Gender Differences In Science Education: How gender has impacted the face of science in the United States

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GENDER DIFFERENCES IN SCIENCE EDUCATION

How gender has impacted the face of science in the United States

Abstract

Historically, there existed a large achievement gap between male and female students in STEM fields in the United States. While this gap has drastically decreased, there are still areas of inequity. Recent data show that males and females now perform equally well on measures of scientific aptitude through twelfth grade and are equally likely to receive bachelor’s degrees. However, men are still more likely to receive bachelor’s degrees in STEM fields, as well as higher degrees in STEM fields. Men are also more likely to have STEM careers.

This inequity appears to be influenced by a wide variety of factors. Biologically, data suggests that females exhibit less overall variance in intelligence and females also tend to have weaker spatial skills; these factors likely influence women’s representation in STEM fields. Sociological factors that impact women’s achievement in STEM fields include the impacts of stereotyping and the tendency to be both pushed away from STEM fields and simultaneously pulled toward other fields. Finally, women have unique challenges to consider when creating a work/life balance.

To address this inequity, a variety of classroom initiatives are proposed. Specifically, teachers can help their students by instilling a belief in the idea of malleable intelligence. Teachers can also work to provide direct instruction on spatial skills to improve students’ STEM ability. All students can similarly benefit from an increased focus on the sociocultural aspects of learning. Finally, teachers can increase equity in STEM fields by providing early exposure to role models from a variety of backgrounds.

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Undergraduate Honors Thesis
Carroll College Department of Education
November 2, 2015
SIGNATURE PAGE

This thesis for honors recognition has been approved for the Department of Education.

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I. Introduction

1.1 Background

As the world is propelled into the 21st century, there is a growing need for students to be competent in the sciences. STEM (science, technology, engineering, and mathematics) education, particularly the technology and engineering pieces, has rightly become an important part of the modern classroom. As summarized by Jacobs, et. al, “for more than half a century, the United States has enjoyed a dominant position intellectually and economically based on the strength of our research in basic sciences and technology;” this dominance is threatened by US students choosing to opt out of STEM courses and careers (Jacobs 91). Preparing students for STEM-related careers is often considered a pipeline because students are directed to academically rigorous courses early in their academic careers that prepare them for higher education and eventual careers in STEM fields. However, this pipeline “has some nontrivial leaks;” women and minorities are disproportionately likely to “leak” out and not pursue STEM careers (Jacobs 90). One reason for this leaky pipeline is that historically there has been a significant achievement gap between men and women in the sciences. This gap has narrowed in many areas but still persists. Assuming that there are no significant biological sex barriers to success, modern educators should be capable of learning specific best-practices to eliminate this gap.

While there has been a multitude of research regarding how gender influences students’ scientific experiences, the purpose of this thesis is to create a cohesive overview of the historical and modern gender distribution in scientific careers, explore the roles
society and biology play in shaping students’ scientific ability and interest, and provide specific recommendations for teachers to create equitable classrooms.

My interest in this topic was piqued in the summer of 2014 when I had the opportunity to assist with a summer science enrichment program through Saturday Academy. Saturday Academy is a non-profit organization affiliated with the University of Portland to “provide adventures for the curious” (“Saturday Academy”). This organization offers classes and camps for students in grades two through twelve in a variety of subjects. In particular, Saturday Academy endeavors to attract girls to STEM, and works to create engaging classes that allow girls to increase their interest and aptitude in the sciences. As a classroom assistant, I was able to observe in co-ed and female-only classes, and I was surprised to see how differently the male and female students engaged with the material. Although I did not collect data in an academically rigorous way, my informal observations would support the conclusions gathered by many researchers: female students, in general, are less likely to take an assertive approach to science when in competition with male students.

After observing the students at Saturday Academy’s summer camps, and the many other students I have had the chance to observe throughout my undergraduate career, I wanted to investigate how I could create a classroom that would allow all my students to thrive academically. My research has been guided by a few key questions: 1) What gender differences can be observed throughout history in regards to academic achievement and scientific success?, 2) What roles do biology and society play in shaping gender differences in science?, and 3) What can classroom teachers do to create gender equity in STEM educational achievement?
1.2 Significance

Through this paper, I will explore how gender impacts the distribution of men and women in scientific careers in the United States. Not only is the demand for individuals in STEM careers increasing, there is a greater demand for all graduates to possess strong scientific knowledge. This need justifies continued research into more effective teaching practices for STEM subjects. Globally, people will benefit from a better educated population, and continuing to examine best practices will allow for more women (and men) to have access to careers they are interested in.

Moreover, this research will assist classroom teachers in creating classrooms where all students can enjoy success in the sciences. By understanding how gender can impact students’ achievement in STEM fields, teachers can alter their methods of instruction to more accurately reflect best practices.

1.3 Scope & Limitations

Because this is an undergraduate thesis, I have limited its scope. The first major limitation is geographic in nature; in this paper, I will only discuss how gender impacts science education and involvement in the United States. Similarly, this thesis will be limited in its analysis of the impact of gender – as will be explained further in the Definitions section, this is not a paper on the psychology of gender. For the purposes of this paper, “gender” and biological sex will be used synonymously unless specifically otherwise stated. Another limitation is the depth and breadth of the topic. Although I will attempt to provide a comprehensive view of the issues related to gender differences in science, I am in the process of completing my undergraduate career. I simply do not
have the necessary level of knowledge to provide a fully nuanced analysis of all the factors that influence the gender divide in the sciences.

As a final point, much of my research has touched on the idea of intersectionality; intersectionality is a concept derived from third-wave feminism that describes how multiple forms or systems of oppression, domination or discrimination can interact to contribute a greater impact than a single disadvantaged identity alone. For the purposes of this thesis, this means that some students can be impacted greatly by an intersection of racial, socioeconomic, and other oppressions which can produce a greater effect than simple gender discrimination. This paper will be limited to focus solely on the effect of gender, but I want to acknowledge that the intersection of multiple disadvantaged statuses can definitely influence individuals in a profound way.

II. DEFINITIONS

II.1 Gender

Gender is a difficult term to define. From a psychological standpoint, there is a distinction between the terms sex and gender; “sex refers to the biological categories of female and male, categories distinguished by genes, chromosomes, and hormones,” while gender “is a much more fluid category” (Helgeson 4). However, this thesis is not on the psychological analysis of gender, so for simplicity’s sake the terms sex and gender will be used interchangeably. It is only recently that many of the nuances of gender have come into the general public’s consciousness, so when dealing with historical data, it is likely that reported gender would typically be matched with biological sex. While transgendered individuals and gender-fluid persons exist, they are a small enough
percentage of the population that their effect on overall gender-influenced trends would likely be insignificant. Finally, because this paper is focusing on the dominant cultural ethos of the United States, I will be using the standard binary male/female sex dichotomy. Although some Native American cultures such as the Lakota recognize more than two genders, these populations are not statistically significant when analyzing broad trends (Helgeson 17).

II.2 Science

Within the context of this thesis, ‘science’ will collectively refer to a large range of topics, including geoscience, engineering, economics, computer science, chemistry, physics, life science, social science, and psychology. Occasionally, these sciences will be broken into two groups: math-intensive and non-math-intensive sciences (Ceci). The math-intensive sciences, abbreviated as GEEMP, will refer to geoscience, engineering, economics, computer science, and the physical sciences of chemistry and physics. The non-math-intensive sciences, abbreviated to LPS, will refer to life sciences, psychology, and social sciences. The term science will also occasionally be used synonymously with “STEM”. STEM is an acronym that stands for science, technology, engineering, and mathematics.

II.3 Education

While students are educated in numerous settings throughout their lives, for the purpose of this paper, “education” will be limited to formal instruction within a classroom setting. Elementary school includes students in kindergarten through fifth grade who are approximately six to eleven years old. Middle school refers to grades six
through eight, with students who are approximately eleven to thirteen years old. High school includes grades nine through twelve, and includes students who are approximately thirteen to eighteen years old. Higher degrees attained do not necessarily have a corresponding age range, but are included in education because they are received in a formal educational setting. Careers are also a direct representation of this education: the distribution of men and women in STEM careers can be seen as an authentic assessment of the effectiveness of students’ educations. Consequently, careers will be discussed as a way to measure the success of students’ educational preparation.

### III. Changing Gender Distribution in the Sciences

#### III.1 Elementary & Middle School

At the kindergarten level, modern boys and girls are equally able to perform scientific tasks. One study looked at a six-lesson robotics program for kindergarten students and compared the sex differences in achievement. Although boys scored higher on a task that involved physically attaching materials to build the robots, in one programming task out of six, “both boys and girls were equally capable of using the concepts from lessons 1 to 6 in order to build and program a culminating robotics project after completing the curriculum” (Sullivan 699).

For fourth-grade students in 2007, “males and females showed no measurable difference in their average science performance” on the Trends in International Mathematics and Science Study (TIMSS) Assessment, while males outperformed females in both 2003 and 1995 – the two other years in which data was collected (Amelink 7). However, by eighth grade a clear gender gap presented itself: in 2007, eighth-grade
“males performed significantly higher than female classmates overall in science, scoring higher in three of the four science content domains” (Amelink 7). Just as with fourth-grade students, there was a clear gender divide for eighth-grade students in 2003 and 1995, with male students achieving significantly higher average scores (Amelink 8).

III.2 High School

Recent data has shown that the gap in scientific ability visible for eighth-grade students in 2007 has continued to persist. Multiple data collection strategies have shown that male students consistently outperform their female peers in STEM. In the elementary grades, K-8, students have little to no choice about the classes they are enrolled in; in high school, students are given more freedom to choose classes that interest them, as long as certain requirements are fulfilled. The National Educational Longitudinal Study (NELS) tracked student enrollment in science courses for high school seniors in the spring of their graduating year when the students were taking non-required science courses. In 1982, 69% of females, and 63% of males were not enrolled in any science courses, showing that more male students were taking science as an elective course. By 2004, this gap had narrowed to 45% and 47%, respectively – a non-statistically significant difference (Amelink 3). Similarly, “the mean number of credits earned in science increased from 1982 to 2004 for both males and females.” (Amelink 4).

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<tr>
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<th>1982</th>
<th>2004</th>
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<tr>
<td>Male</td>
<td>2.3 science credits</td>
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<td>Female</td>
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Table 1
Table 1 shows how both male and female students earned more science credits in 2004 than in 1982 (Amelink 4). By 2004, on average male and female students were receiving the same number of science credits; however, this data does not separate the GEEMP science credits from LPS science credits.

Advanced Placement (AP) testing, provided by The College Board to allow high school students to show mastery in subjects for consideration of college credit, is now more common among female students than male students. In 2013, female AP test-takers outnumbered male AP test-takers 55% to 45%, respectively, but female test-takers outnumbered male test-takers in only two fields of science AP tests – biology, 58% female, and environmental science, 55% female (Ceci 94). Although girls are more likely to take AP tests than boys, for “STEM subjects, boys score on average higher than girls” (Ceci 95).

Another measure of scientific achievement can be found through the American College Test (ACT) science section. While in 2007 the “average ACT score in science for females was 20.5 and for males 21.4” out of a maximum score of 36, when the study looked at other variables including self-perception, high school grade point average, and courses taken, “only 1% to 2% of the additional variance” could be explained by gender or race, showing that gender plays a minimal role in explaining the gender difference in STEM ability (Amelink 11). As briefly addressed in the Scope & Limitations section, the intersection of multiple disadvantaged statuses, such as socioeconomic status and race, can cause a greater impact on a student’s achievement than gender alone.
III.3 Bachelor’s Degrees

According to the US Census Bureau, men and women are now both significantly more likely to possess bachelors or higher degrees than any other time in history. While historically there was a large gap between men and women in overall percentage of the population attaining higher education, this gap has effectively closed. As shown in Figure 1 below, the total percent of the population with a bachelor’s degree or higher is roughly equivalent for men and women.

Since the mid-1980s, women have received more than 50% of all bachelor’s degrees annually (Ceci 78). In 2010, women received an impressive 57% of all bachelor’s degrees (Ceci). Over the past four decades, women have dramatically
increased their representation in STEM field bachelor’s degrees. As shown in Figure 2, in certain LPS STEM fields, women have even surpassed men; in the field of psychology, women receive approximately 80% of bachelor’s degrees (Ceci).

However, female participation in GEEMP fields is still significantly lacking. In 2011, women received only 25% of GEEMP bachelor’s degrees, but almost 70% of LPS bachelor’s degrees (Ceci).
III.4 Graduate Degrees

Similar to the successes in bachelor’s degrees, women have achieved considerable growth in graduate degrees in the past forty years. While in 1970, “fewer than 5% of scientific and medical doctorates” were awarded to women, by 2006, “approximately 50% of MDs and 48-51% of PhDs in biology were being awarded to women, as were 76% of doctorates in veterinary medicine, and 67% of PhDs in psychology” (Valla 134). However, just as with bachelor’s degrees, women are still underrepresented in GEEMP higher degrees: women received only 29.6% of PhDs in mathematics, 21.3% of PhDs in computer science, 29% of PhDs in physical sciences, and 20.2% of PhDs in engineering fields in 2006 (Valla).

III.5 Careers

Even with major gains, there are still fewer women who continue in the sciences at each progressively more advanced level, from interest in high school, to a bachelor’s degree, to graduate degrees, and then to careers. This phenomenon is referred to as the “leaky pipeline” – rather than funneling women (and to a lesser extent, men) from one level to the next, there is a noticeable trend for females to drop out. While the possible reasons behind this leakage will be discussed in following sections, the data show that the gap is present at the career level for women in science.

IV. Biological Impacts

While the gender gap has decreased significantly, it still makes a considerable impact on the world of science, particularly at the highest, most influential levels. This is partly due to the “leaky pipeline” phenomena; not only are women less likely to enter
STEM fields of study, they are more likely to leave STEM careers before attaining the highest levels of research and influence on the world of science (Jacobs). Much research has been done to examine whether there are any biological reasons for this discrepancy. While there is no research that shows males are inherently more able to do science than girls, some researchers have looked for genetic reasons that may give boys an advantage. Three possible areas for a male advantage are spatial skills, variance in intelligence, and overall brain size (Ceci, Ganley, Valla, Wai, Committee). Research supports the idea that spatial skills and general intelligence variance likely have an impact on the overrepresentation of men in the sciences, while brain size is probably not a factor.

IV.1 Spatial Skills

Many researchers are exploring the possibility that boys are predisposed to have increased spatial skills due to a biological, rather than sociological, advantage. This advantage appears very early in life. While results are less definitive for students in early elementary school, “gender differences in mental rotation emerge at an early age, perhaps even in infancy” before formal schooling or sociological impacts would be likely to take hold (Ganley 1421). In 2014, Miller and Halpern found that “four studies have found male advantages in mental rotation tasks among infants as young as 3 months of age,” but these results were not always consistent across racial lines (Ceci 86). Given that “male advantage in science performance in [the areas of physical science and technology/engineering], could be, at least partially, statistically explained by the male advantage in mental rotation,” it makes sense to look for a biological basis for this increased ability (Ganley 1428).
One major difference between developing male and female fetuses is the presence of androgens in utero. If this hormonal difference was responsible for increased rotational ability, girls exposed in utero to higher levels of androgens, such as those afflicted with congenital adrenal hyperplasia (CAH) would be expected to perform better than their non-affected female peers. However, girls with CAH “do not consistently perform better on later math and spatial-aptitude batteries as would be expected if male hormones organized the developing brain for optimized spatial processing” (Ceci 84). One piece of evidence that supports the idea of prenatal androgens impacting mental rotation ability is that the female in a male/female twin relationship exhibits “superior spatial ability” compared to female/female twins (Ceci 85). The authors of the study believe that this “was due to their sharing a prenatal environment with males,” but it is also possible that this advantage was conferred due to early, frequent socialization with males, and specifically, experience with toys that are considered masculine and develop spatial skills as a byproduct, like Legos® (Ceci 85).

Similarly, the length of digits, specifically the ratio of the second digit to the fourth digit, the 2D/4D ratio, has been shown to be related to level of testosterone in utero. If biology plays a role in the inherent spatial ability, both males and females with a higher 2D/4D ratio should have greater spatial and numerical abilities “because the brain organization patterns outlined by brain organization theory arise at approximately the same time as digit length determination” (Valla 139). Support for this theory is mixed, at best. As the authors of the study noted, more research is necessary to “attempt to differentiate between biologically influenced interest and biologically influenced ability”
It is possible that prenatal hormones may influence infants’ interests but not necessarily their abilities.

Finally, while most research shows a clear male advantage in spatial tasks, Huguet and Regner in 2009 showed that “some spatial tasks show a male advantage when they are framed as geometry problems but a female advantage when they are framed as an art task” (Ceci 85). This may mean that spatial ability, even when measured at an early age, is less likely to be an inherently male skill, and may be more socially impacted by the interests of the test subjects. While research supports the idea that males have an advantage in spatial skills, it is likely that this advantage is not entirely biologically based, and is instead heavily influenced by sociological factors.

### IV.2 Variance

While average scores on measures of STEM ability are increasingly similar for male and female students, there are still statistically more men both in the highest and lowest scoring categories. In life, this can be summarized by the idea that “there are more male CEOs, but also more homeless men” ("A Biological Basis for Gender Differences in Math?"). One proposed reason for the disparity in the number of women in top scientific positions, compared to the number of men, is that there are fewer female intellectual outliers at the most capable level. Wai, et. al., performed an analysis of the top 0.01% of scorers on the SAT-Math from the 1980s to 2010. In the early 1980s, there was a 13.5-to-1 ratio of male to female top performers; this dropped to 4-to-1 by the early 1990s, and has remained relatively constant since then. Similarly, there have been significantly more male top achievers on the ACT-Math, ACT-Science, EXPLORE-Math, and EXPLORE-Science than female top achievers, and rates have stayed relatively
constant. Wai proposed the large initial gap may have been due to the fact that male students took more advanced course work in the 1980s, and since the 1990s male and female students take approximately equally rigorous course loads. Figure 3 below, from Wai et. al., (2012) shows “the number of males for each female among the top 0.01% of scorers on the mathematics and science subtests of the SAT, ACT, and EXPLORE from 1981 to 2010, in five-year groups” (Wai). The students in this study “consisted of students who scored 700 or higher on the SAT-Math, students who scored … 30 or higher on the ACT-Science, and students with perfect scores on the EXPLORE-Math and on the EXPLORE-Science” (Wai).

![Figure 3](image-url)
This figure helps to illustrate that there have consistently been between two and four male students for every one female student in the highest scoring categories on many measures of math and science ability for the past 20 years, with little change.

Although there are clearly sociocultural elements that influence ability, it is possible that the preponderance of males in the highest level of achievement on standardized measures of math and science aptitude may play a significant role in the overrepresentation of men in influential STEM careers. However, this entire assumption hinges on the idea that the tests can detect, and accurately measure, true differences in aptitude.

While there are individually exceptional males and females on both ends of the IQ spectrum, there is substantial evidence that males are more likely “to be overrepresented at both ends of [the general intelligence] overall distribution” (Johnson 598). One proposed explanation for this phenomenon is that the X chromosome may play a role in general intelligence. Because males only receive one copy of the X chromosome while females have two, men are more likely to be affected by X-linked genetic diseases; many of these diseases are associated with mental retardation. Genetic studies have also shown that there is a disproportionally high number of genes unrelated to X-linked syndromes that can cause nonspecific mental retardation (Johnson 600). While the effect of the X chromosome can be used to explain some of the reasoning behind the abundance of males on the left tail, it is not sufficient to explain why there are also proportionately more males on the right tail of the IQ distribution.
IV.3 Brain Size

Even when adjusting for overall body mass, male brains are, on average, approximately 10% larger than female brains (Committee on Maximizing the Potential of Women 16). However, this does not imply that men are more intelligent. Through MRI studies, Jay Giedd, of the National Institute of Mental Health and National Institutes of Health, has performed longitudinal studies of children’s brains to examine the differences in developing grey and white matter between boys and girls. His studies found that while male and female brains mature at different rates, “male and female adolescent brains are much more alike than different” (Committee 17). There are subtle differences between the sexes in mature brains, with a larger and later maturing cerebellum in females, as well as significantly more variability in size of structures in male brains, but it is the pathways to maturity that are more strikingly different between males and females. Overall, it is unlikely that brain size or the rate of maturation plays a major role in the gender differences in STEM achievement (Committee 17).

V. Sociological Impacts

While there may be some slight biological factors that influence the male dominance in STEM fields in the classroom and beyond, there are clear sociological reasons why women are less dominant. By better understanding these reasons, it may become possible to reshape the world of science to become more open to all capable individuals, regardless of sex. There are certainly a variety of sociocultural factors that influence a student’s academic success. Particularly for female students, there are three main, data-supported elements that seem to impact their scientific achievement –
stereotyping, being pushed out and pulled away, and the difficulty of creating a work/life balance.

V.1 Stereotyping

Students have strong ideas about what careers are gender appropriate by the time they are approximately seven years old. Influenced by “factors such as socioeconomic status, parents’ occupations and education levels, and parental expectations,” children begin to eliminate possible career choices because they believe that they are inappropriate for their gender (Toglia 15). Similarly, by age five, “girls receive the message that math is for boys;” this message can be seen though “pronounced early gender stereotyping and career choices” (Ceci 93). This assertion that math interest is gendered appears before any significant difference in math ability presents itself. Research has shown that the affective domain of students is influenced early in students’ lives, often before there is any measurable difference in math scores (Kahle 380). This stereotyping likely contributes to a lack of interest in math and the sciences, which compounds in later grades.

Similarly, boys are stereotyped (not necessarily incorrectly) as being more interested in the physical sciences, while girls tend to prefer biological science topics. Culturally, boys are encouraged to explore more aggressive interests that are more aligned with physical science topics, such as “shooting firearms, explosions that involve loud noises, and other extraneous energy transformations” (Fraser 502). This results in boys receiving more scientific knowledge through exploration outside of the classroom, and probably influences their increased aptitude in the sciences as measured by academic STEM scores.
A second major impact of stereotyping is the phenomenon known as “stereotyping threat.” This term has coined by Claude Steele, an American social psychologist. When stereotyping threat is triggered, “the person’s cognitive performance, particularly on tests of mathematics ability among women and tests of general intellectual ability among members of racial and ethnic minorities, is negatively affected” (Committee 2). This phenomenon can negatively impact scores even when a particular female does not buy into the idea that she possesses inferior ability due to her gender. One study showed that “female test takers who marked the gender box after completing the SAT Advanced Calculus test scored higher than female peers who checked the gender box before starting the test” (Ceci 92). This example clearly shows that even unacknowledged biases can have profound effects on students’ academic performance.

V.2 Pushed Out vs. Pulled Away

Another cultural impact on the scientific achievement of women is the idea that they are both pushed out of- and pulled away from- the sciences. As reported by Ceci, et. al., “Individuals with high verbal and high mathematical ability (of whom the majority were female) were less likely to later be in a STEM occupation than were those with high mathematical ability and moderate verbal ability (of whom the majority were male)” (Ceci 95). This finding implies that women who would likely succeed in the sciences are pulled away to other interests due to their high verbal abilities; women who are gifted verbally and mathematically often choose to pursue non-STEM professions, while gifted men tend to be gifted mathematically and not as gifted verbally, so STEM fields become a good-fit placement.
Similarly, confidence in scientific ability is strongly correlated with female success in middle school (Dreves 96). Dreves, et. al, looked at middle school female students and found that “girls who came into the classroom at the beginning of the year feeling more confident about their abilities in science remained more confident throughout the school year,” and scored higher than their female peers who felt less confident in their science abilities (Dreves 96). This confidence was also correlated with the level of engagement and leadership in the science classroom; more confident girls tended to be more involved with the tasks, and were more able to practice the skills necessary for success. Overall, girls rated themselves as less capable in the sciences than their male peers, even when their academic scores were similar. Dreves et. al. suggest this may be that girls tend to “make comparative judgments about their scholastic abilities, perceiving themselves to be better in other subjects (e.g. English) than science” (96). This suggests that girls are pulled to subjects in which they feel more confident in their abilities; they are not necessarily pushed out of the sciences due to a lack of ability.

Another way women are both pushed away and pulled from the sciences is from a “lower sense of belonging,” and consequently, a “loss of interest” in STEM at the undergraduate and graduate levels (Thoman 247). Female students tend to be especially responsive to a sense of belonging, and their interests seem to be strongly tied to areas in which they feel as if they belong. Thoman, et. al. found that it is a heavy combination of feeling out-of-place in STEM courses and feeling a sense of belonging in non-STEM/Humanities and Language Arts classes causes women to be less interested in the sciences.
Finally, women appear to be less interested in STEM professions because women tend to be more interested in communal goals. The general impression is that STEM careers are less likely to fulfill communal goals, such as “working with or helping other people” (Diekman 1051). However, contrary to the general impression many people have for the sciences, many “STEM fields hold the key to helping many people” (Diekman 1051). One possible way to increase female interest and participation in the sciences would be to elaborate the multitude of ways STEM professionals can achieve communal goals.

V.3 Work-Life Balance

A final area of sociological impact is work-life balance. While men clearly are impacted by having a family, there are certainly different considerations for women to make when choosing career paths. Both because women are more bound to a biological window for reproduction and because pregnancy is an exclusively (biologically) female experience, women interested in having children have to consider the impact of their careers on their family formations in more concrete ways than men. Because of these considerations, “four times as many female as male graduate students and 50% more female than male postdocs were worried that a science career would keep them from having a family” (Ceci 121). Similarly, “faculty women were more likely to stay single, to have fewer children, to have children after tenure, and to miss children’s events in order to avoid perceived bias against caregiving” (Ceci 12).
VI. METHODS OF INCREASING EQUITY

This section aims to provide specific best practices teachers can use to increase equity in STEM subjects in the classroom. While some of these recommendations require a more global restructuring of gender ideals, there are many things classroom teachers can do to help attitudes shift within their classrooms. With a rigorous implementation of these best practices, students will then be able to create a more equitable atmosphere as they mature.

Rather than working to create “intervention programs [that focus] on ‘fixing’ girls,” as was common in the 1990s when the issue was initially addressed, it is more effective to “focus on sociocultural aspects of learning” to reshape the sciences so that girls are granted more access to the sciences (Fraser 502). There are a variety of ways that education can be reshaped to make a more welcoming atmosphere for all students. One specific idea that can help all students, and in particular, girls in the sciences, is to emphasize the idea of malleable intelligence. Malleable intelligence is the idea that intelligence is not a fixed entity; intelligence is a quality that can be developed and improved throughout a person’s life. Two studies performed by Blackwell, Trzniewski, and Dwek in 2007 showed that middle school students who believed an incremental, malleable theory of intelligence experienced “positive change in classroom motivation, compared with a control group,” and experienced higher “math grades relative to those who endorsed a more entity, [fixed] theory” (Blackwell 246, 258).

A second concrete way to promote female success in the sciences is to provide more direct instruction on spatial skills. Spatial thinking is a critical skill for almost all areas of science, and addressing weakness in spatial thinking skills can help students to
feel more confident in their overall abilities. While some tasks, such as “memory for objects and their locations, actually shows a female advantage … most other tasks reveal a male advantage of differing magnitudes” (Ganley 1421). Although there is some disagreement among researchers, it is likely that an increase in spatial learning curriculum would help all students be more successful.

A third way to specifically increase girls’ successes in the sciences is to provide more relevance to students in earlier grades as they begin to explore scientific endeavors. The “Science/Technology/Society (STS)” approach integrates the idea of relevance, and has been shown to influence students to “have better attitudes toward studying science and toward careers in science, have improved ability to apply science concepts to their daily lives, exhibit more equitable achievement outcomes in science across gender and ethnic lines, have improved ability for decision making, show greater creativity, and perform on standardized science tests as well as (or better than) students who have used textbook-based science approaches” (Weld 757). The STS method of teaching science results in vast improvements for girls without causing any detriment to boys; multiple studies have shown that “scores on aptitude measures were significantly higher for all students who experienced the STS approach, with girls making even greater gains than boys” (Weld 758). The STS method simply “requires a shift in focus” – it does not attempt to ‘fix’ girls. Instead, the STS approach moves the emphasis from pure rote learning of scientific knowledge to a sociocultural emphasis (Weld 757). In a classroom, this would mean that a teacher first establishes the interest and/or relevance in a topic with students. The teacher would then allow students to explore and research a topic semi-independently; the teacher may guide students to resources or to particular
experiments, but the class becomes more student-directed, and students are responsible for their own learning. As Weld summarized from the results of two separate studies involving 25 middle school classes, “significant and persistent gender gaps on science concept tests were closed when an STS instructional design was used,” and attitudes for all students, male and female, showed improvement (Weld 758). As stated in the Sociological Impacts section, one reason girls often turn away from the sciences is due to thinking that STEM does not promote communal goals. The STS approach emphasizes how science can be used to better the lives of people.

Another classroom initiative that can increase girls’ success is to decrease an emphasis on individual competition and remove time constraints. A study by Niederle and Vesterlund (2010) found that girls performed better in competitions against other girls and worse in competitions in which boys outnumbered girls” (Ceci 92). This means that teachers in co-ed classrooms may want to decrease inter-student competition to help students achieve their full potential. However, at the undergraduate level, female STEM students who experienced a “collaborative learning component … [nullified] any aversion to a competitive environment” (Cannon 125). One major difference between the two studies was the use of group-based or individual competition. If a teacher intends to employ competition in the science classroom, it would be more effective to use group-based initiatives, rather than pitting individual students against each other. Similarly, in competitive environments, the male advantage was significantly decreased or disappeared when the time pressure was removed (Ceci 92).

A final direct classroom recommendation would be for teachers to provide early exposure to students about the many faces of scientists. By exposing students to
scientific role models who look like them, the effects of strong ideas about what careers are sex-appropriate can be ameliorated. This, combined with mentoring programs for women pursuing traditionally male fields of study, has shown to “[increase] the enrollment and retention of under-represented students in [STEM and career and technical education] programs” (Toglia 16).

As summarized by Ceci, et. al., “ultimately, if society deems it important to increase the presence of women in the most mathematical fields, it will be necessary to plan pre–high school and high school interventions for increasing math and science identification and advanced coursework” (Ceci 97).

**VII. Areas for Further Research**

While this thesis focused exclusively on the United States, it would be interesting to expand this analysis on a global scale. While there are some western cultures that will likely have similar gender differences, like western European countries, I can imagine that some cultures will be radically different.

There is also much research to be done on the intersection of multiple identities and how that relates to science ability and interest. This thesis looked only at the impact of gender, but it would be interesting to see how socioeconomic status, race, sexual orientation, or other identities influence students’ science education experiences.

Also, it would be interesting to study how the face of science will continue to change as the world moves more deeply into the 21st century. One study from 1994 found that gender differences in science achievement were reduced when students were measured with performance-based assessments, rather than simple multiple-choice tests.
This study proposed that, while gaps in ability still existed due to students’ gender-related life experiences, students were more able to show and expand their knowledge through authentic measures. Particularly as Smarter Balanced Assessments become more common in the classrooms, it would be interesting to see if the gender gap will continue to be eliminated.

However, this idea of assessment brings up the complicated topic of bias in testing. For the purpose of this thesis, I have blindly accepted that the assessments used are unbiased. In order to analyze the data, I simply discarded the idea that the tests are not providing valid, accurate, and reliable results. It would be interesting to research further into the assessment side of gender differences in academic ability to know if the current differences in STEM ability between genders is real, or if it is a product of biased testing.

Another interesting area of research would be to look into how teacher perception shapes students’ ideas about their scientific capabilities. While some studies touched on the idea of teacher influence on students’ perceptions of science, I think it would be interesting to learn how the gender and experiences of teachers influence the academic and career choices of their students. This will be particularly intriguing as older teachers retire and are replaced by younger teachers, who theoretically should be influenced by the increasingly equitable representation of women in the sciences.

Finally, much of the research currently is contradictory. This is partially because research can only ever provide a single snapshot of the topic studied. The world continues to change faster than research can be conducted, analyzed, and published, but this information allows researchers to analyze data and continue to make
recommendations. While it is difficult to provide meaningful conclusions about data when things change so rapidly, continued research can allow educators to get a true picture of gender differences in the classroom today and to measure the effectiveness of implemented strategies.

VIII. CONCLUSION

While historically there existed a large achievement gap in STEM fields between male and female students, this has effectively been eliminated. However, there remains a large difference in representation between men and women at the highest levels of science, particularly in specific sub-disciplines. Termed the “leaky pipeline,” women and minorities are far more likely than their white, male peers to opt out of science at successively higher levels. This is an issue that deserves scrutiny; as the world moves more deeply into the 21st century, it is imperative that the US prepares its citizens for careers in STEM in order to remain a dominant world power and to find solutions to serious global issues. Changing demographics of the US’s school-age population means that if this leaky pipeline continues, or becomes even “leakier,” the US is in danger of experiencing a dearth of qualified professionals within a generation or two.

This paper has allowed for an examination of some of the biological and sociological impacts of gender on STEM education and achievement. While some studies show a slight male biological advantage in STEM, other researchers claim that this gap can be eliminated by altering classroom practices. Specifically, males show a slight, but distinct, advantage in spatial ability before being exposed to any formal educational setting that likely impacts their future success in STEM fields. However, some of this increase in spatial skills is likely a result of the sociologically driven choices
about appropriate toys and activities for each gender. A second major biological impact on STEM is related to general intelligence levels. If the tests of intelligence level are assumed to be accurate, males are more represented at both ends of the spectrum – there are more men at both the highest levels of cognition and the lowest. This may influence the overrepresentation of men in STEM fields due to the relative increase in men at the highest levels of aptitude. Finally, brain size has been proposed to influence STEM representation, but studies have concluded that although men tend to have larger brains relative to their body size, this does not likely have an impact on STEM abilities.

Sociologically, there are three major areas where gender appears to impact STEM achievement. Stereotyping, and specifically stereotype threat that causes female students to underperform compared to their male peers when they are actively aware of their gender when taking assessments, has been proven to negatively impact female students’ scientific performance. This effect is even seen in students who do not personally believe that their gender should impact their ability to perform on assessments of scientific ability. Also, some of the lack of representation of women in the sciences is due to women both actively feeling like they are pushed out of STEM fields, and feeling as if they are more drawn to other, non-STEM, courses and careers. Women may feel unwelcome in the sciences, while feeling a great sense of belonging in a particular humanities field, which could lead them away from STEM, even if they have all the requisite cognitive abilities. Similarly, women more typically feel that their career should support communal goals, and STEM careers are less likely to emphasize the importance of bettering the world, in spite of their actual capacities to do so. Finally, women can be turned away from pursuing the sciences because of the difficulty in creating a work/life
balance. Women have a smaller window of opportunity for reproduction, and pregnancy, with its multitude of impacts on a woman’s health, is solely a (biologically) female person’s role.

Through direct classroom initiatives, teachers can influence future generations to be more equitable in the sciences. By emphasizing the malleable intelligence theory, teachers can assist all students in reaching their full potentials. Teachers can also create equity by taking a more societal-based approach to the sciences. By making science more relevant to students, and emphasizing the effects on the community, teachers can allow students, male and female, to be more engaged in the material and experience greater success. Teachers can also provide direct instruction on spatial skills to assure that all students are equipped to move on to higher levels of thinking required by advanced math and science topics. Finally, although research is mixed, reducing competition and time constraints tends to be useful in allowing all students equal access to success.

The concept of gender equity in scientific fields remains a valid topic of exploration. As the world is propelled more deeply into the 21st century, the playing field has become much closer to level. However, the pipeline of students into higher levels of science is distinctly more leaky for women than men. Implementing specific classroom initiatives to increase the success of all students should cause the gaps in scientific achievement seen in the US to be eliminated, and will allow the US to create an equitable environment for men and women to succeed.
IX. APPENDIX A: LIST OF FIGURES

Table 1: Average Number of Science Credits Earned upon Completion of High School by Sex: 1982 and 2004 (Amelink 4)

Figure 1: Percent of Populations 25 Years and older, and 25 to 29 years old, with Bachelor’s Degree or higher by Sex: 1947-2014 (United States Census Bureau).

Figure 2: Percentage of Bachelors Degrees Awarded to Women in STEM Fields (Ceci 81).

Figure 3: Sex Difference Among Intellecutal Outliers; Number of males for each female among the top 0.01% of scorers on the mathematics and science subtests of the SAT, ACT, and Explore from 1981 to 2010 in five year groups (Wai 384).

X. CITATIONS

5. Committee on Maximizing the Potential of Women in Academic Science and Engineering, Committee on Science, Engineering, and Public Policy, National Academy of Sciences, National Academy of Engineering, and Institute of Medicine of the National Academies. Biological, Social, and Organizational Components of


