, US. Eighth grade participants consisted of 48.9% males and 50.2% females. Six hundred tenth grade student participants were 44.5% male and 52.9% female. Six hundred twenty-eight college student participants consisted of 28.5 % males and 71.5% females. Participants were administered a demographic, and a science and math barriers and supports questionnaire.

Fouad et al. (2010) found that participants at earlier levels experienced more barriers ($F\ (2, 1545) = 4.6$, $p<.01$) and fewer supports ($F\ (2, 1545) = 9.2$, $p<.001$) than students at higher levels in science. A strength of their study was that Fouad et al. accounted for internal validity by performing Cronbachs' alpha on research measures. A weakness however, was that researchers did not include all of their data in the results section of their published article. This decreases the objectivity and reliability of their findings.

This section surveyed research on the influence of self-perception on science interest and engagement for female science students. Academic self-efficacy and self-regulatory self-efficacy were significantly different according to gender; mastery experiences and social persuasions predicted self-efficacy for girls, and vicarious experiences predicted self-efficacy for boys (Usher and Pajares, 2006). Computer self-efficacy was also found to be predictable by gender (He and Freeman, 2010) with female students scoring significantly lower on measure of computer self-efficacy. This has implications for other research findings showing that boys are more likely to aspire to careers in computer science and engineering. It also aligns with a study by Leaper and Brown (2008) which found that 52 percent of female students experienced discouraging remarks about their abilities in math, science, and computing. In the same study 90 percent of female students reported experiencing sexual harassment at some point in their lives. A longitudinal study between science ability beliefs for middle school students and their future class choice as high school students found significant differences between genders in measures of grades, activity participation, expectancy values, and course enrollment (Simpkins et al., 2006).

Finally, Buday et al. (2011) found no significant difference between genders on measures of science interest. The findings from these studies, when taken together, indicate that while interest and achievement do not vary significantly, self-efficacy and science ability beliefs do vary across genders. The disparity in perceived ability across genders could likely be attributed to environmental influences which are either confirmatory or discriminatory toward female students in regards to their abilities in science.

Pedagogy

The current section examines research literature that is focused on the effect of pedagogy on female science students' engagement and interest in science education and careers. Pedagogy in this paper refers to teaching and schooling practices that are an intentional part of a student's educative experience. In a qualitative case study, Bartolome, Mellado, Jimenez-Perez, and Taboada Lenero (2012) examined the process of development and change during the course of an eight-year science teacher's career. Bolshakova, Johnson, and Czerniak (2011) conducted a qualitative case study to compare self-efficacy beliefs and science achievement to teacher effectiveness with the participation of fourteen Hispanic students from a public middle school in the Southwest. Green, Martin, and Marsh (2007) investigated whether or not motivation and engagement in math, science, and reading was domain specific using a quantitative confirmatory factor analysis design in a study of 1801 Australian high school students. Weisgram and Bigeler (2007) investigated the effect of learning about gender discrimination on girl's interest and self-efficacy beliefs in science in a sample population of 158 middle school aged girls. Yilmaz, Turkmen, and Pederson (2008) investigated fourth graders' perceptions about science teachers and science teaching in a qualitative research design of 112 fourth grade students in Turkey. Delen and Bulut (2011) examined the effects of information processing technology in a quantitative correlational study of 4996, 15-year-old students in Turkey. Grolnick, Farkas, Sohmer, Michaels, and

Valsiner (2007) investigated the development of motivation in adolescents using Self-Determination Theory in a study of 90 seventh grade children from an urban, low socioeconomic status school. Guzzeti and Bang (2011) analyzed science content knowledge and attitudes before and after a literacy-based science unit in three chemistry classes in the Southwest, US. Ma (2008) assessed in-school variables affecting gender differences in science achievement in a quantitative correlation study of 194,668 fifteen year olds from 41 countries. Mayer-Smith, Pedretti, and Woodrow (2000) researched the effect of Technology Enhanced Secondary Science Instruction (TESSI) on science learning and gender differences in a population of 132 students from four 10th grade science and three 11th grade physics classrooms, using a mixed qualitative case study and quantitative research design. In a study on girls' achievement in single sex classrooms, Shapka and Keating (2003) conducted longitudinal quantitative research with 57 female students from single-sex classrooms in Ontario, Canada. Weinberg, Basile, and Albright (2011) investigated the effects of a summer enrichment program on students' motivation and attitudes toward science within a population of 336 middle level students who attended summer enrichment programs at four higher education institutions in the US. In a qualitative research design, Johnson and Winterbottom (2011) assessed the learning strategies of 28 girls from a rural school for 11-18 year olds in the Midwestern US. Robinson and Gillibrand (2004) examined achievement differences by gender in single-sex classrooms in a mixed qualitative and quantitative research design consisting of 170 high school students in England.

Delen and Bulut (2011) explored the effects of information and communication technology (ICT) on students' science achievement in a quantitative correlational study using data from the Program for International Student Assessment (PISA). The PISA data used in their study was taken from a sample of 4996, 15-year students (male=2552, female=2445) from 170 schools in Turkey. Questions from the PISA Student and ICT Survey asked about students' possession of technological devices and their frequency of use. Technology scores were obtained using a Graded Response Model, which is a polytomous item response theory for analyzing cognitive processes. PISA Hierarchical linear modeling (HLM) was used to analyze ICT effects based on variables such as accessibility to ICT at home and in school and technology scores. HLM focuses on the behavioral or performance effects of social variables. It allows examining the variance of students as nested in classes and schools.

Students' exposure to ICT was found to be a strong predictor of math and science performance. Students' exposure to ICT out of school had a larger impact on their math and science achievement than their ICT exposure at school. ICT use at school was a weak predictor of achievement in math and science indicating that computer use at school needs to become more integrated in curriculum. Overall, ICT was found to have a positive impact on math and science performance.

A strength of Delen and Bulut's (2011) study was that they had access to a large participant population by using data from the Program for International

Student Assessment. The quantitative correlational design and the objectivity of research questions create reliability for study's findings. A weakness of the study is the assumption of causality between students ICT exposure and their achievement in math or science. Both of these could be alternatively seen as stemming from a different cause.

To investigate the development of motivation during adolescence, Grolnick, Farkas, Sohmer, Michaels, and Valsiner (2007) used the framework of Self-Determination Theory in a quantitative study of 90 seventh grade children in an urban school. To facilitate the experiences of autonomy, competence and related engagement, the researchers created an after school program called The Investigators Club, a 15-week program which 90 seventh grade students attended three days a week for 1.5 hours daily. Participants consisted of 47 boys, and 43 girls, 62% received free and reduced lunch. Thirty-four percent of participants were of European descent, 31% were Latino, 21% were African American, 11% were Asian, and 2% were Native American.

In their study, Grolnick et al. (2007) developed a stratified selection procedure with randomization to after school versus in-school control groups in order to oversample low achieving students and students from racial and ethnic minority groups. Students placed in in-school control and sample groups were matched in terms of variables of grades, ethnicity, sex, and free lunch status. Researchers assessed motivational resources connected to Self-Determination Theory including level of autonomous versus control motivation, students' perceptions of competence, learning vs. performance goals, and the extent to which students changed patterns of behavior in classroom and grades. Researchers assessed the effect of participation in the "The Investigators Club" by evaluated questionnaires given to sample and control groups before and after the 15-month period of the study. Measures used in Grolick et al.'s (2007) study included questionnaires to measure self-regulation, performance versus learning goals, theories of intelligence, and engagement. All measures were scaled using an adapted likert scale.

Grolnick et al. (2007) found using ANOVA data analysis that program completers were less likely than non-completers to endorse an entity view of intelligence ($F(1,44)=7.87$, $p<.01$, $d=-.78$), rated themselves as more engaged in science ($F(1,44)= 6.45$, $p<.05$), and received higher science grades ($F(1,44) =11.93$, $p< .01$), than non-completers. Program completers were also rated as more engaged than non-completers in English ($F(1,44)= 12.60$, $p<.01$), Math ($F(1,44)= 16.42$, $p<.001$), social studies ($F(1,44)= 18.47$, $p<.001$), and science ($F(1,44)= 16.49$, $p<.001$).

Strengths of Grolnick et al.'s (2007) study were the ethnically diverse participant population, which increased the reliability, and the likelihood that findings would be replicated in other diverse populations. The findings that indicated increased engagement, higher grades, and an increased entity view of intelligence also lend credence to Grolnick et al.'s (2007) study.

A weakness of the study was that the treatment of an after school program is access limiting because it requires funding that many schools do not have. While the findings suggest the benefit of an afterschool program on numerous measures, they do not suggest a way to mitigate the additional costs for schools that this type of program entails.

Ma (2008) performed a correlation analysis using data collected by the Program for International Student Assessment (PISA) to assess within school variables that account for gender achievement differences. Standardized achievement tests, school and student questionnaires were used to assess 194,668 fifteen-year-old students sampled in 2006, from 41 countries and 7,232 schools. To perform statistical analysis, Ma (2008) used a two level hierarchical linear model to assess gender differences. Small gender differences in science favoring males were found in 14 countries. Ma (2008) concluded that psychosocial or cognitive differences might account for the finding that in 14 out of 51 countries, male students performed better in science than their female counterparts.

Ma's (2008) study has some notable strengths and weaknesses. A strength of the study is that it had access to a sample population of 194,668 fifteen year olds from 41 countries. Because of the varied and large number of subjects sampled, the findings have validity in that they are representative of a worldwide population of fifteen year olds. One weakness of the study is that while it accounts for in-school variables that could account for gender differences in performance, the study does not account for the differences in culturally influenced gender socialization between the countries that were surveyed. The finding that in fourteen out of 41 countries, male students performed better than female counterparts in science, might further say something about the gender socialization in the countries surveyed, and Ma (2008) does not discuss or account for these cultural implications.

In a mixed qualitative case study and quantitative research design, Mayer-Smith, Pedretti, and Woodrow (2000) conducted research to investigate whether or not the Technology Enhanced Secondary Science Instruction (TESSI) project was effective for improving science learning. Mayer-Smith et al. (2000) also investigated gender differences in achievement in technology enhanced science curriculum.

Data were collected between 1995 and 1996 in four 10th grade science classes and three 11th grade physics classes. Research data consisted of observations and videotaped classroom episodes, records of student achievement (n= 132, female n =72, male n = 60), videotaped and audiotaped interviews with a subset of participating teachers (n=2) and students (n=81; female n = 48; male n= 33), student questionnaires (n=98); and researchers' journal entries and field notes from weekly classroom visits. Students in the TESSI program were interviewed throughout their year and asked questions about their learning experience. At the end of the year, students completed an exit questionnaire to ascertain whether or not students' views had changed over the course of the year.

In their study, Mayer-Smith et al. (2000) found no significant gender difference for success between men and women; the average grades for both genders was 69%. Their findings suggested that women can be successful learning science and technology. Researchers also noted that the careful use of technology enhanced curriculum can encourage the participation of female students with 35% female attendance in TESSI programs as compared with an average of 30% female attendance in other districts. More important than gender on measures of engagement and success, are the ways in which technology is integrated into curriculum. In their discussion, Mayer-Smith et al. (2000) reported that effective technology curriculum like in the TESSI program makes learning fun and engaging.

Mayer-Smith et al.'s (2000) study gives credible evidence that female students can achieve in a technology rich learning environment contrary to research that has suggested otherwise. Researchers found no significant difference between the genders on the study measures, which varied from interview questioning, grades, and self-assessment measures. The variation in qualitative and quantitative data is also a strength of the study, as a more complete picture of participants experience is explained by a compilation of different sources of data.

A weakness of the study was the lack of researcher transparency with regards to qualitative data coding methods. In their report of findings, Mayer-Smith et al. (2000) failed to explicate the process used to quantify student interview answers as measures of their interest and engagement.

Guzzeti and Bang (2011) analyzed science content knowledge and attitudes before and after a literacy based science unit in three chemistry classes in the Southwest. This quasi-experimental design measured 140 students in the literacy based science treatment group and 147 students in three normal chemistry classes from a demographically similar school. Measures were administered to students three weeks prior to the start of the unit, and again at the end of the semester. Chemistry content knowledge was measured, as well as attitudes toward science, and interviews, observations and field notes were used to gather data about students' engagement. Quantitative data analysis found statistical significant gains for the control group in chemistry content knowledge and scientific inquiry skills ($F=21.02$, 1, 196, $p=.000$). Qualitative data was analyzed using thematic analysis and found that one half of students in the science literacy classes liked science more because of the unit (56%).

A strength of Guzzetti and Bang's (2011) study is that the student demographics were varied, with subjects representing diverse socio-cultural backgrounds. This gives internal validity to the study in that it is representative of the multicultural population. Researchers found that students learned more in the treatment group to the significance level of .000, which has a higher validity than many analyses that use a significance level of .05. A weakness of this study is that researchers did not examine the effect of gender on student performance in the control or experimental groups.

In a qualitative case study, Bartolome, Mellado, Jimenez-Perez, and Taboada Lenero (2012) examined the process of development and change during the course of an eight-year science teacher's career. The study follows a secondary science teacher, Marina, as she develops as a teaching professional with special reference to an action based teacher-training program that she participated in. Marina, a geology graduate, had eight years of teaching experience at the start of the study. Pre-assessment consisted of a teaching content questionnaire at the start of her teaching. Within the first few years, Marina participated in an action-research teacher-training program. She also facilitated an action-research group with other participating teachers.

Bartolome et al. (2012) collected data from Marina's teacher diaries, interviews, memos, student work, videotaped sessions, classroom programs, units, and transcriptions from work group meetings. Researchers found that Marina's development involved coming to a new way of approaching open and closed problems in the classroom. She was in a process of developing a new way of posing questions to her students that was more complex. Marina's reflection and practice were considered by researchers to be "integrated." Bartolome et al. (2012) also found that Marina had barriers related to beliefs that were resistant to change but which had become less stringent over time. Over time Marina gained mastery of pedagogical content knowledge, possibly because of the use of action-based research and reflection.

Bartolome et al.'s (2012) longitudinal study depicted teacher practice in development over a long period of time. Another strength of the study was the raw nature of collected and analyzed data. Researchers did not fit data to a preconceived framework but rather, they organized and presented data as it was naturalistically gathered. Bartolome et al.'s (2012) research was also presented in a clear and coherent formatting and graphic organizers in the literature. A weakness of the study was the limits of confirmability of research findings. The analysis of the Marina case study was qualitative and anecdotal. By its nature, a case study is very hard to replicate because of the uniqueness of the setting and human element. It is very challenging to have consistency of findings and transferability with this kind of research.

Bolshakova, Johnson, and Czerniak (2011) conducted a qualitative case study to compare self-efficacy beliefs and science achievement to teacher effectiveness with the participation of fourteen Hispanic students from a public middle school in the Southwest. Teachers in the case study participated in a eight, monthly, full day professional development sessions and received two inquiry-based modules from Frey Scientific to use with students. The modules were aimed at coaching teachers to make personal connections with their students and allowing students' voices to impact course work and curriculum.

The fourteen Hispanic science students involved in the study attended a culturally diverse urban public school. Four to six students from six, seventh, and eighth grades were randomly selected to participate in the study. Students were interviewed three times during the academic year and themes in student and teachers' stories were cross analyzed using the Woolfolk, Hoy and Davis's (2006) framework.

Two classroom observers completed 14 classroom observations using the Horizon Research (1999) Local Systemic Change (LSC) Classroom Observation Protocol. Observations were categorized according to four subscales; design, implementation, classroom climate, and science content. Researchers assessed congruency between teaching practices observed and experienced by students and outsiders. Qualitative data were analyzed by two independent researchers to increase the credibility of findings.

In this study, Bolshakova et al. (2011) found several concurrent themes from the collective cases in the study. The first was that students were curious and naturally interested in science. The second was that students had schema about what science class should be like, and this was not always concurrent with reality. Thirdly, linking science learning to real life increased students' engagement. The fourth theme was that a teacher's level of enthusiasm toward science was emulated by students in beliefs about science and behaviors. The fifth theme was that teaching strategies often were dichotomized by being either traditional or innovative, and by being either creative or repetitive. Sixth, was that the student-teacher relationship was mirrored by the student-student relationships. Classrooms with better teacher-student communication evidenced more supportive student-student learning communities. Bolshakova et al. (2011) found that having a teacher with high self-efficacy and rapport with students increased students' self-efficacy and interest in science.

A strength of the study was the transparency of data gathering and analysis procedures in the published literature. Researchers used empirical data collection methods and independent researchers in order to confirm the legitimacy of their findings. Another strength in the case study format, allowed researchers to compare personality differences and the nuances between science teaching styles and teacher-student interactions.

Green, Martin, and Marsh (2007) investigated whether or not motivation and engagement in math, science, and reading was domain specific using a quantitative confirmatory factor analysis research design. Participants in Green et al.'s (2007) study consisted of 1801 Australian high school students from six high schools in years 7- 8; 52% were in junior high, 40% were in middle high, and 8% were in senior high. The gender ratio for participant populations was 33% females, and 67% males.

Researchers administered The Motivation and Engagement Scale on which students rated their motivation and engagement in the context of the target subject; English, mathematics, and science, respectively. Confirmatory factor analysis modestly supported domain specificity for motivation and engagement (2 = 16,497.26 df = 7,854, RMSEA = .025). Further confirmation of domain specificity for motivation and engagement was the studyÕs finding that science motivation and engagement correlates significantly more strongly with science educational constructs than with mathematics or English educational constructs (FIML χ 2 = 7823.40, df = 2854, RMSEA = .031).

A strength of Green et al.Õs (2007) research is their mention of various recent findings in the field which informed decisions for their criteria and desig

(2007) research is their mention of various recent findings in the field which informed decisions for their criteria and design

n. Another strength is the finding that interventions must be domain specific as indicated by the correlational analysis. A weakness of the study, is the two-thirds ratio of males in the participant pool. The male majority decreased the external validity and the reliability that the same research findings would be found in any school.

Weisgram and Bigeler (2007) investigated the effect of gender discrimination education on girls' interest and self-efficacy beliefs in science. One hundred fifty eight middle school aged girls ranging in age from 11 to 14, elected to participate in an intervention program aims at increasing girls' interest in science. Participants attended a 1-day conference entitled "Expanding Your Horizons" which entailed hearing presentations from female scientists. A treatment group attended a 1-hour presentation outlining the ways that sexual discrimination affects female scientists today. Pre and post assessment measures included questionnaires on perceptions of gender discrimination, task-specific attitudes, interest in science, estimated proportion of women in science, and cognitive and affective reactions to the discrimination lesson.

ANOVA statistical analyses were performed to compare pre and post test measures. No statistical significance was found across conditions for any of the measures. Participants in the discrimination group reported significantly greater self-efficacy after the participation in the gender discrimination workshop ($F(1,44) = 9.34$, $p<.05$). Seventy-one percent of participants in the discrimination treatment group stated that "This session made me feel like I should become a scientist because I can fight discrimination." Egalitarian beliefs also increased significantly in the discrimination treatment group ($F(1,136)= 2.95$, $p<.05$).

A strength of Weisgram and Bigeler's (2007) study was their accommodations for control and treatment groups to experience analogous dependent variables. This increased the internal validity of the study and the likelihood that the findings are caused by the researchers' treatments. Weisgram and Bigeler (2007) did not, however, include a detailed description of the content or context of the discrimination workshop, which decreases the objectivity and external validity of the study.

Yilmaz, Turkmen, and Pederson (2008) investigated fourth graders' perceptions about science teachers and science teaching in a qualitative research design. Participants were 112 fourth grade students from western primary middle schools in Turkey. The final sample consisted of 55 fourth-grade students (34 female, 21 male). Yilmaz et al. (2008) gave students a modified Draw-A-Science-Teacher-Test (DASTT) and were prompted to "draw a picture of your science course including teacher and students." Additionally, researchers asked participants the question, "How should your science and technology course be?"

In the students' drawings, science topics were most often related to chemistry. Most of the teachers were female and were smiling. Outdoor learning environments, individual learning environments, crest-shaped desk arrangements, dramas, lab safety, facial-haired male teachers, and science exhibitions were not seen or rarely drawn. A chart of the frequency of categories in the DASTT showed a normal distribution. Students depicted teacher-centered learning environments more often than student-centered learning environments (25.4% and 18.2%, respectively). Data analysis consisted of tabulating the number of responses for each category and their attributes using the DASTT. Stereotypic elements of participants' drawings were counted in order to create a checklist score from 0 and 13.

A strength of Yilmaz et al.'s (2008) study is its use of a surveying method that generates authentic student voice. Students' work is used as a source of evidence of stereotypes and other perceptions. This limits the impact of researcher interpretation on data that is gathered. A weakness of their study is the small sample size. It also does not report any data and in that way it is a qualitative analysis, rather than a mixed methods study which it purports to be.

Shapka and Keating (2003) studied girls' achievement and course choice after participation in single-sex science classrooms in a longitudinal quantitative study. Participants of the study included 57 girls from single-sex classrooms, 51 coeducational girls from the target school, 123 coeducational boys from the target school, and 121 coeducational girls from the comparison school. Students ranged from Grades 9-11 and attended two public high schools in Ontario, Canada. Students were required to have at least a 70% average in math class. Students in the target school participated in one year of single-sex science and math classes with no curriculum, teaching, or size differences from the comparison school.

Shapka and Keating (2003) analyzed the effects of the sex segregated science classes on achievement and attitudes, while controlling for preexisting characteristics. Researchers examined seven math-related outcomes because math is considered a pre-requisite for science ability. Questionnaires were administered before and after students participated in sex-segregated math and science programs and they examined math and science achievement math and science course enrollment, perceived math anxiety, perceived math competence, and effort expended in math.

Class condition had a significant affect on achievement in math and science, and class enrollment ($p<.001$) $F(8,1436) = 7.80$. Girls in single-sex classrooms achieved in science and math at a higher rate than girls in the control group (difference = -4.90, $p< .01$, and -4.66, $p< .01$). Girls in the treatment group also took more math courses (difference= -.09, $p< .01$) and science courses (difference= -.15, $p< .001$) than girls in the control group.

A strength of Shapka and Keating's (2003) research design was their use of pre and post assessments, which increased the reliability that their findings were an effect of the treatment and not something extraneous. This study also used a comparison to mitigate the effects on sex ratios in control classes from the removal of girl students.

Shapka and Keating's (2003) research design does not account for the novelty effect of pulling students out of regular classes for a sex-segregated math and science class. A similar study on single-sex classes for boys should be performed in order to see if results were gender or situation specific. Another weakness of the study is that segregating students by sex has a lot of social-psychological.

Johnson and Winterbottom (2011) examined the effect of peer and self-assessment in a single-sex science classroom on learning. Researchers performed a pre-assessment on mastery goal orientation before the treatment in a single-sex science class. Students were grouped into a single-sex science class for over 22-months. Assessment for Learning (AFL) strategies were implemented through group work and with context driven, open-ended tasks.

Mean mastery goal orientation scores decreased between pre and post assessment ($p < .01$). Researchers made note of various qualitative data to explain the surprising results. Students reported feel negative about self-assessment, lacking confidence in own assessment abilities, and not trusting the assessments of peers.

Johnson and Winterbottom's (2011) findings have limited reliability because of a small sample size, the absence of a control group, and a lack of explicitness about the context and content of the science curriculum treatment. The study has dependability issues as the findings are inconsistent with similar research on single-sex science instruction that produced statistical support for single-sex science instruction (Shapka and Keating, 2003). Researchers were however, explicit about the limitations of their findings, which demonstrates objectivity in their research methods.

Weinberg, Basile, and Albright (2011) investigated the effects of a summer enrichment program on students' motivation and attitudes toward science learning in a mixed qualitative and quantitative research design. Participants in the study consisted of 336 middle level students who attended a mathematics or science summer enrichment program in 2008 or 2009 at one of four cooperating higher education institutions. Participants sampled were 158 male and 176 female students, with 180 students being from minority ethnic groups and 153 students from non-minority groups. Weinberg et. al (2011) used a variety of data collection methods including the Science and Mathematics Student Motivation

Assessment (SMSMA) for a pre and post-test, a student interview guide and an instructor online questionnaire. The SMSMA pre-test was administered on the first day of the summer enrichment program.

Weinberg et al. (2011) found that students interest in science increased significantly after participation in the summer enrichment program ($z=2.54$, $p=.01$). Researchers also found significant increases in students' perceived usefulness of science ($t(332) = -2.59$, $p= .01$), the importance of science in how students define themselves ($t(331) = -2.05$, $p= .04$), and expectations for future success in science, $t(154)= -2.39$, $p= .02$).

Weinberg et al.'s (2011) study has some notable strengths. The current study offered rationale for researchers' choice of methods, and the Cronbach's alpha on that was performed on assessment instruments for to determine their reliability. Researchers also presented the theoretical framework and assumptions with which they approached their research design. A weakness of Weinberg et al.'s (2011) study is the low reliability that the significant findings are a direct result of participation in a summer enrichment program and not another variable that is unexplicated.

Robinson and Gillibrand (2004) examined achievement differences by gender in single-sex classrooms in a mixed qualitative and quantitative research design consisting of 170 high school students in England. Students in the study participated in a year of sex segregated science instruction comparing three groups; a single-sex boys' science class, a single-sex girls' science class, and a mixed sex science cohort. Students were further delineated as being either high set (high achieving) or low set (low achieving) science students. The treatment consisted of one year of sex segregated science instruction. Previous year grades, SAT scores, and other measures were used as a pre-assessment.

After a year, students were surveyed about their preference for single or mixed teaching, and for their self-conceptions about their competence in science, and their grades were assessed over the course of their high school studies. Qualitative data was collected through teacher and participant interviewing. Robinson and Gillibrand (2004) separately asked teachers and students to comment on their experiences.

Robinson and Gillibrand (2004) found that low set boys ($t= 2.29$, $p= 0.025$) and low set girls ($t= 2.48$, $p= 0.016$) earned lower grades following single-sex teaching. The only group that earned higher grades after single sex teaching were the high set girls ($t=6.76$, $p < 0.0001$). A strength of this study is the high confidence interval that researchers used to assess their statistical findings. A weakness of Robinson and Gillibrand's study is that the teacher practice and curriculum involved in the single-sex classrooms were not discussed.

The previous section highlights research on student engagement as correlated to teaching, instructional methods, and the learning environment. Teaching practices that were self-reflective, innovative, and student centered, were found to correspond with more teacher effectiveness and student self-efficacy and engagement (Bartolome et al., 2012; Bolshakova et al, 2011; and Yilmaz et al., 2008). Classroom instruction that included discrimination education, integrated computer technology, and science literacy, were shown to increase grades, attendance, and knowledge of science (Delen and Bulut, 2011; Guzzetti and Bang, 2011; Mayer- Smith et al, 2000; Weisgram and Bigeler, 2007). Sex-segregated classroom instruction was found to increase the achievement of high set female students while decreasing the achievement of low set male and female students in one study (Robinson and Gillibrand, 2004). In another study, single sex instruction was found to decrease female students' mastery in a measure independent from students' previous achievement (Johnson and Winterbottom, 2011). Other instruction that was found to increase engagement was a summer enrichment program, and an afterschool "Investigators Club", indicating that science learning experiences outside of the school day can positively impact regular classroom learning. (Grolnick et al., 2007; Weinberg et al., 2011.

Goal Orientation

The following section describes current research on the learning goals and aspirations of secondary students in the sciences. Goal orientations including motivations, learning goals, and beliefs about future possible selves, are examined in order to explain the divergence of interest in the sciences for female secondary students. Chen and Pajares (2010) quantitatively researched 508 students to investigate theories of ability and science motivation in sixth grade students from a suburban public school in the Southeastern US. Chiu (2010) examined the effects of science interest and environmental responsibility on science aspirations and achievement in a correlation quantitative research design using data from the 2006 Program for International Student Assessment (PISA) of 398,750 15 year olds from 57 countries. Blackwell, Trzesniewski, and Dweck (2007) conducted research to explore the role of implicit theories of intelligence on adolescents' mathematics achievement in a mixed methods qualitative and quantitative research design, with a participant pool of 373 7th graders from a public secondary school in New York City. Riegle-Crumb, Moore, and Ramos-Wada (2010) surveyed 15,000 high school sophomores to investigate the interaction between gender, race, and career choice in STEM fields. In a correlational analysis of nearly 400,000 fifteen year olds from 57 countries, Sikora and Pokropek (2012) found that girls and boys differed in their interest in science career fields and that girls had lower science self-concepts than boys. Pajares, Britner, and Valiante (2000) researched the relationship between achievement goals and self-beliefs in a quantitative analysis of 281 students in grade seven from four public middle schools in the Southern, US. Sevinç, Özmen, and Yiğ it (2011) performed a quantitative correlational study to examine the relationship between motivation and science learning in a study of 518 middle school students in Turkey.

To study theories of ability and science motivation in sixth grade students, Chen and Pajares (2010) quantitatively researched 508 students from a suburban public school in the Southeastern US. Participants included 97 Asian students, 242 White students, 83 Black students, 51 Hispanic students. Twenty-eight percent of participants qualified for free and reduced lunches. Three percent were enrolled in ESOL.

A 73-item self-report survey was administered to students during the fall semester of the academic year. Motivation variables were assessed using a 6-point Likert scale for the following measures: implicit theories of ability, epistemological beliefs, science grade self-efficacy, science achievement goal orientations, and self-efficacy for self-regulation.

Chen and Pajares (2010) found that holding the view that scientific knowledge can be increased had significant effects on sophisticated epistemological beliefs ($B= .297$, $t= 7.39$, $p<.0001$). Holding the view that science ability is fixed had direct effects on naive epistemological beliefs, including the belief that knowledge originates in external authorities ($B= .213$, $t=8.76$, $p<.0001$), and the belief that knowledge does not evolve ($B= .305$, $t= 7.59$, $p<.0001$). Boys reported stronger views about the incremental nature of science ability than did girls ($M=4.8-4.5$).

Two strengths of Chen and Pajares (2010) study are the relatively diverse participant population, and the large sample size. A weakness is a lack of objectivity about the students' classroom and curricular context while the study took place.

Chiu (2010) examined the effects of science interest and environmental responsibility on science aspirations and achievement in a correlation quantitative research design. Researchers used data from the 2006 Program for International Student Assessment (PISA), which is a survey on the science, math, and reading knowledge of 15-year students internationally. PISA data also include students' background information. Chiu (2010) analyzed four measures; science Interest, development of the natural environment, science aspiration, and science achievement.

Statistical analysis was performed using LISREL 8.72 software. MANOVA was used to explore gender differences on the four student measures. Chiu (2010) found gender differences in the four measures ($F(4, 398745)= 532{,}537$, $p<.05$). Boys showed higher science interest and higher aspiration than girls ($F(4, 398748) = 488.206$) and ($F(4, 398748) = 1153.822$, $p<.05$). Girls show higher environmental responsibility than boys ($F(4, 398748)= 1153.822$, $p <.05$) There were no differences in science achievement ($F(4, 398748)= 0.0$, $p>.05$)

A strength of Chiu's (2010) study is the large data sample derived from the most recent PISA survey. The large international participant population creates reliability in the findings and increases the external validity. A weakness of the study is that Chiu (2010) cannot ensure internal validity of findings, which may be impacted more by cultural sexism than gender.

Blackwell, Trzesniewski, and Dweck (2007) conducted research to explore the role of implicit theories of intelligence on adolescent's mathematics achievement in a mixed methods qualitative and quantitative research design, with a participant pool of 373 7th graders from a public secondary school in New York City. The participant population was varied by socioeconomic status, ethnicity, race, and achievement. 53% of the student group were eligible for free and reduced lunches. Blackwell et al. (2007) followed four waves of entering high school students. Implicit theories were measured using an integrated causal model to link achievement related beliefs and actual achievement outcomes. Implicit theories and other achievement related theories were measured at the outset of junior high and as they progressed through seventh and eighth grades.

At the beginning of fall term, students filled out a motivational questionnaire assessing theory of intelligence, goals, beliefs about effort, and helpless versus mastery oriented responses to failure. Each year at the end of spring quarter, math scores were obtained for all seventh and eighth-grade students participating in the study. Researchers examined a correlation between theories of intelligence, learning goals, effort beliefs, and helpless response to failure measures at the onset of junior high, with math grade outcomes at the end of fall and spring semesters as participants progressed from seventh to eighth grades. Blackwell et al. (2007) referred to research measures as indicating participants' trajectories of achievement over the junior high school transition.

The current research found that an incremental theory of intelligence was positively associated with positive effort beliefs, learning goals, low helpless attributions, and positive strategies ($z=2.04$, $p<.05$). Theory of intelligence and other motivational variables measured at the beginning of seventh grade were not significantly correlated with prior math test scores and thus were not correlated with ability or achievement.

A strength of Blackwell et al.'s (2007) research is their explication of the theory and process they used with which to create their statistical models. Thus the study has strong external validity because the research pathway is clear. Researchers also performed detailed analysis of participants' prior academic performance in order to increase the internal validity of their findings to ensure that results are effects can be attributed to the researched variables. Researchers did not make their reasons for school or classroom choice explicit, however. Another weakness of Blackwell et al.'s study is that participant selection was not explained nor were the considerations made for randomness of the sample population.

Sikora and Pokropek (2012) examined gender differences in career choices and self-confidence in a correlation qualitative analysis using data collected from the 2006 Program for International Student Assessment. Participants were nearly 400,000 15-year olds from 57 countries whose PISA data was analyzed using two-level random intercept models of linear form. Sikora and Pokropek (2012) studied the relationship between the dependent variables of science self-concept, expectation of employment in biology, agriculture, or health (BAH), and expectation of employment in computing, engineering, or mathematics (CEM), and the independent variables of gender, and science performance. Researchers found that girls outnumbered boys in planning careers in BAH fields in every country included in the survey (For advanced industrial countries, girls: 26%, boys: 9%; for transforming and developing countries, girls: 25%, boys: 11%). Oppositely, Sikora and Pokropek found that boys were more likely than girls to plan for careers in CEM fields in all of the countries surveyed (For advanced industrial countries, girls: 7%, boys: 21%; for transforming and developing countries, girls: 9%, boys: 23%). These researchers also found nearly universally that girls had lower science self-concepts than boys when controlling for academic performance (For advanced industrial countries, average correlation coefficient: -.30, $p<.05$ for transforming and developing countries, average correlation coefficient: -.11, $p<.05$). These findings coupled with the finding that there is no significant difference between girls and boys achievement in the sciences, suggests that the gap in girls' engagement is related to self-concept and may be differ by area of science.

The current study's strengths are its use of data from an international participant population. A weakness of Sikora and Pokropek's study is the low significance level (

($\alpha=.05$) used for the reported correlation coefficient findings.

Pajares, Britner, and Valiante (2000) researched the relationship between achievement goals and self-beliefs in a quantitative analysis of 281 students in grade seven from four public middle s档溽獬□

chools in the Southern, US. Researchers approached their study with the question, "What is the relationship between achievement goals, motivation constructs, and gender, in middle school writing and science?" The study participants were 281 students in grade seven (139 girls and 142 boys) from racial diverse backgrounds (143 students were African American and 120 students were Caucasian).

Pajares et al. (2000) assessed achievement goals using a scale derived from the Patterns of Adaptive Learning Survey (PALS). Writing self-efficacy was measured by students' judgment in their confidence that they could earn an A, B, C, or D in their science class. Additionally, researchers measures science apprehension, self-efficacy for self-regulation, and previous achievement.

MANCOVA results revealed the effect of gender was non significant. Task goals were positively related with expectancy beliefs such as self-efficacy (.21, $p < .001$) and self-concept (.29 $p < .0001$). Performance avoid goals were significantly correlated with apprehension (.26, $p < .0001$). Students with lower achievement in science were more likely to hold a performance-avoid goal orientation ($F(1,255) = 28.15$, $p < .0001$).

A strength of Pajares et al.’s (2000) study was the diversity in the participant population which increases the external validity of the findings. A weakness of the study was a lack of objectivity about the classroom context and curriculum, which could effect the findings.

In a longitudinal, quantitative correlational research design, Riegle-Crumb, C., Moore, C., and Ramos-Wada, A. (2010) surveyed 15,000 high school sophomores to investigate the interaction between gender, race, and career choice in STEM fields. Riegle-Crumb et al. (2010) used survey data from the 2002 Educational Longitudinal Study (ELS). Researchers distinguished between biological and engineering sciences, and non-STEM career fields.

Riegle-Crumb et al. (2010) found no correlation between career choice for racial and ethnic minority groups. They did find that men were significantly more likely to work in engineering than were women ($p<0.01$).

A strength of Riegle-Crumb et al.’s (2010) study was the large sample population for which they made an effort to ensure racial and ethnic diversity. A weakness of the study is the lack of statistical objectivity. Riegle-Crumb et al.

(2010) did not include the data for their statistical analysis in their published paper.

Sevinç, Özmen, and Yiğ it (2011) performed a quantitative correlational study to examine the relationship between motivation and science learning in a study of 518 middle school students in Turkey. Students were surveyed using a likert-scaled, Students' Motivation Toward Science Learning (SMTSL) measure. Researchers performed a two way ANOVA to analyze the concurrent effect of parental education levels and motivation. A Mann Whitney test was used to assess science motivation related to gender, performing laboratory activities, and taking private courses in science.

A Kruskal Wallis test was used to determine the significance of students' motivation level toward science learning according to academic success. Sevinç et al. (2011) found that gender had a significant effect on motivation toward science learning ($p < 0.05$, no R values were reported). Female students performance and achievement goals were higher than males' ($p<0.05$).

The finding that girls had higher motivation toward science learning than their male counterparts is not congruent with other literature that have found no difference between motivation for science learning in boys and girls. While Sevinç et al. (2011) found a significant correlation between gender and motivation for science learning, their failure to report R-values and their relatively low significance interval make their findings less reliable. A weakness of the study was the inconsistent quality of the written article and the lack of distinction between motivation and academic success.

The current section examined research on the correlations between secondary students' future goals, aspirations, and motivations, and their interest in science. Blackwell et al. (2007) showed that an incremental theory of intelligence was correlated to positive effort beliefs, learning goals, low helpless attributions, and positive strategies. In similar research, Chen and Pajares (2010) showed that male science students were more likely than their female counterparts to have an incremental theory of intelligence. Two studies found that male students were more likely to plan for careers in computing, engineering, or math (Riegle-Crumb et al. 2010; Sikora and Pokropek, 2012). Chiu (2010) found that boys had more science interest and that girls had more environmental responsibility. Girls were also shown to more often plan for careers in biology, agriculture, and health, and to have lower science self-concepts than boys (Sikora and Pokropek, 2012). In one study, gender was found to be unrelated to achievement goals (Pajares et al., 2000), while Sevinç et al. (2011) found that female science students had higher performance and achievement goals.

Summary

In chapter two, the gender gap for engagement in secondary science was examined through research into biological factors, self-perception, pedagogy, and goal orientation. This section discussed recent research findings, which have implications for reducing the gap in engagement for female secondary students in the sciences. Weiss et al. (2003) found that female students performed significantly better at memory and verbal tasks than male students, who in turn performed significantly better at visual and spatial reasoning tasks. This finding can be connected to other findings indicating that female adolescent students are more pro-social (Gregory et al., 2009), and empathizing than their male counterparts, who were shown to have cognitive processing that was significantly more systemizing (Zeyer and Wolf, 2010). Academic self-efficacy and self-regulatory self-efficacy were also significantly different according to gender; mastery experiences and social persuasions predicted girls self-efficacy for girls, and vicarious experience predicted self-efficacy for boys (Usher and Pajares, 2006).

Sikora and Pokropek (2012) found that secondary science students from 57 countries had gender differences in career planning, with male students more often planning for science careers in computing, engineering, and mathematics (CEM), and girl students more often planning for science careers in biology, agriculture, and health (BAH). Riegle-Crumb et al. (2010) also found that boys were more likely to aspire to careers in CEM fields. Their finding is congruent with the previous finding in that CEM careers could be seen are more systemizing, with careers in BAH being more empathizing. It also has implications for Chiu’s (2010) finding that boys had more science interest and that girls had more environmental responsibility.

A finding by Leaper and Brown (2008) may explicate the difference in career choice across genders. They found that 52 percent of female adolescents experienced discrimination about their abilities in science, mathematics, and computing. Self-efficacy in terms of computing ability was found to be predicted by gender with female students reporting significantly lower self efficacy in terms of their computing ability (He and Freeman, 2010). This study also found that female participants reported less experience with computers and technology than male participants, and after controlling for previous experience, no difference in self-efficacy across genders was found. Delen and Bulut (2011) found that exposure to information processing technology outside of school had a positive impact on performance in school.

Interestingly, some research indicated no difference across genders in measures of motivation to learn science (Zeyer and Wolf, 2010), and achievement motivation (Pajares et al., 2000), while Sevinç, Özmen, and Yiğ it (2011) found that female students were significantly more motivated than male students in their achievement motivation and motivation for science learning. Similarly, Buday, Stake, and Peterson (2011) found no significant difference in science interest across genders, while Simpkins, Davis-Kean, and Eccles (2006) found evidence of higher course enrollment, grades, and activity participation for male secondary students; which was confirmed by Chiu (2010). The conflicting findings show that gender does not always predict the interest and motivation of secondary science students.

Research in engaging science pedagogy yielded the findings that teaching practices that were self-reflective, innovative, and student centered, corresponded with student self-efficacy and engagement (Bartolome et al., 2012;

Bolshakova et al, 2011; and Yilmaz et al., 2008). Classroom instruction that included discrimination education, integrated computer technology, and science literacy were shown to increase grades, attendance, and knowledge of science (Delen and Bulut, 2011; Guzzetti and Bang, 2011; Mayer- Smith et al., 2000; Weisgram and Bigeler, 2007). This finding aligns with the previously discussed finding that female adolescents have less information and communication technology (ICT) exposure at home, and that increasing the ICT instruction in school incurs a positive impact on math and science grades (Delen and Bulut, 2011; He and Freeman, 2010). In one study, sex-segregated classroom instruction was found to increase the achievement of high set female students (Robinson and Gillibrand, 2004), while in another study, sex segregated instruction decreased female students' mastery independent from previous achievement (Johnson and Winterbottom, 2011). Science learning experiences outside of the school day such as summer enrichment programs, and after school clubs were shown to positively impact regular classroom learning (Grolnick et al., 2007; Weinberg et al., 2011).

Historically, biological differences have been cited as a way to explain the disparity between men and women working in the sciences. The current research literature suggests rather an interaction between pedagogical, biological, and sociological factors that evidences differences in science interest between the sexes. The conflicting findings of the differences between male and female students' motivation and interest, indicate that a broad statement about gender and interest in secondary science is impossible. It is thus preferable to examine individual students' histories to understand the biological, sociological, and pedagogical influences on their interest or disinterest in the sciences. This is support by Fouad, Hackett, Kantamneni, Fitzpatrick, Haag, and Spencer, (2010), who found that low level science students reported more barriers and less supports in their science learning, demonstrating the importance of individualized and differentiated supports in a student's environment.

Chapter Three provides a summary of the findings, discusses the implications for teaching, and makes suggestions for further research.

CHAPTER THREE: CONCLUSION

Introduction

Historically, biological differences were given for women's lack of equal representation in science education and careers. This ideology has deep roots, stemming from the writings of influential thinkers at the origins of Western society (Behringer, 1985). Within the last half-century however values have shifted to create a more equal picture of intelligence and ability across the genders. Women now comprise half of the workforce in the United States, and are seeking degrees in higher education at higher rates than men. Chapter 3 draws conclusions from the literature presented in chapter 2, makes recommendations for classroom implications, and provides suggestions for future research to increase engagement for female students in science.

Summary of Findings

What influences the gap in engagement and interest for female secondary science students? With women underrepresented in STEM career fields, (Halpern et al., 2007) insights found through research at the secondary science level are imperative. A summary of findings are presented from four areas of research on female secondary students' science engagement; biology, self-perception, pedagogy, and goal orientation.

Biological Factors

In the current research review three studies presented the gap in engagement for female secondary science students as resulting from gender differences in cognitive processing styles, brain quotient, and pro-social behavior. Weiss et al.'s (2007) finding that males outperformed females at spatial rotation tasks is supported by literature going back three decades (Vanderberg & Allan, 1978). The cognitive processing difference that Zeyer and Wolf (2010) identified, that females score higher on empathizing quotients and males score higher on systemizing quotients, is consistent with the theory that men and women have different cognitive processing styles. The attribution of biology for these cognitive processing differences, however, has been more recently challenged by research in developmental psychology and epigenetics. Research in both fields has provided many examples of the influence of the environment on development, even at the level of genetic expression (Perry & Pauletti, 2011). This research supports the view of development as involving a wider variety of factors beside biology and genetics. An individual can therefore not be understood outside of their social and cultural context. Similarly the finding that women exhibit greater pro-social tendencies (Gregory et al., 2009) cannot be attributed to female biology alone. Pro-social behaviors are developed through the environmental influences and socialization (Gregory et al., 2009). Thus biological differences between female and male secondary science students must be considered within their social context.

Self-Perception

Research on adolescents' science self-efficacy and ability beliefs has yielded further evidence of the effect that gender socialization has for females on engagement in science. Ninety percent of adolescent girls surveyed by Leaper and Brown (2008) had experienced sexual discrimination and 52 percent had been discouraged with regards to their math, science or computing abilities. Similarly, He and Freeman (2010) found that gender was a strong predictor for computer self-efficacy with females who scored statistically lower on measures than males. The implications of discriminatory social norms and the self-concepts that they breed, are revealed in Simpkins et al.'s (2006) finding that science ability beliefs during fifth and tenth grades correlate to grades and class choice in high school.

It is possible that the impact of gender discrimination in science is especially pernicious for female adolescents, whose self-efficacy has been shown to correlate to social persuasions (Usher & Pajares, 2006). Fouad et al. (2010) showed that students' perceived experiences either hindered or advanced their choice in education and careers. Similarly, supportive social and family environments have evidenced a positive impact on career perceptions and science possible selves for adolescent females (Buday et al. 2011). Research aimed at the engagement of female adolescents in science puts a focus on the environment surrounding the student, her school and home culture and community, as a powerful influencer of self-perceptions and beliefs.

Pedagogy

A review of research on teaching instruction that increases female science students' engagement surrounds a few prevalent themes. Sexually-segregated instruction, technology enhanced instruction, and science learning experiences outside of regular school, are the three most effective frameworks for engaging girls in science.

Shapka and Keating (2003) found that girls who participated in a year of single sex science class took more science courses and achieved higher in future science classes on average than their peers in coeducational science classrooms. Additionally, Robinson and Gillibrand (2004) found that high achieving girl students in single sex science classrooms earned significantly higher grades compared to their peers in mixed classrooms. These studies suggest strengths in single sex instruction, especially for high achieving adolescents girls. For low achieving girls, however, the research suggests that single sex instruction can be detrimental to their learning and can lead to a decrease in mastery goal orientation (Johnson & Winterbottom, 2011; Robinson & Gillibrand, 2004). The varying effectiveness of single sex instruction points to a need for differentiated instruction for all learners. While low achieving students were not successful in a sexually segregated classroom, Guzzetti and Bang (2011) showed that literacy-based instruction increased chemistry knowledge and inquiry skills in a subset of low achieving students. Differentiating to meet students' needs is therefore essential for engaging a diversity of female adolescents in science.

Increased exposure to technology at home and in a summer enrichment program was shown to increase grades (Delen & Bulut, 2011) and engagement for girls (Mayer-Smith et al., 2000). An after school program studied by Grolnick et al. (2007) which emphasized scientific learning and inquiry using technology, showed an increase in student engagement and grades. Similarly, Weinberg et al. (2011) found that their summer enrichment program, which was inquiry intensive, increased students' interest, engagement, perceived usefulness, and expectations for future success. These studies support the notion that students will be successful in science class when they have had experience using the technology and inquiry skills that they need. For adolescent girls, an un-discriminatory, supportive, social science experience is vital for building positive experiences with scientific inquiry. These experiences should be focused on building confidence in science, because though female students' achievement is matched with their male counterparts, female adolescents' self-efficacy and beliefs about their abilities is significantly lower (Chiu, 2010; Sikora & Pokropek, 2012). Technology enhanced instruction is especially important for female students who are significantly less likely than men to seek higher education and work in engineering and technology fields (Riegle-Crumb et al., 2010).

Bolshekova et al. (2011) published promising findings to engage students in science with effective teaching practice. They found that student self-efficacy, beliefs, and achievement were correlated to teacher effectiveness. Bartolome et al. (2012) found similar findings in a qualitative case study of a career teacher's developing effectiveness through self-reflective, critical teaching practice. Both studies align with pedagogical theory aimed at self-reflective teacher practice and differentiated instruction to meet individual students' learning needs.

Goal Orientation

The ability to articulate learning goals is an important metacognitive step in the process of learning. The goal setting, motivations, and science aspirations of female science students will be discussed in this section. Pajares et al. (2000) showed that the goals of secondary science learners were mediated by expectancy beliefs; what they expected to achieve by doing a certain task. They also found that expectancy beliefs for students depended on self-efficacy and self-concepts. As was previously discussed, 52% of adolescent females have been the recipients of discriminatory statements about their abilities in science (Leaper & Brown, 2008). Pajares et al.'s (2000) finding that such beliefs mediated goal setting, suggests significant sociopsychological obstacles for female secondary students to believe in their abilities and set goals for future success in science.

Sevinc et al. (2011) found that adolescent girls were significantly more motivated toward academic success than boys in science. Surprisingly, Chiu (2010) found that boys had higher science interest and aspirations. It is possible that these findings suggest that while girls are more motivated to succeed, they are less interested in the subject than they are in earning good grades. This might be related to stereotype threat; so as not to confirm negative stereotypes about girls' abilities in science, female students are more motivated to achieve at a high level. Chen and Pajares (2010) found that boys significantly more often held the belief that science knowledge can increase and is not fixed. This suggests that female students more frequently attributed science knowledge to being inherent in the individual. Holding the epistemology that knowledge is fixed poses an additional obstacle for females in secondary science, because this view can be discouraging and prevent the individual from learning new things. Likewise, Blackwell et al. (2007) found that an incremental theory of intelligence was associated with positive effort beliefs, learning goals, low helplessness, and positive strategies for learning. The current research suggests that female secondary science students are thus dealing with a subject in which they are highly motivated, but are not highly interested, and do not believe that increasing learning will increase their understanding because knowledge is fixed.

Using data from the Program for International Student Assessment (PISA, 2006), SIkora and Pokropek analyzed career goals for fifteen-year-old students from 57 countries and found that gender differences for science careers were significant. Female adolescents were significantly less likely than males to plan for careers in the “hard” sciences such as computing, technology, and engineering (For advanced industrial countries, girls: 7%, boys: 21%; for transforming and developing countries, girls: 9%, boys: 23%). These findings among the others listed above, suggest that female science students’ self-perceptions, socialization forces, learning and schooling experiences, and goal orientations, are having a significant impact on what they believe they can become and achieve. The missed opportunity caused by the unequal participation of women in the sciences is truly unjust and has no place in society today.

Classroom Implications

In order to create equitable opportunities for female students to engage and excel in science, changes to classroom and curriculum need to be informed by findings from the current research literature. Curriculum must be targeted at addressing students' self-perceptions and community and societal biases, and at creating interesting, differentiated curriculum that forces all students to engage and participate. This is supported by research indicating a high prevalence of discriminatory beliefs about female secondary students abilities in the science (Leaper and Brown, 2008). Many of the suggestions in this section are influenced by research about engaging girls in science, but can also be applied to engaging racial and ethnic minority students in science. This is because making changes to increase equity in the classroom has the effect of creating equal learning opportunities for all students.

It is necessary for teachers to challenge the unconscious biases held by female secondary science students about their beliefs and abilities. More than half of adolescent girls experience discrimination about their abilities in sciences (Leaper and Brown, 2008). Female secondary students have also been to shown to have lower science self-concepts than boys (Sikora and Pokropek, 2012). This indicates that teachers must educate the entire learning community about the impact of such discriminatory beliefs and challenge the misconceptions that fuel discrimination. Teachers can also challenge biases by using examples and showing pictures of female scientists and by being mindful of gender pronouns that are used in class. An example of this is refraining from addressing a class of mixed gendered students as "Guys."

Classroom teachers also need to solicit the help of students' communities to challenge the stereotypes and biases that girls are receiving at home about their abilities in science. Inviting parents into the classroom to participate, and communicating by phone or letter about their daughter's achievements in science, will help break down unconscious biases that girls receive from home about their science abilities. This is supported by Fouad et al. (2010), who found that advanced science students experienced greater supports and less barriers than low level science students. Secondary science curriculum needs to explicitly challenge stereotypic beliefs by educating entire communities about the equal abilities of female students in science.

Some research has shown that single sex class structures can be beneficial for increasing the achievement of high set female students in science (Robinson and Gillibrand, 2004; Shapka and Keating, 2003). While sex segregation is not usually possible in public school, single sex instructional grouping can be accomplished in most classes. Single sex groups in science class can diminish the social pressures that high achieving girls face when their behavior confirms or breaks from gender stereotypes. Some research suggests that sex segregated instruction is not beneficial for low achieving students

(Johnson and Winterbottom, 2011). In those cases, teacher supports must in place to either create heterogeneous groups or adapt learning materials to increase student success.

Considerate teaching and best practices are necessary when teachers attempt to challenge and remove barriers to success for girls in science. Creating equal opportunities for every student in science does not mean treating every student the same. Differentiated instruction is necessary because students enter the classroom with different cultural backgrounds, language, self-concepts, goals, and barriers to their success. A considerate teacher is aware of a student's unique strengths and challenges and helps them to navigate their learning. Green et al. (2007) found that adolescent motivation was content specific. This research finding indicates that teachers should engage students by integrating student interest into the classroom learning.

Technology enhanced instruction has been shown to have a positive impact on the learning of female secondary science students (Mayer-Smith et al., 2000). This group has been shown to have less information and communication technology experience, which has been correlated with better grades in math and science (Delen and Bulut, 2011). Also shown to increase science knowledge is literacy-enhanced instruction (Guzzeti and Bang, 2011). The instructional emphasis on science literacy moves away from traditional lecture and lab based science instruction, which privileges one type of learner, and thus provides learning opportunities for students with varied learning styles. Science enrichment programs and after-school science clubs have been effective at increasing science interest and engagement in the regular science classroom (Grolnick et al., 2007; Weinberg et al., 2011).

Teachers and students benefit from self-reflection and metacognition about the process of teaching and learning (Bartolome et al., 2012). Metacognition, or the awareness of one's own thinking processes, would help female science students to be aware of their theories about knowledge. Research has shown that female secondary students are unique in thinking that science knowledge is fixed and cannot be increased (Blackwell et al., 2007). Metacognition about the learning process would help female science students to have more understanding about their learning to help them identify their own strengths and challenges, and the best strategies for continued learning. Teachers must also be metacognitive to ensure that they are being innovative, have relevance, and connect their teaching to their own and students' real life experiences (Bolshakova et al., 2011).

Finally, teachers should help female science students to develop science possible future selves. This is supported by research suggesting that female secondary students do not plan for careers in computing, engineering, and mathematics (Riegle-Crumb et al. 2010; Sikora and Pokropek, 2012). By being transparent, challenging stereotypes and biases, and teaching students to be metacognitive about learning, teachers can alter female students beliefs about their abilities in science and the possibilities for careers in science in the future. The impact of a supportive environment is powerful and can have a lifelong impact. Teachers can instruct and model self-reflection, the ability to challenge biases, and can teach the codes for success in science.

Societal and cultural norms for behavior shift over time and we are on the doorstep of such a change for women in science education right now. The way that change begins is in the daily grind; teachers making change happen student by student, and day by day in the classroom.

Suggestions for Further Research

Based on the current literature review, more research needs to be targeted at specific instructional strategies that engage female secondary science students. While literacy enhanced instruction was shown to increase learning and interest for all students (Guzzeti and Bang, 2011), specific findings on the impact for female students specifically are still needed. Pedagogy that is involves social and active learning, and creates opportunities for female students to have leadership roles, is also supported by the literature (Gregory et al. 2009; Usher and Pajares, 2006; Sikora and Pokropek, 2012).

Curriculum that teaches students about the history of discrimination in science should also be investigated for its impact on learning communities of mixed gender students, their families and teaching staff. This is supported by Weisgram and Bigeler’s (2007) finding that female adolescents experienced increased self-efficacy and interest in science careers after participating in a history of discrimination against women in science workshop. Antidiscrimination education is necessary for the entire community in light of the finding that male peers were most often the perpetrators of discriminatory remarks about female students abilities in science, math an computing (Leaper and Brown, 2008).

Future research should be aimed at correlating female students' science engagement and achievement to sexual discrimination in classroom, school, and home cultures. While many factors were examined in the research literature to explain a gap in female adolescents engagement in sciences, few studies directly examined the impact of sexual discrimination on ability in science. This issue should not be in the shadows of researchers examinations of gender differences, but rather at the forefront. This is indicated by Leaper and Brown's (2008) finding that more than half of female adolescents experienced discrimination about their abilities in science, math, and computing, solely because of their gender.

Conclusion

Chapter one provided a historical background for examining the differences in engagement for female students in secondary science. Chapter two was a critical review of the literature regarding the biology, self-perception, pedagogy, and goal orientations of female secondary science students. Finally in chapter three, pedagogical best practices are offered addressing some of the factors influencing the gender difference in science engagement. The following topics were implicated in the literature as having an impact on engagement for female secondary science students.

Interest in Science

Buday et al. (2011) found that there was no difference between the genders in measures of science interest. Oppositely, it was found in two studies that male students were more interested in science learning (Chiu, 2010; Sevinç, 2011). These contradictory findings indicate that there is no conclusive measure of science interest across genders.

Motivation for Science Learning

Researchers found that motivation was content specific (Green et al., 2007) and there was not a gender difference in motivation to learn science (Zeyer and Wolf, 2010). Further, Pajares et al. (2000) found that achievement goals were not predicted by gender

Self-Efficacy

Sikora and Pokropek (2012) found that science self-concepts were lower for female students, than for male students, in a measure of nearly 400,000 fifteen year olds from 57 countries. Simpkins et al. (2006) found that science ability beliefs in middle school affected future class choice in high school.

He and Freeman (2010) found that gender was a significant predictor of computer self-efficacy (CSE) with female students having lower CSE. These findings implicate the importance of self-efficacy in increasing female students' engagement in the sciences. This is supported by Pajares et al.'s (2000) finding that task goals are related to self-efficacy. Usher and Pajares (2006) found gender differences in self-efficacy such that self-efficacy for female students was mediated by social persuasions, and self-efficacy for male students was mediated by vicarious experiences. To increase science self-efficacy for female students, science learning environments should thus have a social, interactional aspect.

The Learning Environment

Congruent with the finding that female students' science self-efficacy is correlated to social persuasions (Usher and Pajares, 2006), Gregory et al. (2009) found that female adolescents were more pro-social than their male counterparts. Similarly, Zeyer and Wolf (2010) found that females were more empathizing in their cognitive processing, while males were more systemizing. Both of these findings indicate that female adolescents have strong social tendencies in their cognitive processing. In order to accommodate a social learning style, the teaching environment must be student-centered and afford opportunities for active, social learning. Yilmaz et al. (2008) studied students' perceptions of science teachers and classrooms. They found that students overwhelmingly depicted teacher-centered classroom environments. Bolshakova et al. (2011) confirmed the effectiveness of innovative, relevant teaching with their finding that self-reflective, progressive teachers were correlated with students' increased self-efficacy.

Incremental Theory of Intelligence

The belief that science knowledge can increase with time and experience, was found to have a positive impact on secondary science student learning. Chen and Pajares (2010) found that boys held stronger views about the incremental nature of intelligence. Similarly, Blackwell et al. (2007) found a difference between the genders on incremental theory of intelligence measures, and that it was correlated with positive effort beliefs, learning goals, low helpless response, and positive strategies for learning. Instruction on theories of intelligence, and metacognition in learning could ameliorate a gender disparity in theories of intelligence. One possible reason for the gender difference in theories of intelligence is the incidence of sexual discrimination about science ability (Leaper and Brown, 2008).

Sexual Discrimination about Science Ability

Fifty-two percent of adolescent females reported experiencing discrimination about their abilities in math, science and computing (Leaper and Brown, 2008). The implications of this widespread discrimination are far reaching. Fouad et al. (2010) found students in advanced science classes in college experience supportive environments and fewer barriers in comparison to students in low-level science classes in college. Adolescent females experiencing discrimination have additional obstacles preventing their achievement in science. Weisgram and Bigeler (2007) found that female secondary science students who underwent a women in science anti discrimination workshop reported increased self-efficacy and interest in science careers. Educating students about discrimination against women in science has strong implications for ameliorating its impact on adolescent female science students. Anti-discrimination education should also be targeted at students' families, communities and male peers, who are often the perpetrators of discriminatory beliefs and remarks.

Technology Enhanced Instruction

Increased exposure to and experience with information and communication technology (ICT) was shown to increase grades in math and science (Delen and Bulut, 2011). In the same study, female students were found to have less background experience with ICT. Mayer- Smith et al. (2000) also found that female students who experienced technology enhanced science instruction attended more science class than female students in the control group. Male adolescents planned for careers in computing, engineering, and mathematics (CEM) at higher levels than female adolescents (Riegle-Crumb et al., 2010; Sikora and Pokropek, 2012). While this indicates greater interest for males in CEM fields, it also indicates that females could benefit from technology enhanced instruction is needed to lessen the gap between genders and careers in CEM fields. Other research indicates that female students learn socially, and thus would require technology-enhanced instruction to be framed in a social learning context (Gregory et al., 2009).

Out-of-School Science Learning

Research indicates that science learning that happens outside of the regular classroom setting can have positive affects on science achievement in school settings. Students who participated in a summer science enrichment program were found to have increased interest, engagement, and perceived usefulness of science and science careers (Weinberg et al. 2011). Grolnick et al. (2007) found that students who participated in an afterschool “Investigators Club” were more engaged and received better grades in their regular science classes. Both of these out of school learning settings provided students opportunities to actively investigate self-relevant questions using scientific inquiry in a social setting. These results also correspond to Fouad et al.’s (2010) finding of the positive impact of supportive science learning environments.

Literacy Enhanced Science Instruction

Guzzeti and Bang (2011) found that literacy enhanced instruction in a secondary chemistry class increased science knowledge and inquiry skills, and increased interest in comparison to a tradition chemistry class. This finding indicates that differentiated, innovative instruction in science is important in order to accommodate all learning styles. It is possible that male students were privileged by the traditional paradigm of science instruction of lectures, and labs, which would fit with the finding that adolescent males have a more systemizing processing style, and more visual and spatial reasoning (Weiss et al., 2003;

Zeyer and Wolf, 2010). Using literacy-enhanced instruction is more equitable because it invites other learning styles to be privileged during certain class activities. Female students were found to have more empathizing processing style and to perform better than males on verbal and memory tasks (Weiss et al., 2003; Zeyer and Wolf, 2010). These psychosocial tendencies might learn better in a science setting that emphasizes science literacy.

Single Sex Instruction

In one study of female secondary science students, sexually segregated classroom instruction evidenced students earning better grades, and choosing more science and math courses in the future (Shapka and Keating, 2003). In another study of sexually segregated instruction, Johnson and Winterbottom (2011) found that female students evidenced less mastery of science content. Robinson and Gillibrand (2004) found that high set female students achieved more during single sex instruction, however low set females and high and low set male students, did not evidence any differences in achievement. Findings for single sex instruction therefore indicate mixed results. The finding that not all groups benefit from homogenous grouping based on gender or achievement indicates the need for differentiated instruction and varied learning environments to meet the needs of a variety of learners.

The culture of the science classroom has a major impact on how students think and feel about science. Across all of the research findings it is clear that the classroom environment reflects societal and cultural beliefs, which are then mediated by the values of the teacher. Research confirms that teachers must be innovative, self-reflective, and non-biased in order to confront gender disparities in self-efficacy and engagement, and the social norms and student self-concepts that fuel those disparities. It is imperative for teachers to directly confront discriminatory stereotypes about groups and students and to be self-reflective and transparent about their own biases. Teacher must also be empirical and gather data about students' individual learning needs and backgrounds in order to equitably teach to them. Without differentiating instruction to the variations in gender, interest, cultural backgrounds, and learning styles, teachers are propagating the status quo, in which differences in engagement for males and females in the sciences originated. It is unjust that the cultural norms of the past should limit students of the present and future to careers that are gender delineated. It is up to families, communities, schools, and teachers to be agents of change, to challenge discriminatory biases and to create an environment of equity and inclusion in the classroom so that children grow up to propagate equity and inclusion in our society and in our world.

REFERENCES

Bandura, A. (1997). *Self-efficacy: The exercise of control.* Freeman: New York.

Bartolome, V. B., Mellado, V., Jimenez-Perez, R., & Taboada Lenero, M. C. (2012). The process of change in a science teacher's professional development: A case study based on the types of problems in the classroom. *Science Education, 96*(2), 337-363.

Behringer, M. P. (1985). *Women in science.* J. B. Kahle (Ed.). Philadelphia: The Falmer Press.

Blackwell, L.S., Trzesniewski, K.H., & Dweck, C.S. (2007) Implicit theories of intelligence predict achievement across an adolescent transition: A longitudinal study and an intervention. *Child Development. 78*(1), 246-263.

Bolshakova, V.L.J., Johnson, C.C., & Czerniak (2011). "It depends on what teacher you got": Urban science self-efficacy from teacher and student voices. *Cultural Study of Science Education. 6,* 961-997.

Buday, S. K. Stake, J. E., & Peterson, Z. D. (2011) Gender and the choice of a science career: The impact of social support and possible selves. *Sex Roles, 66*, 197-209.

Brownlow, S., Jacobi, T., & Rogers, M. (2000). Science anxiety as a function of gender and experience. *Sex Roles. 42*(1-2), 119-131.

Chen, J. A. & Pajares, F. (2010). Implicit theories of ability of Grade 6 science students: Relation to epistemological beliefs and academic motivation and achievement in science. *Contemporary Educational Psychology. 35*

(2010) 75-87.

Chiu, M.S. (2010). Effects of science interest and environmental responsibility on science aspiration and achievement: Gender differences and cultural supports. *Educational Research and Evaluation. 16*(4), 345-370.

Delen, E., & Bulut, O. (2011) The relationship between students' exposure to technology and their achievement in science and math. *The Turkish Online Journal of Educational Technology. 10*(3), 311-317.

Fouad, N. A., Hackett, G., Kantamneni, N., Fitzpatrick, M., Haag, S., and Spencer, D. (2010). Barriers and supports for continuing in mathematics and science: Gender and educational level differences. *Journal of Vocational Behavior. 77*(2010), 361-373.

Green, J., Martin, A.J. and Marsh, H.W. (2007). Motivation and engagement in English, mathematics and science high school subjects: Towards an understanding of multidimensional domain specificity. *Learning and Individual Differences. 17*, 269-279.

Gregory, A. M., Light- Häusermann, J. H., Rijsdijk, F., and Eley, T. C. (2009). Behavioral genetic analysis of pro-social behavior in adolescents. *Developmental Science. 12*(1), 165-174.

Grolnick, W.S., Farkas, M.S., Sohmer, R., Michaels, S., and Valsiner, J. (2007) Facilitating motivation in young adolescents: Effects of an after-school program. *Journal of Applied Developmental Psychology. 28*, 332-344.

Guzzetti B. and Bang, E. (2011). The influence of literacy-based science instruction on adolescents' interest, participation, and achievement in science. *Literacy Research and Instruction, 50*, 44-67.

Halpern, D. F., Aronson, J., Reimer, N., Simpkins, S., Star, J. R., & Wentzel, K. (2007). Encouraging girls in math and science. National Center for Education Research, Institute of Education Science, U.S. Department of Education.

He, J., and Freeman, L. A. (2010). Are men more technology-oriented than women? The role of gender on the development of general computer self-efficacy of college students. *Journal of Information Systems Education. 21*(2), 203-212.

Johnson, N., and Winterbottom, M. (2011). Supporting girls' motivation in science: A study of peer- and self-assessment in a girls only class. *Educational Studies. 37*(4), 391-403.

Leaper, C. and Brown, C.S. (2008). Perceived experiences with sexism among adolescent girls. *Child Development. 79*(3), 685-704.

Ma, Y. (2008) Within-School Gender Gaps in Reading, Mathematics, and Science Literacy. *Comparative Education Review, 52*(3) 437-460

Mayer-Smith, J., Pedretti, E., and Woodrow, J. (2000). Closing the gender gap in technology enriched science education: A case study. *Computers and Education. 35,* 51-63.

Meece, J. L., Anderman, E. M., & Anderman, L. H. (2006) Classroom goal structure, student motivation, and academic achievement. *Annual Review of Psychology. 57*, 487-503

Miller, P.H. (2011). *Theories of developmental psychology* (5th ed.). New York:

Worth.

Page, M. C., Bailey, L. E. & Van Delinder, J. (2009). The blue blazer club: Masculine hegemony in science, technology, engineering, and math fields. *Forum on Public Policy.*

Pajares, F. (1996). Self-efficacy beliefs in academic settings. *Review of Educational Research. 66*(4), 543-578.

Pajares, F., Britner, S.L. and Valiante, G. (2001). Relation between achievement goals and self-beliefs of middle school students in writing and science. *Contemporary Educational Psychology. 25*, 400-422.

Parker, T. C. & Rosenthal, R. (2011). Sustainable equity: Avoiding the pendulum effect in the life sciences. *Forum on Public Policy Online.*

Perry, D. G., & Pauletti, R. E. (2011). Gender and adolescent research. *Journal of Research on adolescence. 21*(1), 61-74.

Riegle-Crumb, C., Moore, C., and Ramos-Wada, A. (2010). Who wants a career in science or math? Exploring adolescents' future aspirations by gender and race/ethnicity. *Science Education, 95*(3), 458-476.

Robinson, W.P. (2004). Single-sex teaching and achievement in science. *International Journal of Science Education, 26*(6), 659-675.

Rossiter, M. W. (1984) Women scientists in America. The Johns Hopkins Baltimore, MD: University Press.

Sevinç, B., Özmen, H., and Yiğ it, N. (2011). Investigation of primary studentsÕ motivation levels towards science learning. *Science Education International. 22*(3), 218-232.

Shapka, J.D., and Keating, D.P. (2003). Effects of a girls-only curriculum during adolescence: Performance, persistence, and engagement in mathematics and science. *American Educational Research Journal. 40(*4), 929-960.

Sikora, J. and Pokropek, A. (2012) Gender segregation of adolescent science career plans in 50 countries. *Science Education, 96*(2), 234-264.

Simpkins, S.D., Davis-Kean, P.E., and Eccles, J.S. (2006). Math and Science motivation: A longitudinal examination of the links between choices and beliefs. *Developmental Psychology. 42*(1) 70-83.

Spring, J. (2010). The American school, a global context: From the Puritans to the Obama administration (8th ed.). New York: McGraw-Hill.

Sterling, S. (2005). Perspectives unit 3. Linking thinking. Scotland: World Wildlife Federation.

Usher, E.L. and Pajares, F. (2006). Sources of academic and self-regulatory efficacy beliefs of entering middle school students. *Contemporary Educational Psychology. 31*,125-141.

Vanderberg, S. G., & Kuse, A. R. (1978). Mental rotations, a group test of three-dimensional spatial visualization. *Perceptual and Motor Skills. 47*(2), 599-604.

Weinberg, A.E., Basile, C.G., and Albright, L. (2011). The effect of an experiential learning program on middle school students' motivation toward mathematics and science. *Research in Middle Level Education. 35*(3), 1-10.

Weiss, E. M., Kemmler, G., Deisenhammer, E.A., Fleischhacker, W.W., and

Delazer, M. (2003). Sex differences in cognitive functions. *Personality and Individual Differences. 35,* 863-875.

Weisgram, E. S., and Bigeler, R. S. (2007) Effects of learning about gender discrimination on adolescent girls' attitudes toward and interest in science. *Psychology of Women Quarterly, 31*, 262-269.

Yilmaz, H., Turkmen, H. and Pederson, J.E. (2008). Evaluating science education reform via fourth-grade students' image of science teaching. *Science Education International, 19*(1), 27-40.

Zeyer, A. and Wolf, S. (2010) Is there a relationship between brain type, sex and motivation to learn science? *International Journal of Science Education. 23*(16), 2217-2233.