GENDER DISCREPANCIES IN MATHEMATICS

by

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ABSTRACT

This paper addresses the question: How should educators address gender differences to support all students' learning and achievement in mathematics? Mathematics is becoming increasingly important for all students, but female students are participating less in higher-level mathematics courses. Stereotype threat, competency beliefs, internal and external influences may cause anxiety and declining mathematical participation and achievement for female students. Female students have lower competency beliefs and more negative emotions in mathematics. Expandable intelligence theory, diverse teaching practices, and specific interventions help mitigate gender disparity in mathematical achievement, ability, and participation.

TABLE OF CONTENTS

CHAPTER ONE – INTRODUCTION

Introduction

The United States is often labeled as the land of equal opportunity; the commitment to provide every individual with a fair chance to develop their talents and abilities to the fullest extent is a central principle of American culture and identity. A large portion of immigrants come to the United States because of "golden opportunities" that allow for upward mobility. Freedom of choice, civil liberties, the Constitution, and the Bill of Rights are all illustrative of a nation where individuals can make of themselves what they will, with minimal external pressures. Paramount to this ideal of equal opportunities is the right and need for equality in education. Without equality in the classroom, our liberties and freedoms are not, truly open to all. Equity in the classroom requires individual attention, but also needs to address the student body on a larger scale. If there are gendered differences that make mathematical instruction and achievement inequitable it is important to take these differences into account when instructing mathematics.

Mathematics is a shared language throughout and across all cultures. Mathematics is both universal and a crucial tool in the understanding the world around us. Everyday, each and every person uses inputs from the environment to help interpret, understand, and make decisions. Having multiple and different tools available to make accurate and informed decisions is imperative if one wants to reach the best possible decisions. Understanding the language of math gives people another tool to help them make accurate and informed decisions. A strong background in mathematics is also seen as an increasingly important job skill due to the importance of technology in the modern global economy.

Mathematics education has increasingly been the focus of intense gender-based studies due to its relative importance in education, curriculum and higher education and because of its apparent lack of gender parity. Mathematics has long been considered a male domain. One can easily find biting clichés and jokes, such as: "There have been only two female mathematicians. One was not a woman; the other was not a mathematician.." reffering to Emmy Noether and Sofia Kovaleskaia (Henrion, 1997, p. 68). Throughout history, females were often derided as less intelligent than men, but this idea has begun to change and continues to evolve over time. An increasing majority of education researchers have begun to believe that males and females are equally intelligent and equally able to succeed in mathematics.

As a potential educator, gender equity in mathematics is an important issue for me. Ever since I was a young boy attending school, my favorite subject had always been mathematics. I was always pretty good in mathematics and enrolled in the highest mathematics courses offered at my school. I wondered what made mathematics fun and enjoyable for me while so many of my friends—especially my female friends—would lament, almost boastfully, "I am no good at math," or "I hate math!" Were my friends influenced by socialization: through media, parental views, perceived learning differences and gender roles, or did it all boil down to teacher practices and personal preference? Was there an innate mathematical ability either present or lacking, which made mathematics easy for some and near impossible for others? Was mathematics too difficult without an entry point, where other students did not or could not experience initial successes from which to build more knowledge? What caused these differences in ability and enjoyment in mathematics, and how can everyone be successful in mathematics?

During my final year in high school I took two sections of pre-calculus. I had a traditional mathematics teacher, whom taught through a direct instruction model and was female. It is important to point out this teacher as female because it reinforced my belief that females could achieve just a much—mathematically speaking—as males. At my high school, the highest mathematics courses were regularly taught by females, although female participation in these classes was severely limited. In my pre-calculus classes for example, only two of the students were females. Why were my mathematics classes so predominantly male? Henrion (1997) stated, “There is a prevalent assumption that being a woman and being a mathematician are incompatible—one can be one or the other, but not both” (p. 67), and that this belief perpetuates the myth that mathematics is a male domain and affects how women in mathematics are treated.

While teaching a mathematics course this year, a student told me that my handwriting looked like girls’ handwriting; meaning that my handwriting was nice and that my students held gender views about male and female learning domains and expectations; at least concerning penmanship. When I was younger did I feel that mathematics was a male domain, and that reading and writing were female domains? In high school that was not the case, but I did feel that I should be good at mathematics while I did not necessarily need or want to be good at penmanship (although my parents made me practice penmanship everyday in fourth and fifth grade). Any investigation into mathematics education must then also look to address engendered views such as these.

This paper attempts to investigate the question: How should educators address gender differences to best support equity in students' learning and achievement in mathematics? This question will be looked at through research articles that investigate whether or not gender differences in mathematical ability and achievement exist, and if so, then potential causes and effects of mathematical gender disparity. First we will look at the historical origins of the American school system in regards to female participation and opportunities. In the following section, an examination of literature in a historical perspective attempts to create a brief overview of the progression of ideas concerning female academic capabilities.

Next, the paper will look at current research being carried out on gender differences in education, with a specific focus on what and how these studies affect mathematical education. This topic will be broken down further; first focusing on whether or not gender differences are present in mathematics, then on how stereotype threat impacts mathematical ability and achievement, thirdly on the external influences that hinder or help mathematical achievement, and finally by investigating the emotions, beliefs and attitudes toward mathematics and specific instructional practices or interventions that minimize gender differences in mathematics. This paper concludes with a summary of these findings and discusses the implications for teachers in the field of mathematics.

Rationale

The importance of mathematics and mathematical knowledge is increasing with the increase of technology-driven industries. Halpern (2007) used the 2000 Biennial Report to the US Congress by the Bureau of Labor Statistics to point out the importance of mathematics in the changing job market. The report predicted an overall growth rate of jobs at fourteen percent, but the growth rate of jobs requiring higher-level mathematics skills and knowledge would rise by fifty percent. Halpern (2007) also used data from the National Science Foundation, which found that women constitute nearly half of the American paid workforce; yet comprise only twenty-four percent of the total science and engineering workforce (p. 1). There is evidence that perhaps the gender achievement gap has inverted itself from the mid twentieth-century to the present day except for at the highest levels of education.[i]

This dynamic relationship between women and the *status quo* has an established history in the United States. During the 1920s, the women's suffrage movement fought to gain some of the social and civil rights that men held. During World War II, women entered the workforce in order to maintain industrial production, thereafter cementing themselves as income-earners in ever-increasing numbers. With their increasing economic importance, the fair and equitable education of women also became an important issue. Gender educational equity issues were partly addressed with the passing of Title IX in 1972 which stated that: "No person in the United States shall, on the basis of sex, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any education program or activity receiving Federal financial assistance" (Carpenter, 2005, p. 3). As per Title IX's intent, as a mathematics instructor I have a legal obligation to teach each and every student to the best of my ability regardless of their gender.

When addressing the question of 'how can educators address gender differences to best support student learning in mathematics,' it is important to understand that educational equity does not necessarily prescribe identical educational practices and opportunities. The United States is supposed to be the land of equal opportunity, and to make this statement true, educators must provide each individual with the tools necessary to become successful in any and all fields that they choose.

Controversies

There are several contentious points to consider when looking at gender discrepancies in education. Such controversies are: whether or not gender differences in mathematical ability and achievement exist, and if so, the causes of gender differences in mathematical ability and achievement and what are the most effective methods to achieve gender equity in these areas.

Kiefer and Shih (2006) and Halpern (2007) both cited Lawrence Summers' 2005 statements for the *NBER Conference on Diversifying the Science and Engineering Workforce* as a key controversy in regards to gender differences in the mathematically intensive fields of science and engineering. Lawrence Summers, the former president of Harvard University (2001-2006), and the current director of the National Economic Council, publicly stated that women's under-representation in mathematics and science academia was a function of the innate abilities of men for mathematical skills and abilities, thereby implying a deficit amongst women. Summers cited differences in socialization and discrimination in hiring practices as not having a significant effect on the gender disparity. Summers (2005) also said that females were not inclined to spend the required time in the subject field because raising families kept females from higher-level academic positions. He later resigned under a vote of no confidence from the faculty, demonstrating that his controversial statements and attitudes were not well-received or welcomed by his academic peers.

Summers does bring up a valid point, however, in that if differences do exist between males and females, it needs to be demonstrated what these differences are and how they are established (i.e., biological or social). If there are no inherent biological differences in mathematical ability there must be other factors that influence mathematical ability and representation in mathematics courses, fields, and achievement. Using statistics from The College Entrance Examination Board from 2004, Halpern (2007) demonstrated that the average SAT–Mathematics test scores, broken down by gender for students entering college, has favored male students from 1967 to today. In 1972 Maccoby and Jacklin found that male students tended to do better in mathematics from fourth grade on, and male students also did better on visual spatial ability tests. Halpern's study is just one of many that point toward a quantifiable gender achievement gap in mathematics, but this view is by no means uncontroversial and this theme will be explored shortly.

The controversy over predictors of mathematical achievement and their reliability concerns gender bias and implementation. Educators can use these predictors to help students attain maximum levels of achievement, but this idea brings up the question of who then should receive extra attention and help. Studies have been shown that high-achieving students would actually benefit more from the allocation of extra resources than low-achieving students. Dependent on how the predictor information is used, all resources might be used to try and bring everyone up to the same standard level, or more money may just be spent on the best and brightest. In either case, students might feel that they would not receive an equal or fair education and they might have legal recourse to complain under the protections afforded by Title IX.

The concept of 'stereotype threat,' an important component of gender-gap research, is also controversial. Stereotype threat is generally proposed as the innate ability or disability to achieve or perform a given task. The primary controversy concerns whether or not stereotype threat exists; but other controversies center on stereotype threat and its effect on mathematical achievement. Does stereotype threat trigger emotions or beliefs that either hinder or encourage mathematical achievement? Another debate is whether gender stereotype threat affects all students, either positively or negatively. For example: a female student feels challenged by the stereotype threat and does better (possibly to prove that it can be done) but other female students may do worse under the same pressure, which would mean that other beliefs are the cause of these gender differences and not the stereotype threat itself. Another theory is that stereotype threat causes anxiety and affects people differently because of different reactions toward anxiety. Confirmation to norms, historic gender roles, innate ability beliefs, and socialization can all contribute to stereotype threat.

Pinpointing examples and creating research experiments that seek to find the specific causes of achievement differences is important but difficult. If gender achievement gaps are created through socialization and the engendering of mathematics as a male domain, determining how these views are created and propagated can be problematic. Furthermore; multiple-interference in regards to prior experiences may contaminate any data obtained.

Definitions

This paper investigates differences between male and female students in mathematics and how educators can best address these issues to support all student learning. In order to do so, a couple of key words need to be defined. In this paper, I define *mathematical achievement* as scores from standardized test, grades earned from mathematics courses, and/or highest level of mathematics course completion. *Stereotype threat*, is, "the threatening feeling that emerges in a situation in which a person is made aware that results of a competence test may be used to confirm the stereotype for the larger group or to judge that individual's own abilities." (Davis, 2006, p. 288). Delgado and Prieto (2007) stated, "stereotype lift has been assigned to the phenomenon consisting of a performance boost observed among non-stigmatized subjects who are aware of negative stereotypes targeted at stigmatized others." (p. 635). This means that *stereotype threat* is a threat of poor achievement or performance for a specific population of students. *Stereotype lift* can enhance mathematical achievement for those not under the stereotype threat and know that the stereotype threat impacts a categorical population other than those to which they belong.

Limitations

There are many factors that impose limitations on our ability to fully understand and respond to achievement gaps in mathematics. The biggest limiting factor is our inability to fully quantify the social influences that effect all students. Socialization through media and the effects that this plays on female students compared to male students, is a factor that is problematic due to its widespread reach and distribution. Other issues involved with socialization and gender roles are difficult to address as well.

Many studies point to SAT scores or other large data sets (WASL scores, ITBS test scores, and other mandated state tests), but do not include, discuss, or in fact have any knowledge of the ways in which students prepared for these tests and other useful background information. Studies involving parental views and socialization as processes effecting achievement gaps are necessarily constrained by the complexity these interpersonal relationship have. Current studies have difficulty in determining the socialization practices and therefore effects on student achievement and so conclusions reached concerning these effects must always be taken into consideration.

Another limiting factor is the dynamic nature of single-sex classrooms. Researchers have argued that single-sex male classrooms experience higher incidences of behavior and verbal/and or physical distractions, and so comparing single-sex classrooms itself may perpetuate or magnify discrepancies and inequalities not based on achievement or teaching practices, but on biological, bio-sociological and physical limitations and inequalities.

The final and perhaps greatest limitation on achievement gap research is how learning strategies and learning styles are quantified and qualified in research. For example, actual learning styles may differ from generalized learning styles attributed to genders, such as the above-mentioned example of the girl experiencing stereotype uplift while her female classmates (under similar pressures) experience the opposite. Coupled with the fact that on average, upper-level mathematics courses are generally taught in a traditional direct-instruction model and not in a guided instruction model, but lower level classes exhibit a plethora of different teaching methods, and quantifying the effects and impacts of learning styles on actual achievement becomes increasingly difficult.

Summary

Mathematical knowledge is becoming increasingly important in an increasingly global and technologically driven economy. If female students experience achievement gaps in mathematics, then they will be unable to fairly compete in these burgeoning employment opportunities, creating further financial disparity between genders. Either biological or social factors cause or create the perception of gender achievement gaps in mathematics. Title IX originated to even the disparity between genders (even if most people believe it is primarily concerned with sports funding and equality) in all federally funded programs. This paper takes the postulate that male and female students are equally intelligent and capable of studies in all fields and that inherent sex-differences cannot fully explain the disparity in mathematical achievement and ability when answering the question ‘how should educator address gender differences to support all students’ learning and achievement in mathematics.’

CHAPTER TWO – HISTORICAL BACKGROUND

Introduction

Before examining how educators should address gender differences to best support equity in students' learning and achievement in mathematics, the historical views of women and education should be discussed. Prominent teacher education historians Sadker & Sadker (1994) rightly describe the traditional education system as one that kept girls from full participation for the two centuries following America's inception. It is important to understand how these historical views led mathematics to become a male-dominated field. In addition, an exploration of past beliefs and attitudes is crucial in establishing why so few female scholars were given the same educational opportunities as their male counterparts.

In the early seventeenth century the, "Massachusetts Bay Colony enacted legislation requiring families to teach their children to read and understand the principles of religion and the capital laws of the country" (Cremin 1970, p. 16). The law required that once a settlement reached fifty households, it must appoint a teacher for reading and writing, and once one reached 100 households, it had to establish a grammar school. In Connecticut, similar laws were passed in 1650, requiring both servants and children be taught to read in English and the capital laws of the colony. Children were also to be instructed in a vocation or profitable trade skill useful for the colony or commonwealth (Cremin 1970, p. 125). Although girls were included alongside boys in this parental-driven educational system, the curriculum set aside for girls comprised of subjects and skills thought appropriate for their feminine nature. More importantly, it was vastly different than the education their male brethren could expect to receive. The dichotomy created by the establishment of two separate 'male' and 'female' appropriate curriculums would last well into the twentieth-century and became pervasive in all stages and forms of education, from home schooling to higher education.

During the American colonial period, the purpose of women's education was based solely on religious principals. Women were, "viewed as mentally and morally inferior, women were relegated to learning only domestic skills" (Sadker & Sadker, 1994, p. 15). Women's education at this time was limited to the basics: reading, writing, and arithmetic (Spring, 2001). Puritans sought to educate women enough so that they could read the Scriptures and therefore avoid 'Satan's trickery,' and allow them to instill religious values in their own children in order to keep them safe from evil (Sadker & Sadker, 1998, p. 269). This left little time for females to develop a strong grasp of mathematical concepts and thus the subject became relegated to the purview of men.

One of the first, and perhaps earliest, female school in the United States was The Bethlehem Female Seminary, founded in 1742 (Mcclelland, 1943). Oberlin College became the first college in the United States to admit both women and men, after they admitted four women into their program in 1833[ii] (Sadker & Sadker, 1994, p. 21). Neither institution was particularly ground-breaking; both institutions offered differing and unequal courses and educational opportunities for their female and male students. Churgin (1978) stated that the women attending Oberlin college were given a less strenuous and rigorous literary course and were expected to serve the male students food in the dining hall. Even more shocking to modern sensibilities was the prohibition against women speaking in mixed gender classes—again illustrative of the underlying assumption of the inferiority of women's mental faculties perpetuated by gender-specific curriculum.

The common school movement of the early nineteenth-century saw the beginnings of more equitable educational opportunities for women. Under the leadership of Horace Mann, ideas such as common public educational institutions became popular. This movement culminated in the establishment of public elementary schools, with the first founded in Boston in 1821 (Spring, 2001) The establishment of these early public schools allowed for the creation of a common curriculum, which saw boys and girls not only integrated, but also working and using the same books, classrooms, and teachers. This is not to say that integration was complete and equal, girls and boys still sat on segregated sides of the classroom and physical exercises and sciences were still subjects limited to boys, but change would gradually come to lower-level educational institutions.

Attitudes toward women in higher education, however, still remained stubbornly negative. Dr. Clarke, in his treatise *Sex and Education* (1873), cautioned women from attending high school and university warning that the disruption of blood flow from their reproductive organs to their brains would have lasting negative effects on their fertility. This tug-of-war between the expansion of women's opportunities, and negative social attitudes about women's education continued on into the 1970s. Only with the establishment of the Title IX provision have educational historians credited women with real and sustained increases in educational opportunities and equality. Within the last few decades, academic scholars are beginning to understand and interpret the changes imposed on the American educational system more than forty years ago.

The presence of real or imagined gender-based gaps in mathematics achievement, then, can be seen as a natural product of a legacy formed around the basic assumption of gender differences in innate ability and mental acuity. As we will see, these ideas have had a long and storied past.

Gender Differences

Differences in mental capabilities and physiology between the sexes has been a recurrent motif for thousands of years. In ancient Greek education for example, opportunities and expectations were distributed according to gender (Huerta, 2008). Etsay & Snetzler (1998) stated that "gender differences in cognitive abilities, ha[ve] a long history."[iii] As time progressed, the absolute inferiority of women became increasingly challenged. Prominent thinkers in American history held divergent views on the limits of women's mental faculties. Blinderman (1976) stated that Benjamin Franklin wrote in *Reflections on Courtship and Marriage* (1750) that if women were educated as men were, they would then reason and think the same, but unfortunately women were not generally afforded this right. Blinderman (1976) highlights an opposing view held by Noah Webster,[iv] who believed that "women are by nature intellectually inferior to men" (p. 29).

As early as 1976, modern research had begun to identify an opportunity and participation gap between male and female students in mathematics, with fewer women continuing study once the subject became optional (Estay & Snetzler, 1998). From the mid 1970s onward, gender differences became prominently discussed when examining education policy and teaching pedagogy. For example: Moir and Jessel (1992) wrote that "[t]he biggest behavioral difference between men and women is the natural, innate aggression of men, which explains to a large degree their historical dominance of the species," (p. 7) and "from school age onwards, boys will generally outperform girls in areas of mathematics involving abstract concepts of space, relationships, and theory. . . for every exceptional girl there were more than thirteen exceptional boys" (p. 16). The debate continues, with a ever-amassing database and body of research being conducted concerning gender differences in education. For instance, a simple subject phrase search on ERIC using 'gender differences' elicits a list of more than 7,000 scholarly articles published just in the last two decades.

Gender differences, when applied to mathematics, has a much more recent scholarly history, starting in the last half of the twentieth-century. Ai (2002) showed a progression of ideas starting with Aiken's 1976 research on gender differences in mathematics. Aiken believed that attitudinal explanations of the gender achievement gap were not enough; the influences from parents, teachers, peers, and schooling must also be considered in mathematical achievement. Ai cited Goldin's 2000 study, which concluded that affective factors play a key role in learning and teaching mathematics. Ai also, pointed to Fennema's 1984 work and Tocci & Engelhard's 1991 study, which showed that social factors influenced mathematical achievement.

Current scholarship has focused on two main arguments of gender-gap research: one, the existence or non-existence of such gaps, and two, the causes and effects of such gaps. Frost, Hyde, & Fennema (1994) found evidence suggesting the existence of gender differences in mathematics. Expanding upon that premise, Lachance & Mazzocco (2005) posited that the disparity in mathematical careers between genders resulted from inherent or culturally influenced gender differences in math ability and performance. Frost, Hyde,

& Fennema (1994) found evidence suggesting the existence of gender differences in mathematics. Stubig (2005) stated "[s]ocial historians of female education have often pointed out the huge difference between the education of the two genders, the discrepancy of contents," (p. 8) but Herbert & Stipek (2005) cited research (Cole, 1997; De Lisi & McGillicuddy-De Lisi, 2002) that found no gender difference in performance on mathematic achievement tests for elementary school students.

Clearly then, not all scholars are in agreement on the existence of gender disparity in mathematical education. Brescoll and Lafrance (2004) found that reports of gender differences can influence beliefs and expectations of gender stereotypes and the discussion of gender differences in the media may lead to expectations of gender differences in mathematical achievement.

There is no clear agreement on the existence of actual achievement gaps in mathematics. Many studies claim overall gender achievement gaps while others show gender differences only on particular mathematical skills or even an absence of such a gap in mathematics education. Ding, Song, and Richardson (2006) pointed out that research has found gender differences first occur in elementary students, and that other research point toward junior high or high school as the first occurrence of gender achievement differences. The idea of mathematical achievement differences has been studied at great length, and the key issues are still debatable. All of this conflicting and contradictory research (which will be examined further below) forces the question: Are there gender differences in mathematical achievement? Secondarily, if these differences do exist, then what are the causes?

Stereotype threat

Stereotype threat was first introduced by Steele and Aronson (1995) when studying African American and Caucasian college students' test performance. From their research further investigations into stereotype threat were instigated. These studies sought to understand and quantify the effects and implications of stereotype threat if and when they occurred. Some studies tried to determine for whom stereotype threat was a high risk; while other studies investigated outcomes from stereotype threat.[v] Although stereotype threat is a relatively new educational field of study, there is a significant amount of research and interest in this area. Walton & Cohen (2003) studied stereotype lift. The importance of stereotype threat for mathematics education is currently the subject of much interest amongst researchers. Rosenthal (2006) writes:

> other researcher have found similar effects [of stereotype threat for African American college students] in additional stereotyped domains, such as low social-economic status and intelligence (Croizet &Claire, 1998; Good, Aronson, & Inzlicht, 2003), homosexual men and childcare (Bosson, Haymovitz, & Pinel, 2004), . . . and women and mathematics (Ambady, Paik, Steele, Smith, & Mitchel, 2004; Brown & Pinel, 2003; Gonzales, Blanton, & Williams, 2002; Inzlicht & Ben-Zeev, 2000; Josephs, Newman, Brown, & Beer, 2003; Keller & Bauenheimer, 2003; Marx & Roman 2002; McIntyre, Paulson, & Lord, 2003; Pronin, Steele, & Ross, 2004; Rosentahal & Crisp, 2006). (p. 587)

Influence from People

Parents have long played a key role in the education of their children. Early American children learnt almost everything they needed to from either their parents or from apprenticeships chosen by their parents or progenitors (Spring, 2001). More recently, Hall, Davis, Bolen, & Chia (1999) also stated that "Eccles (1993) found strong evidence that parents' perceptions about their child's ability and interest in academic subjects [were] related to the child's attitudes and academic performance" (p. 679). They also cited Entwisle & Alexander (1988) who investigated parents' psychological support and this support's influence on academic success. These relationships create several areas for further research to expand upon. Crosnoe, Riegle-Crumb, Field, Frank, & Muller (2008) pointed out the competing hypotheses of friends or course-mates having the most influence on mathematics course-taking. They cited earlier research into the area of peer relationships and mathematics (Giordano, 1995; Riegle-Crumb, Farkas, & Muller, 2006; Ryan, 2001; and Brown & Klute, 2003). The course-mate hypothesis (Field, Frank, Schiller, Riegle-Crumb, & Muller, 2005; Friedkin & Thomas, 1997) postulated that course-mates would typically exert the strongest influence on course selection and achievement by a student, while the competing friend hypothesis (Brown & Klute, 2003; Hartup & Steven, 1997) saw friendship as the major instigator of class selection and further achievement. Other hypotheses sought to establish a link between current success in mathematics and future successes and involvement, still others researchers tried to establish whether or not previous mathematical experiences help build confidence and therefore increased the likelihood of continued course selection (i.e. with a particular favored instructor).[vi] Another controversy raised by Crosnoe, Riegle-

Crumb, Field, Frank, & Muller (2008) was whether or not influences vary amongst high-achieving and low-achieving students. To further complicate this issue, there are different gender hypotheses for each of these issues. An example of this is of a poor performing female students who is influenced more by her friends' successes in mathematics and is therefore compelled toward taking further classes, while a poor performing male students could be more influenced by his course-mates' success in regards to further mathematics course taking. These factors then may even change with the progression of time.

Riegle-Crumb, C., Farkas, G., & Muller, C. (2006) studied the relationship between gender, friendship, and upper-level course enrollment. These studies show the importance of interpersonal relationships in mathematics achievement and course selection despite the fact that many of these studies themselves are contradictory or limited in scope.

Attitudes and Competency Beliefs

Several studies have been initiated in order to link mathematical attitudes and beliefs with specific gender-normative ideals. Farooq & Shah (2008) cited Costello's (1991) investigation of the perception that mathematics was a male domain. Boswell's (1979) report about the negative influence of sex-role stereotype on females and Leder's (1984) report on the differences in attributions of failure and success between genders all point out the importance that gender-nominative studies have on educational practices.

Halat (2006) studied the differences in motivation between genders in learning geometry whilst Thompson & Dinnel (2007) investigated perceptions of self-worth and mathematical ability and achievement. Skaalvik & Skaalvik (2004) highlighted Sax's

(1994) study which found, “gender differences in academic self-evaluation may result in subsequent gender differences in academic achievement and motivation” (p. 241). Skaalvik & Skaalvik (2004) also stated that many studies point toward a gender difference in mathematics self-concept that favors male students (i.e. Bryne & Shavelson, 1986 and Eccles, Wigfield, Harold, & Blumenfeld, 1993) (p. 241). Skaalvik & Skaalvik (2004) related a Hyde, Fennema, Ryan, Frost, & Hoppp (1990) study that demonstrated differences in math self-concept for elementary school students (p. 242). As Eccles (1987) succinctly put it: “Gender difference[s] in math and verbal self-concepts are most frequently explained in terms of gender stereotypes and differential gender role and its importance for socialization patterns” (p. 242).

Teacher Practices and Interventions

Teacher practices have been the increasing focus of research into gender inequalities in modern education systems. In studies investigating the perceived or actual gender gaps present in mathematics, this trend is also carried out. Saltzen (1981) studied the effects of instructional grouping on gender differences in mathematical achievement. Suydam (1981) studied aspects of mathematics instructional practices, learning theory, and student achievement and Thompson (1984) investigated instructional practices and impacts on mathematics, stating that most early research on teacher practices was on teachers’ knowledge of mathematics and not on their actual teaching practices (Beagle, 1972; Eisenberg, 1977). Artzt & Armour-Thomas (1999) examined teachers' instructional practice in secondary school mathematics. Laster (2004) investigated same-sex instruction and Lau and Yuen (forthcoming 2010) investigated the importance of both pedagogical knowledge as well as understanding the mental representations used by students and its importance for inclusion into instructional decisions.

Summary

The role and extent of male and female education differed for thousands of years. For a long time women were thought to be mentally inferior to men. In ancient Greece gender (along with status) played a major role in determining the type and extent of education one would receive. During the colonial period in the United States, women were educated for the purposes of educating their own children and for religious reasons. The common school movement, of the early nineteenth-century, began a move toward more equitable educational opportunities for females. In the 1970s, the United States Government established laws preventing the discrimination of women in federally funded educational programs with the enactment of Title IX, which showed that the government believed intellectual equality between the sexes.

Gender differences, when applied to mathematics, has a more recent scholarly history. Many contradictory findings showed a disparity, or a lack of disparity, in mathematical achievement. Research studies that showed a mathematical achievement disparity pointed toward many different reasons for the disparity: including, innate differences, differences in socialization, stereotype threat, competency beliefs, attitudinal differences, teacher and student practices, and the influence from people. Many of the findings from these studies contradicted each other.

One key piece of evidence is that female students are less likely to enroll in upper-level mathematics courses from high school onward. In chapter three, I will look at studies which try to determine if parental anxieties, beliefs, and perceptions of mathematics can influence their children's mathematical learning, abilities, and achievement. In addition, I will discuss research that studied the effect attitudes of peers toward mathematics can have on mathematical achievement, both positively and negatively. Some studies showed that female students experience less enjoyment and pride in mathematical ability and achievement than their male counterparts while also experiencing more anxiety, hopelessness, and shame concerning mathematics. I will also discuss the impact stereotype threat can have on both male and female students. I will look at studies that showed male and female students can have different reactions to different types of instruction, courses of instruction, types of classes, tracking systems, and interventions and specific teaching practices that lead to a change in attitude and perception for female students.

CHAPTER THREE – CRITICAL REVIEW OF THE LITERATURE

Introduction

The first chapter of this paper described the importance of the question 'how should educators address gender differences to best support equity in students' learning and achievement in mathematics?' both personally and professionally. Personal reasons for studying perceived or actual gender differences were that I liked mathematics as a child and want to better understand why I was able to succeed in mathematics while so many of my friends experienced difficulties. Professionally, as a perspective mathematics teacher, I want to better understand the perceived and actual gender gap in mathematics so that I can use my findings to better serve portions of the population that may experience difficulties in mathematics. The importance of mathematics is increasing in the new global economy and while traditionally mathematics has been seen as a male domain, this trend needs to be reversed lest it exclude or hamper female participation in fields with the most growth, especially those dealing with technologies. Chapter two of this paper attempts to highlight the progression of research and ideas concerning mathematical gender achievement gaps, creating a basis for the critical review of literature in chapter three.

This chapter uses research articles to help answer the question of how educators should address gender differences to best support equity for all students' learning and achievement in mathematics. The first section of this chapter reviews scholarly research concerning perceived gender differences in mathematical ability and achievement. Contradictory evidence suggests that gender differences in mathematical achievement and ability are present in our education system. The second section of this chapter will deal with stereotype threat and its implications for students. The third section, will look at the influence of parental units and peer groups on mathematical ability, learning, and continued course enrollment. The fourth section of this chapter investigates attitudes and competency beliefs and their impact on mathematical ability and achievement between genders. The fifth section of this chapter studies how emotions and anxiety affect mathematical ability and achievement. The last section of this chapter investigates teaching practices and interventions that can help gender equity in mathematical achievement and ability.

Gender Differences

While investigating the question of how educators should address gender differences to best support equity for all students' learning and achievement in mathematics, we first need to explore whether or not the potential for gender differences in mathematical ability and achievement actually does exist. If in fact the potential for gender differences in mathematical ability and achievement exists, one needs to ask when does it develop and what those differences are. Current research provides contradictory evidence with regard to ability and achievement, however most researchers agree that the evidence depicts an overall net trend of female students enrolling in fewer upper-level mathematics courses.

The field of research concerning the presence or absence of measurable gender-based differences in mathematical abilities and achievement is littered with conflicting viewpoints and conclusions. Ai's (2002) study found that low-achieving female students showed the greatest growth in mathematical achievement and ability. Ai stated that teachers had the greatest impact on the growth of mathematical achievement and knowledge for those female students. Conversely, parental encouragement negatively effected their achievement. Ai concluded that no significant gender-based mathematical ability and achievement existed between male and female students.

Additional studies have been carried out in recent years. Ding, Song, & Richardson (2006) made the determination that gender alone was not a predictor for mathematical achievement, but they nevertheless found that both middle and high school female students had a higher grade-point average (GPA) in mathematics courses. Lachance & Maxxocco (2006) studied gender differences in mathematical skills, ability, and mathematical IQ's, and found that female and male students outperformed each other on different mathematical skills and tests and concluded there was no overall pattern of mathematical dominance for male or female students. Carr, Steiner, Kyser, & Biddlecomb (2007) investigated gender differences in: applied mathematical strategies, fluency, accuracy, spatial ability, and confidence; and whether or not these differences could predict mathematical achievement and ability. Their study found that by second grade, gender differences indeed had begun to emerge. Gierl, Bisanz, Bisanz, & Boughton (2003) researched content and cognitive skills that could produce differences in mathematical ability and achievement and found a slight, but statistically not significant, achievement gap which favored male students.

Other studies have focused on high school students and their mathematical achievements. Catsambis (1994) studied opportunities, attitudes, and achievement that lead to decreased participation in mathematics for female students over time. She found that by tenth-grade, female students' self-concept of their mathematical ability was lower than their male counterparts. Linver & Davis-Kean (2005) investigated predictors of mathematical ability and achievement for genders in middle school and high school and uncovered that higher teachers' expectations led to higher levels of mathematical achievement for students, especially female students on the upper-level mathematics track. Tsui (2007) investigated the relationship between gender and mathematical achievement for students in the United States and China and found a large disparity favoring male students in the uppermost tiers on ability tests.

Despite these conflicting conclusions, one can still extrapolate meaningful patterns and more importantly, some strong causal connections concerning gender-based inequalities in mathematical education. Before considering the outcomes and patterns evident in these findings, we will first critically evaluate the leading studies pertaining to gender-based mathematical inequalities. We will now briefly survey some of leading research adding to the current debate surrounding achievement gaps in mathematics education.

Ai (2002) studied gender differences in mathematical growth and achievement in relationship to attitudes towards mathematics, self-esteem, parental academic encouragement, teacher expectations, and peer influences. Ai investigated initial status and growth rates of students by gender. Ai used data collected from two cohorts of students (younger and older student cohorts). The participants were a group of 3,116 randomly selected seventh grade students from 52 different public schools that participated in the study through the completion of high school.

Ai (2002) used a three-level analysis to describe: each individual's mathematical growth, variations across individuals' mathematical growth, and variations in initial status and growth rate between schools. Students were separated into four groups: low-achieving girls, low-achieving boys, high-achieving girls, and high-achieving boys. The growth patterns of the four groups, in regards to mathematical achievement, showed that the high-achieving groups had a higher growth rate from eighth grade onwards, but that there was no discernable difference in growth rate between genders. For the differences across schools, Ai found that there were differences in growth rate, but that it favored either male or female students depending on the school. For female students, mathematical attitudes were related to other school level variables, but for male students the effect of mathematical attitudes was independent from those same variables. Ai found that there were large individual differences in initial status and growth rate for both male and female students, but between-gender differences were much smaller and only significant in low-achieving groups. Girls initially out-performed their male counterparts in low-achieving groups, but growth rates thereafter were dependent more on schools. The effect of mathematics attitude on math scores was stronger for males than females, and no effect was found to come from mathematics teachers' encouragement for female students. Ai found encouraging mathematics teachers had a significant impact on male students, while female students demonstrated a more muted response except in low-achieving classes.

Ai (2002) concluded that there was a significant, but small, gender gap in mathematical achievement in favor of female students' growth rates who started lowest in mathematics, and that there were school-to-school difference in mathematical growth rates of male and female students in all ability groups. Differences in mathematical achievement and growth within each group were stronger than between gender-based groups. For female students that started in remedial classes, teacher encouragement was a positive influence on achievement while parental encouragement had a negative effect on achievement. Because his results showed no distinct difference based upon gender, Ai concluded that there is no mathematical achievement gap.

The validity of Ai's (2002) quantitative study was high. Ai explained the methods used so that the experiment could be reproduced and here was no multiple-treatment interference, nor was there evidence of the Hawthorne effect. The data analysis, quantification, and collection were effective, un-biased, timely, and consistent. The duration of the experiment was sufficient and the selection of participants was random and from a very large sampling size. There was no evidence of confirmation bias, nor was there any indication that the results found in this study could not be replicated by different researchers and so Ai's study has high transferability for populations of similar students.

Ding, Song, & Richardson (2006) used student performance on standardized tests and student transcript data to study potential patterns of gender difference in mathematics performance in schools in the United States. There were 174 female participants and 168 male participants from seven schools, with four percent of them being classified as special education and eleven percent being classified as gifted.

The first study by Ding, Song, & Richardson (2006) examined SAT-9 scores over a four year period for each student. The results indicated that male scores were numerically, but not significantly, higher. There was also no difference in the growth rate in regards to mathematical achievement on the SAT-9 between genders. "It seemed that these variations in mathematics performance could not be explained by the gender variable" (p. 286). This means that all seven schools had similar initial mathematics scores and that the growth rate over time for both males and females was not significantly different.

The second study by Ding, Song, & Richardson (2006) examined the mathematics GPA of participating students during middle and high school. The results of the second study indicated that the coefficient for time was negative, showing a decline in mathematics performance over the middle school years measured by mathematics GPA. The coefficient was positive for gender, with males being the reference group. The results of this study indicated that females had a higher average mathematics GPA than males during both middle school and high school. Students who had a higher initial mathematics GPA tended to have a lower rate of increase in mathematics GPA over the course of the study.

Ding, Song, & Richardson (2006) concluded from these two studies that there is no difference in mathematical ability or achievement between genders, even though female students did have better mathematics GPAs in both middle school and high school. In all groups, students that had lower initial achievement showed the most growth in mathematical ability and achievement measured through GPA and SAT-9 scores.

These studies were externally and internally valid, but one question that was not addressed by them was whether or not female and male students took the same number or level of mathematical courses. Some researches argue that female students take less mathematics courses in high school, which could be a confounding variable. One conclusion they reached that seems problematic is regarding the importance given to GPA improvement. Although Ding, Song, and Richardson reported that students with the lowest GPA had the highest growth rate, it is not clear if the highest growth rate correlates to the highest increase in actual ability. It is entirely plausible that the low-achieving sub-group of students had the greatest improvement in their GPA due to this sub-group having the most room for improvement numerically within their GPA range. This over-simplified linking of GPA growth with increased achievement also isolates high achieving students who maintain a high GPA and therefore register ‘no growth’ as defined by this study.

Lachance & Mazzocco (2006) studied the gender differences in mathematical achievement, mathematical ability, and math related tasks for students in primary school. Participants hailed from the same school district, and all kindergarten students were invited to participate in the longitudinal study. Data collected for the study consisted of IQ tests, mathematical ability tests, mathematics achievement tests, and spatial ability tests. The participants were tested individually each year and the order of tests was fixed across all participants. What Lachance & Mazzocco (2006) discovered was that there was no difference in the mean IQ scores between genders. Female students outperformed male students on three of the seven tests measuring visual spatial skills while male students outperformed female students on addition, measurement, and time and money tests. There were no statistically significant differences between genders for counting and basic math facts. In addition, Lachance & Mazzocco (2006) reported no gender difference in initial starting points and individual students’ growth rates of mathematical abilities.

Lachance & Mazzocco (2006) concluded that: “our findings support the notion that sex differences in math, on standardized tasks similar to those seen in school for primary school age children, are minimal or nonexistent" (p. 210). No pattern of male or female advantage for all of the math tasks or all of the spatial skills existed.

Carr, Steiner, Kyser and Biddlecomb (2007) studied strategy use, fluency, accuracy, spatial ability, confidence, and the viability of using these factors to predict mathematical competency. Participants included 241 second-grade students from Georgia (118 male and 123 female). Carr et al. investigated whether strategy use was influenced by gender, fluency, accuracy, spatial ability, and/or confidence. Participants were tested for strategy use on a twenty question test (eighteen double-digit and two triple-digit arithmetic problems), fluency and accuracy on single-digit arithmetic problems, spatial ability on a three-dimensional spatial ability test, and for mathematical achievement using the CRTC mathematics competency test.

Carr, Steiner, Kyser, & Biddlecomb (2007) found that there were gender differences in spatial ability, fluency, confidence, correct cognitive strategy used, and correct manipulative strategy used. Male students had higher spatial ability and were more likely to use cognitive strategies correctly. Male students were found to be more confident and fluent than female participants. Female students were found to use manipulative strategies correctly more often than male students. No differences were found between genders and competency or accuracy scores. Carr et al. (2007) also found that fluency, accuracy, correct cognitive strategy usage, gender, and gender confidence interaction predicted performance on mathematics competency tests. Spatial ability was not a predictor of mathematical competency. The two most significant predictors of mathematical competency were fluency and correct cognitive strategy usage, both of which were shown to favor male students.

Carr, Steiner, Kyser, & Biddlecomb (2007) concluded that by second grade, differences in strategies usage and fluency are present between genders. Male students had higher confidence in mathematics, but this tended to negatively predict mathematics competency. Female students' lower mathematical confidence reflected a more accurate representation of actual mathematical skills. Spatial ability does not predict mathematical competency, while fluency, accuracy, and correct cognitive strategies do predict mathematical competency.

Gierl, Bisanz, Bisanz, & Boughton (2003) studied content and cognitive skills that can produce difference in mathematics achievement between genders. To do this Gierl, et al. used a Differential Item Functioning (DIF) hypothesis tested by statistical analysis testss. Multiple linear regressions were used to determine if content and cognitive differences predicted gender related DIF. The data used in this study was from the 1996 and 1997 ninth grade mathematics achievement tests administered in Alberta, including 6,000 female and 6,000 male students selected randomly, from a potential 36,000 students. The tests were developed with high quality control standards, screening out content-related gender differences and went through multiple reviews.

Gierl et al. (2003) found that although male students outperformed female students in both years, the difference was small. The shape of the distributions were similar for both males and females, difficulty and discrimination were similar for both groups, and internal consistency was similar for both male and female students. Items associated with spatial skills favored males, while memorization skills favored female students. Statistical analysis only confirmed males' advantage with spatial skills and not a female advantage in memorization skills. From the multiple regressions Gierl et al.

found that only spatial ability was a significant predictor of achievement and it favored male students, and that males performed better on both items requiring spatial and verbal ability. Gierl et al. (2003) concluded that specific content and cognitive skills would produce gender differences in mathematical achievement. The authors pointed to the nine categories tested; in which males routinely performed better on items that required spatial ability, while other tests yielded no significant gender-based gap.

Catsambis (1994) studied the process of decreasing female participation in mathematics that coincides with adolescence, placing an emphasis on mathematical learning opportunities, attitudes, and achievements from middle school to high school. Catsambis used data from the National Education Longitudinal Study (NELS: 88), which used a stratified sample, and data obtained from a follow-up after two-years. For this study Catsambis restricted data samples to only students attending public schools, with a starting sample of 19,000 students and ending sample of 14,000 students.

The three variables that Catsambis (1994) measured; opportunity, achievement, and attitudes were broken down further. Opportunity incorporated: ability levels, curriculum, and mathematics course enrollment. Achievement data utilized both grades and standardized test scores. Attitudes included: aspirations for careers involving math and science, attitudes towards mathematics classes, and extra-curricular activities. The results of Catsambis' study (1994), in regards to achievement were, "difference[s] in mathematics achievement occur mostly among racial-ethnic groups, rather than between male and female students" (p. 203). Catsambis found that there are differences in mathematics course level enrollment between ethnicity, race, and gender. White female students had the highest enrollment in upper-level mathematics courses in eighth grade, while African American males had the highest level of enrollment in lower level mathematics courses. By tenth grade, fewer female students enrolled in advanced courses than male students and that White and Latina female students had a lower self-concept of their mathematic ability than their male counterparts. Catsambis also found evidence which suggested that attitudes toward mathematics and career decisions develop independent of opportunity and achievement.

Catsambis (1994) concluded that some similar patterns of gender differences in opportunity, achievement, and attitudes exist for all students. White, African American, and Latina female students do not experience an achievement gap and may have more learning opportunities, but this may be due to school requirements rather than by preference. Catsambis also stated that confidence and attitudes may not predict achievement and are probably a product of judging their performance by their own mathematical grades.

Linver & Davis-Kean (2005) created a study to determine predictors of math grades for middle school and high school students. Their study asked three questions:

> What is the average trajectory for school grades from seventh through high school by gender and by school ability track? Will interest and self-concept of ability predict to grades over and above contextual socializing influences of mothers' and teachers' expectations? Do these predictors differ for young women and young men, and for those in high versus low math ability tracked classes? (Linver & Davis-Kean, 2005, p. 52)

To answer these questions Linver and Davis-Kean examined data from an eighteen-year longitudinal study, done by the Michigan Study of Adolescent Life Transitions. The

1,651 participants had nine separate treatments, with fifty-four percent of total participants being female and ninety-two percent identifying as white.

The measurements studied were: contextual measure, school grades, math interest levels, self-concept, standardized test scores, and math track levels. From these measurements, Linver and Davis-Kean (2005) found that school grades declined for all groups from middle school to high school, but that female students in the highest tracking group had the highest grades overall. This study also found that both a mothers' educational levels and accompanying educational expectations for her children, and that higher teachers' expectations were associated with adolescents' performance in mathematics. Higher teacher expectations promoted greater mathematical achievement, especially for females on the highest math track. For male students on the highest mathematics track, teachers' expectations did not influence their achievement as greatly as it did female students, but the expectations from their mothers was still influential with regards to achievement. For male students math interest and self-concept were generally unrelated to math grades, but prior mathematical achievement was related to present mathematical achievement. One interesting finding was that a mother's education had a negative influence on grades over time.

Linver and Davis-Kean's study had enough participants over a long duration to accurately study the impact of multiple variables on mathematical achievement trends. The study was homogenous and that is an area of concern, because one must ask are the social expectations of mothers' across cultures the same, are mothers' across cultures given the same educational opportunities, and how do interactions between teachers from different cultures effect each culture of students?

Tsui (2007) studied the relationship between gender and mathematical achievement for students in the United States and China, emphasizing mathematically gifted students in China. The Chinese students all attended the twelfth grade at three local schools, with 633 male students and 445 female students. Tsui collected data from 2002 college entrance examination provided by the three participating schools. Tsui also re-examined the mathematical test scores of 489 male students and 551 female students from an earlier survey he had conducted..

The results from Tsui's (2007) eighth grade study showed no statistical difference between gender achievements on mathematical tests. There was no achievement difference between female and male students on the college entrance examinations, but for students scoring over the 50^{th} percentile male students scored higher than did female students. In the upper three percentile the ratio of male to female students was twelve to one.

In both the United States and China, male students dominated the highest score levels of college entrance examination tests. Tsui (2007) hypothesizes that the lack of gender difference in the mean mathematical examination scores of Chinese students compared to the persistent gender gap for SAT math scores for American students may be explained through the child population laws of China, which increases spending and attention on single children's education. Another difference highlighted by Tsui was that only thirty-four percent of American eighth graders attended one day of algebra a week compared to Chinese eighth grade students, for whom have algebra, trigonometry, and geometry are compulsory and meet daily. Another factor that can contribute to the Chinese students' lack of achievement gap is the cultural belief of hard work. From the survey of eighth grade students Tsui found that female students tended to underestimate their mathematical ability.

The validity of this research was not very high because no American data was shown to support any of his claims. The variables and methods were not explained for parts of the study, so this specific study could not easily be reproduced. Portions of the data collected were done in a professional manner, but the overall concerns surrounding this study limit its usefulness as an effective study about gender gaps in mathematics. Rather than completely dismissing this study, one can still use it as a starting point for further research into gender disparity in both American and Chinese education systems.

The main conclusion from the above mentioned studies is that the potential exists for differences in mathematical achievement and ability. This should affect educators pedagogical decisions for many reasons including gender and support parity. The causes and remedies for gender differences must be present in mathematical instruction and planning to ensure equity of opportunity. As early as second grade differences start to occur and by high school fewer females enroll in upper-level mathematics courses. Although studies pointed to contradictory outcomes, one thing each study had in agreement was that—for better or worse—teachers' expectations can play a key role in the achievement and ability for female students. Female students average higher mathematical GPA's in middle school and high school, but this could be because fewer female students take upper-level mathematics courses; more male students could mean a wider variety in skill and ability levels, or less female students can mean those with higher-levels of confidence and ability take the upper-level mathematics courses. Female students do not do as well on the mathematical portion of the SAT, but this data may suffer from the same bias as those for GPA's. Many of the studies showed that female students outperformed male students early in their educational careers, yet later in mathematics female students constitute a smaller percentage of students in mathematics courses and higher-level mathematical jobs. Female students have lower mathematical confidence and mathematical confidence and achievement decline for all students over time. Many different factors can influence mathematical achievement including competency beliefs, attitudes about math, and stereotype threat.

Stereotype Threat

Stereotype threat can play an important role in the mathematical achievement and abilities. In order for educators to know how to address gender differences and best support equity in students' learning and achievement in mathematics, they need to be aware that stereotype threat can both hinder and enhance mathematical ability and achievement. Stereotype threat is generally proposed as an innate ability or disability to achieve or perform a given task. Both socialization and gender roles influence stereotype threat. When stereotype threat affects ability, both intelligence and aptitude are also questioned. In effort stereotype threat, the effort levels of groups are threatened. Both types of threat produce different results and can cause either stereotype lift or threat. This section will look at several aspects of stereotype threat: performance avoidance goals, differences between minorities and economically diverse populations, and actual performance in different mathematical domains.

Smith (2006) studied stereotype threat, performance-avoidance goals, and women's mathematical performance and expectations. Smith found that women endorsed performance avoidance goals more frequently than males when encountering stereotype threat. Good, Aronson, & Inzlicht (2003) investigated the effects of stereotype threat and interventions for different populations and found that when stereotype threat was coupled with intelligence expandability theory the gender gap on mathematical tests became nil. Rosenthal, Crisp, & Suen (2007) researched the effects of stereotype threat on mathematical performance. Rosenthal et al. found that when female students generated shared academic characteristics between genders there was improved performance expectations. Thoman, White, Yamawaki, & Koishi (2008) studied the relationship between female students and stereotype threat for different types of threats for mathematics. Thoman, et al. found that females who were threatened with effort threat actually answered more questions on a mathematics test than those that were not threatened or just experienced with ability threat.

Smith (2006) looked at the interplay among stereotypes, performance-avoidance (PAV) goals, and women's math performance expectations. The research asked, "Does stereotype threat affect mathematical performance and does it affect performance goals?" Participants were asked to fill out demographic information and an eight-point Likert-style measure of mathematical domains. Then the participants read an ostensible journal article which explicitly reminded the participants of mathematical stereotypes (two different treatments). One of the groups was told that research showed that men outperform women on the upcoming math test, while the others were told that research does not support stereotypical gender differences and men and women perform the same on the upcoming math test.

The results from Smith's (2006) first study showed that women endorse PAV-goals to a greater extent when experiencing stereotype threat compared to when the stereotype is countered, but since men were not part of the study there can be no comparison to how males would have reacted and how they might differ in regards to PAV-goals. Women in the stereotype-consistent condition would be more likely to endorse PAV goals.

For Smith's (2006) second study, participants were exposed to the stereotype-consistent manipulation used in the first study. The participants read the same journal article as in the first study in order to remind participants of the stereotype stating men as superior to women in mathematics. Then participants were shown ten test items, and then they completed the same twelve-item performance goal survey, rating each item along a seven interval data sheet. The results of this study showed that less women believed they would receive an excellent grade on the mock exam than men would, and that under gender math stereotype-salience conditions women endorse PAV-goals to a greater extent than men do. A statistically significant relationship was found between PAV-goal endorsement and performance expectations, with the higher the PAV-goal endorsement correlating with lower performance expectations. Smith argued that women's performance-avoidance goal adoption in stereotype threatening situations led to lower math performance expectations.

The weaknesses of this study are that the sample sizes are small, homogenous, and were taken from college students. The treatment only occurred once and did not address long term stereotype threats and whether or not their effects change over time. The duration and frequency of this study are also questionable. This article does not show what the PAV-goal adoption would do to overall performance, however it is assumed it would be negative.

Good, Aronson, & Inzlicht (2003) studied the effects of stereotype threat and an intervention for female, minority, and economically disadvantaged students. Good, Aronson, & Inzlicht investigated the impact of teaching students different perspectives on school achievement on stereotype threat and test performance. The four groups consisted of 138 seventh-grade students. One group of students had mentors that discussed expandable intelligence and a second group of students' mentors explained that all students face academic difficulty during the transition from junior to senior-high school. The third group of students received a combination of the previous two messages from their mentors. The fourth, or control, group were mentored about the dangers of drugs. Test scores from all groups were compared.

Good, Aronson, and Inzlicht (2003) found that the interventions influenced students' mathematics test scores significantly, and had a significant effect for gender. Male students in the anti-drug intervention scored better on standardized tests than females in the same group. In all other conditions, the gender gap for mathematic test scores was not found. Female students in anti-drug treatment were significantly outperformed by female students from all three other treatment groups.

Good, Aronson, and Inzlicht (2003) concluded that the typical gender gap in math standardized test performance was evident in the control group, but when given treatment about intelligence expandability the gender gap on mathematic standardized tests was removed. "Similarly, the gender gap in math performance disappeared when participants were encouraged to make nonpejoriative attributions for their difficulties and when they were exposed to both the incremental and the reattribution intervention message." (p. 657). There was no additive effect of having both intervention methods, but each intervention led to significant increases in students' standardized test scores. Students' test scores improved through learning attitudes that help contend with anxiety, addressing the stereotype threat of those assessments.

Rosenthal, Crisp, & Suen (2007) performed quantitative analysis on stereotype threat and how it can influence mathematical performance. The first study compared the effectiveness of different versions of the shared task previously employed by Rosenthal and Crisp (2006), which are the effects of asking participants to generate shared academic characteristics, shared non-academic characteristics, and shared physical characteristics.

The results of the first Rosenthal, Crisp, & Suen (2007) study indicated that, overall, participants believed that they would score lower on the test compared to the imagined others. On a subject by subject comparison, there was a significant gender, condition, and target interaction amongst females regarding mathematics. Female participants felt overall that they would score lower compared to the imagined others. The generation of lists of shared academic characteristics between women and men was effective at improving performance expectancies in female participants. Women who generated shared academic characteristics between the genders improved their performance expectancies within a math context, and in fact, it was the only imagined condition that a higher self score was found compared to the others (although it was not statistically significant).

Rosenthal, Crisp, & Suen's (2007) second study reviewed the actual math scores in relation to the shared characteristics task, along with the role of performance expectancies as a potential mediating factor. Students were randomly allocated to one of four shared characteristics conditions (baseline, physical, academic, non-academic characteristics task). They were again asked to complete the shared characteristics task before receiving mathematical instruction on a specific task. The baseline group did not receive a characteristics task. The directions included, "The test you are about to take assesses your current mathematical ability in comparison to other students." (p. 592) They were then asked to predict the score they would receive out of 100, and the scores they expected males to receive out of 100. The participants then took a five minute math test. A set of Helmert Contrasts was used to test the optimal effectiveness of generating shared characteristics. The result demonstrated that listing shared academic characteristics improve performance expectancies, and supported their previous findings.

The two studies conducted by Rosenthal et al. (2007) showed that finding academic similarities between genders was the most effective means of improving performance expectations. Because the study was done on college students, the results may not be applicable or representational of all students' ages and abilities. The sampled participants are somewhat unreliable because the scope of these studies created an artificially high number of academically engaged female participants (since only college-aged students attending higher education were sampled). There are also mitigating factors and confounding variables that may influence the results of the test and could not be controlled, among them: anxiety, working memory, capacity, mental load, intrusive thoughts, and performance expectancies.

Thoman, White, Yamawaki, & Koishi (2008) studied the relationship between female students and stereotype threats in mathematical domains. They investigated gender-math stereotype's effect on female mathematical performance. To do this, Thoman et al. studied sixty-six female undergraduate students, who received extra credit for their participation. The participants were randomly assigned to one of three groups: threat ability, threat effort, and the control group. The participants in each group were told that they were taking part in a newly developed mathematical examination and that they needed women for the study because they already had enough male data. Participants were given surveys both before and after their examination. For the threat ability group, prior to the examination participants were given an article that stated gender achievement differences in mathematics were biological in nature, whilst the threat effort group was given an article that stated males tried harder on mathematics and this accounted for achievement disparity. The control group was not given an article prior to the examination.

Thoman, et al. (2008) found that female participants explicitly threatened with the ability threat performed the same as those who were not threatened. Female students threatened with the effort threat solved a higher ratio of problems than those in the ability threat and the control groups, and although not statistically significant, participants in the threat effort group answered the most items correctly. The study found no correlation between motivation, anxiety, and perceived competence, anticipated difficulty of the examination, effort, or performance expectations across groups. For the control group, higher achievement correlated to lower anxiety and anticipated difficulty of the examination. Participants threatened with the ability stereotype threat performed better when the participants had higher motivation to do well on the exam and post-examination ratings of ability to perform on a mathematical examination. No significant correlations were found for the threat effort group.

Thoman et al. (2008) concluded negative stereotype threat effects performance and can be nullified when the content is framed as an effort—rather than an ability—threat; students who are taught that intelligence is based on effort rather than on natural ability perform better on standardized tests than those that have not received that instruction. By shifting the focus from natural ability towards effort, students likely feel more in control of changing their current level of achievement and have better hopes of higher achievement in the future.

This study exhibits some of the same problems as previous studies, namely the under-representational nature of the study's participants—all of whom were female college. In addition, the participants for this study were not randomly selected, but rather volunteered in order to earn extra credit for collegiate courses—which is important considering the small sampling size utilized by Thoman et al.

Some conclusions can be drawn from these research articles. Female students under stereotype threat increase their performance avoidance goals (PAV), and as the PAV goals rise, female students lower their expectations of mathematical achievement. Female students under stereotype threat believed that they would score lower than fictitious others, but if the female students under stereotype threat created a list of shared academic characteristics across gender then the effects of stereotype threat were lessened or nullified. When competency is questioned, female students may do worse, but when effort is threatened female students try harder.

From these conclusion, it appears likely that female students simply follow expectations. If students are thought to be incapable of doing a mathematical task because of inherent intelligence, then they will not be able to complete the task because of feelings of futility and/or inevitable failure . If students' effort is threatened, they have the ability to do something about their effort, and are able to modify their behavior and/or effort accordingly. This is similar to findings on expandable intelligence which suggest that intelligence is not fixed or set, but rather something that can be improved upon (Good, Aronson, & Inzlicht, 2003). In effort threat, threatened students will actually put more effort into the mathematics while threats of intelligence raised anxiety and potentially caused lower scores for those that were threatened. Furthermore, stereotype threat and anxiety appear to be closely linked, and this connection will be explored in the following section.

External Influences

Muller (1998) wrote, "Researchers and policy makers have long known that family background is an important determinant of success in school (Coleman et al., 1966), yet they know much less about why this is the case" (p. 336). Muller points out that socialization differences between young females and males and their parents may differ in respect to the gender(s) of both parents and the children. One must ask if there exists differences in how parents raise male and female children and if parents involve themselves in schooling differently based on child gender? While addressing the question on how educators should address gender differences in regard to equity in mathematical education and achievement, socialization and the influence from friends and families are need to be considered.

In this section studies pertaining to outside influences on mathematical ability, achievement, and further course enrollment are examined. Crosnoe, Riegle-Crumb, Field, Frank, & Muller (2008) investigated the relationship between gender differences, peer relationships, and mathematical courses taken. Muller (1998) researched differences in parental involvement and mathematical achievement. Hall, Davis, Bolen, & Chia (1999) studied the relationship of parental anxiety toward math and performance for gender and race and found that parental anxiety toward mathematics had a negative impact on students mathematical achievement and ability.

Crosnoe, Riegle-Crumb, Field, Frank, & Muller (2008) studied the relationship between gender differences, peer relations, and mathematics course enrollment. The national longitudinal study of adolescent health and the adolescent health and academic achievement study were both used as sources of data for this quantitative study. Participants were from wave one of the longitudinal study and consisted of 11,396 adolescents from seventy-two high schools. Measurements were taken on adolescent academic factors, friend's academic achievement, course mates' academic achievement, school variables, and individual demographics.

Crosnoe et al. (2008) found that female students had a statistically significant higher average course level than male students. Female students failed less frequently than male students, and the friends of female students tended to make slightly better grades than those of male students. Failure in one school year predicted lower levels of math course taking in the subsequent years; friends' academic achievement predicted higher levels of mathematics course enrollment for both genders. Course mates' academic achievement predicted higher levels of mathematics courses being taken for female students. Friends' achievements were more important than course mates' achievement with regards to impact on further mathematics course taking.

Crosnoe et al. (2008) concluded that friends' achievement had a stronger association with adolescents' future mathematics course-taking than did course mates' achievement, but both groups are associated with further mathematics course enrollment and gain importance over time. Lastly, "efforts to supply at-risk youth with positive supports and opportunities help them do better. Yet, they do even more to help youth who are not at risk, which leads to larger disparities" (p. 153). The study concludes, then, that per capita resources produced a much more profound effect in students who were already at the top of the achievement ladder. This research had both external and internal validity and allows for transferability with similar populations.

Hall, Davis, Bolen, & Chia (1999) studied the relationship between gender, race, and mathematical performance. Participants included seventy-four fifth and eighth-grade students who took the California Achievement Test (CAT) the previous year.[vii] Data for this study was taken from the mathematics section of the CAT, parental questionnaires, and school transcipts. Hall et al. (1999) investigated whether or not an achievement gap existed between genders and races, and if parents had an impact on their chilren's mathematical achievement.

Hall et al. (1999) found a significant negative correlation between the three math scores (calculation, math concepts, and total math skill) and parents' reported level of anxiety about their mathematical skills. Conversely, they uncovered a positive correlation between the three math scores and the most advanced mathematics course the parents completed and overall levels of the parental educational attainment. For the African American students, five correlations were found to have statistical significance: math concept scores and math calculation scores, mathematical concept and total math scores, mathematical calculation scores and total math scores, parental education levels and parental perceptions of their children's mathematical skills, and parental education level and parents' highest mathematics course taken. The Caucasian students had similar findings except that parental mathematical anxiety negatively correlated with scores for total math and math concepts. This study also found that there was no significant gender difference in regards to mathematical performance, and that achievement is equal up through middle school, but there was a significant racial difference in mathematical achievement.

Hall et al. (1999) concluded that there are significant differences for race, but not gender, in regards to mathematical achievement and performance, and that the gap between races is small at the early stages of schooling. The achievement gap between genders does not occur until the end of junior high school or during high school. Hall et al. believed that students would perform best in settings that reduce negative stereotypes about their peer and racial groups.

Muller (1998) wanted to study the relationship between gender differences in parental involvement and adolescents' mathematical achievement. To do this Muller used data from the National Education Longitudinal Study (NELS) including a base year and the following two follow-ups. The students in the study completed "questionnaires about their background; schoolwork, teachers, and activities; and home lives, attitudes, and social relationships" (p. 339). The students were evaluated on multiple subjects, including mathematics, and subsequent follow-up evaluations occurred in two-year intervals. The sample size was 12,766, which only included public schools students.[viii]

Comparing the students' reports of current parental involvement, Muller (2008) measured nine and seven forms of involvement in eighth and tenth grade students, respectively. Muller obtained measures of parental involvement, home-based management, educational management or intervention, and the outcomes from mathematics achievement tests. Muller found that female students had conversations with their parents' more than male students and that these conversations were more likely to occur with the same sexed parent. The study concluded that conversations with fathers tended to be more about discipline or intervention than conversations with mothers. Parents in the study intervened in the lives of their sons more but obtained more information from their daughters. In each grade examined, girls' grades were higher, but boys' test scores were higher. When grades and expectations of the students were controlled Muller found that boys scored one-tenth a standard deviations higher than girls and more than two-tenths of a standard deviations higher when parental involvement was controlled. Parental conversations about school correlated with positive performance, while parental restriction of the students' activities correlated with higher test scores. Parental intervention, however, negatively affects test performance. Muller also found that the strongest predictors of tenth grade test scores were parental restriction of students' activities and engaging in conversations about schooling. If the grades and expectations are controlled for, then tenth graders boys scored higher.

Muller (1998) states that, " parents may contribute to equalizing the mathematics opportunities available to girls" (p. 354). Furthermore, Muller concluded that parental involvement did not appear to reinforce mathematical stereotypes, but that parental involvement did have limiting factors including: race, economic resources, and parental education levels.

This body of research clearly shows that parents do indeed influence their children's mathematical ability, beliefs, and achievement both—positively and negatively. Levels of parental education, beliefs about the importance of mathematics, and levels of anxiety can all influence students' mathematical achievement. Different styles of parental interactions with their children can also effect mathematical achievement. Intervention behaviors, which are mainly associated with fathers, negatively effects mathematical achievement. Parental restriction on children's behavior and conversations about schooling are the two prominent factors that positively impact mathematical achievement. Friends play an important role in mathematical success and intended course selection. The opinions of friends and their success are more important than that of non-friend classmates. External sources of pressure are active agents in the formation of each students' individual mathematical identity and learning experiences, and such sources, be they parents, teachers, or peers, have a complex relationship with the creation and/or manipulation of gender-based differences inside and outside the classroom.

Attitudes and Competency Beliefs

In order to investigate how educators should address gender differences to support equity in students' learning and achievement in mathematics, differences in attitudes and competency beliefs need to be investigated and addressed. Attitudes and competency beliefs can affect students' participation and achievement in mathematics. Female students have lower competency beliefs than male students, which could be a more accurate representation of actual abilities, whereas male students consistently over-evaluate their own competencies. One needs to look at the ways in which males believe themselves better at mathematics and compare those beliefs with the differing attitudes espoused by females concerning their overall lack of mathematical prowess. Socialization and beliefs about gender-based ability norms can lead to differences in beliefs and attitudes about mathematics. Prior successes in mathematics typically leads to further successes, but female students succeed just as frequently—if not more—than male students in early mathematical education, so this discrepancy in acknowledged mathematical ability remains puzzling.

Estay & Snetzler (1998) studied gender differences in attitudes, anxiety levels, and self-confidence toward mathematics and found that female students showed both more mathematical anxiety and better overall attitudes about mathematics. Most importantly, however, female students still viewed mathematics as a male domain. Herbert & Stipek (2005) studied gender differences and children's competency beliefs. Herbert & Stipek found that female students rated their competency lower than male students, which effects students' behaviors in learning situations. Brakatsas, Kasimatis, & Gialamas (2009) investigated the relationship between mathematical self-confidence, confidence utilizing technology, attitudes about learning mathematics through a technology medium, engagement, achievement, and gender. The authors concluded that levels of achievement were related to levels of confidence. Githua & Mwangi (2003) similarly studied the relationships between mathematics self-concept, motivation to learn mathematics, and gender, and found that motivation is important for mathematical learning and achievement. One can easily conclude then, that students' self-concepts impact their ability to achieve in mathematics.

Estay & Snetzler (1998) studied gender differences in attitudes toward mathematics, anxiety level, self-confidence in mathematics, attitudes about mathematics as a male domain, and attitudes about the usefulness of mathematics. They used meta-analysis of more than 95 primary studies, totaling 30,490 students (15,877 female and 14,613 males). They found that female participants were marginally more likely to view mathematics as a male domain. More important results were derived, however, concerning attitudes toward math when divided on the basis of gender. The study concluded that females showed a more positive general attitude about mathematics but also reported more mathematics-based anxiety. At all grade levels, female students reported more mathematical anxiety than male students, with the amount of anxiety increasing rapidly as schooling progressed. In remedial classes, however, male students experienced more mathematical anxiety, possibly due to their perceived failings at a male-identified field. Male students exhibited more confidence in learning mathematics, and in grades nine through twelve male students were more likely to consider mathematics as a male domain than they had previously. For college-aged students this trend was reversed; female students in college were more likely to see mathematics as a male domain than male students. Using this large data set, Estay & Snetzler (1998) concluded that "gender differences in students attitudes toward mathematics do exist but are small in size. They mainly favor males indicating more positive attitudes toward mathematics" (p. 14). Furthermore, since the difference is small, students' attitudes toward mathematics may not fully explain these gender differences.

Estay & Snetzler (1998) did not explain their methodology as clearly as they could have, so their meta-analysis can not be easily reproduced, however their study is internally and externally valid and has a high transferability due to its enormous sampling size. There was no multiple-treatment interference, nor evidence of the Hawthorne effect promoting a sampling bias. The data analysis, quantification, and collection were effective, un-biased, timely, and consistent. The duration of the experiment was long enough, and the selection of participants was adequate to rule out sampling errors based on subject selection or temporal restrictions. There was no evidence of confirmation bias, nor was there any indication that the results found in this study would not be similar to the same study carried out by different researchers and allows for a high degree of transferability.

Herbert & Stipek (2005) studied the emergence of gender differences in children's academic competency beliefs. The data used for this study came from a longitudinal study of children from kindergarten to fifth grade and included competency ratings from students, teachers, and parents, as well as achievement scores. The study started with 378 participants and ended with 345. The participants were tested in either kindergarten or first grade, once more in third grade, and one final time in fifth grade.

The data derived from their study saw no statistically significant difference in gender interaction on test scores, but did show a healthy discrepancy between male and female student's own ratings of their mathematical skills. Female students rated themselves lower than their male counterparts. Parental ratings approached statistical significance, with parents rating mathematical achievement for male students higher than for female students. Once again, one sees that although there were no actual differences between male and female mathematics achievement, there is a discrepancy between genders on how this achievement is internalized and socialized. The data obtained strongly supports the author's claim that students' self-perception of competencies and ability are strongly associated with their behavior in learning situations and that further research is needed to help understand the factors affecting student-held perceptions. Toward this end, Herbert & Stipek (2005) call for a more extensive search as to how parents might subtly convey gender stereotypes that lower perceptions of mathematical competency. Their study is important because it is sound, lacks such problems as: multiple-treatment interference, sampling biases, incorrect quantification, and can be easily reproduced and allows for transferability for similar student populations.

Brakatsas, Kasimatis, and Gialamas (2009) studied the relationship between students' mathematical self-confidence, confidence using technology, attitudes towards learning mathematics through a technology medium, engagement, achievement, and gender. The participants of this study were 1,068 ninth grade Greek students from randomly selected classrooms. Data used in the study included grades during the 2004-2005 year and a Mathematics and Technology Attitude Scale (MTAS). The MTAS has five subsets: mathematics confidence, confidence with technology, attitude to learning mathematics with technology, affective engagement, and behavioral engagement. The MTAS is an excellent test to use because it can easily be adapted to measure the main focuses of current mathematical pedagogy in the U.S.; chiefly the advent of technology and its inclusion in both teaching and coursework, as well as the increasing importance that technology plays in the modern economy.

Brakatsas, Kasimatis, and Gialamas (2009) used a cluster analysis, which created seven clusters of students. Cluster One included students with low mathematics achievement, low levels of mathematics confidence, low levels of affective engagement, low levels of behavioral engagement, confidence in using computers, and positive attitudes toward learning mathematics from computers. Students in Cluster One were significantly more likely to be male than female. Cluster Two was comprised of students with average mathematical achievement, average levels of mathematics confidence, average levels of behavioral engagement, neutral levels of affective engagement, were not very confident in using computers, and had an extremely negative attitude toward learning mathematics with computes. Students in Cluster Two were more likely to be female than male. The next five clusters repeated this phenomenon, with male students typically sharing confidence in technology an its usefulness as a teaching tool, as well as a positive to neutral attitude toward mathematics. Female students, on the other hand, exhibited average to below average levels of mathematic confidence, while having a broader range of feelings toward technology and behavioral engagement. At the opposite ends of the spectrum, their study of Greek schoolchildren also revealed that low-performing participants who were extremely negative towards both mathematics and technology tended to be female, while those participants who achieved the highest marks and were the most open to the inclusion of technology in the mathematics classroom were males (p. 568-569).

Brakatsas, Kasimatis, and Gialamas (2009) concluded that students with high levels of mathematical achievement demonstrated high levels of mathematics confidence, strong positive levels of affective and behavioral engagement, and were not confident with using computers but had positive attitudes toward learning mathematics with computers. Mathematics confidence and affective engagement were the two most important factors associated with the development of positive attitudes to learning mathematics with computers and these two factors were fairly gender-specific. Although the study was taken in a country with a differing education system and cultural identity, the core concepts researched—behavioral achievement and attitude—are seen as seminal in describing achievement gaps in the United States education system.

Githua and Mwangi (2003) studied the relationships between mathematical self-concepts, motivation to learn mathematics, and gender. Githua and Mwangi (2003) had 649 students from 32 randomly selected schools complete a validated questionnaire to quantify students' mathematical self-concepts (MSC) and motivation to learn mathematics (SMOT). Descriptive statistics, correlation, and simple regression were used to analyze the data. They found that there was a statistically significant correlation between MSC and SMOT. Githua and Mwangi (2003) stated that "the results indicate statistically significant gender differences, favoring boy, in students' mean motivation to learn mathematics" (p. 492). Another finding was that male students in mixed and single-sexed environments had a higher mean score on MSC than female students, and that female students in mixed gender settings had the lowest MSC scores.

Githua and Mwangi (2003) concluded that motivation was important for students and the learning process and that teachers could improve students' satisfaction with learning mathematics by considering students' needs and facilitating positive learning attitudes. Even though this study and many of the above research projects are contradictory in their conclusions, this study reaffirms the importance of high mathematical self-concepts in mathematical achievement and feelings of competency.

The validity of Githua and Mwangi's (2003) quantitative study is moderate to high. There could be multiple-treatment interference because mathematics was taught in

English, which was not the native language of the participating students. The results have transferability, but is limited by the differing cultural and social factors inherent in an international study.

Several patterns become evident from these various studies despite the fact that their conclusions are oftentimes in disagreement with one another. Although no clearly defined gap or parity has been conclusively established between male and female mathematical achievement, there are some areas where each study is in agreement. The importance of self-concept was reported throughout much of the current literature, with male students routinely having higher degrees of reported mathematical confidence and more positive attitudes. It is also clear, although to what extent remains debatable, that this difference in self-perception can influence student achievement and class enrollment and participation. In addition, the vast majority of studies posited that these perceptions can also influence learning behaviors. Prior research questioned confidence's impact on mathematical achievement, but I conclude confidence and engagement levels are extremely important factors for achievement and further mathematical study. It seems clear that competency beliefs are inflated for male students, while female students have more accurate representations of actual skills and that this has a direct bearing on student achievement and learning. These differences in self-concept and attitude are important factors in the reluctance of female students to enroll in and participate in upper-level mathematics courses and may help widen the established opportunity gap between male and female students in high school and other forms of higher education.

Due to this discrepancy in self-concept, male students have higher mathematical attitudes and competency beliefs, which can lead them to experience feelings of success and interest for further opportunities in mathematics more than their female classmates. A student's self-perceptions influence achievement and interest in further study in mathematics and the discrepancy between male and female self-concepts in regards to mathematics is a contributing factor to the perceived achievement gap present in the U.S. education system.

Emotions and Anxiety Toward Mathematics

Emotions and anxiety can affect mathematical performance, so it is important for educators to consider both when supporting mathematical achievement. Because the emotions and levels of anxiety tend to differ between male and female students (as previously discussed), educators also need to take these differences into account when trying to support mathematical achievement. First, however, one must look at how education in general relates with emotions and anxiety levels before examining their effects on mathematics education.

The acknowledgement and discussion of emotions has historically been considered a female domain despite their universal nature. Although fairly general, it has been firmly established that positive emotions and feelings toward mathematics can lead to better achievement in mathematics, while negative emotions and feelings toward mathematics may hinder mathematical achievement. It is therefore necessary for modern educators to create learning environments where more positive emotions can be cultivated in both male and female students.

Frenzel, Pekrun, & Goetz (2007) studied the relationship between gender, competency beliefs, and emotions regarding mathematics, and found that female students experienced significantly less enjoyment and pride in mathematics. Frenzel et al. (2007)

wrote that female students also had more anxiety, hopelessness, and shame regarding mathematics and mathematical achievement. Skaalvik & Skaalvik (2004) explored gender differences in general math and if self-concept and motivation could explain differences in mathematical achievement. They believed that gender stereotypes and socialization played a key role in the differences in mathematic self-concept and performance expectations amongst males and females. Delgado & Preito (2008) studied gender differences and what role anxiety, mental rotation, and stereotype threat played. Delgado & Preito found that stereotype threat directly correlated to feelings of anxiety—although its effects on individuals was often varied. Baloglu & Kocak (2006) studied the relationship between mathematical anxiety and gender and found that female students had higher levels of mathematical anxiety, and that this anxiety increased with age, with the exception of anxiety related to numerical operations.

Frenzel, Pekrun, & Goetz (2007) studied the relationship between gender, competency beliefs, and emotions regarding mathematics. Their goal was to investigate whether competency beliefs were associated with emotions and if domain values were related to activity-related emotions. The data used in this study was collected from 2,053 fifth grade German students from forty-two different *grundschule*. Emotion competency beliefs and value beliefs were assessed through a questionnaire at the end of the school year and compared with students' mathematics grades. What their study found was that male students reported considerably more enjoyment and pride in mathematics, while female students reported the exact opposite. Females experienced considerably higher degrees of anxiety and hopelessness toward mathematics than male students did. Students' perceptions of competency also favored male students, which were on the whole more confident than female students regarding their personal mathematical ability. Once again, even though their individual attitudes and feelings toward mathematics varied considerably, there was no significant difference in mathematical achievement amongst genders. Prior achievement had very positive correlation on enjoyment and pride whilst previous negative experiences exacerbated feelings of anxiety and hopelessness. Frenzel, Pekrun, & Goetz (2007) concluded that female students experienced significantly less enjoyment and pride than male students concerning their mathematical achievement due to their high incidence of reported anxiety, hopelessness, and shame. What this demonstrates for educators in general is that teachers and curriculum planners need to look at the sources which foster differing emotional response to mathematical achievement among male and female students and not simply on actual or perceived performance parity.

Other studies performed outside of Germany have reached similar conclusions. Skaalvik & Skaalvik (2004) examined four sets of Norwegian students to explore gender differences in general math self-concepts. The study found that no significant differences were found for math grades between genders, but female students had higher grades on average than male students in all four grade levels. In each sample, male students had significantly higher mathematics self-concepts and performance expectations than their female classmates. Male students enjoyed a significantly higher self-enhancing ego orientation, while female students experienced higher task orientation. Skaalvik & Skaalvik (2004) uncovered differences in self-concept, performance expectations, and intrinsic motivation which were not explained by grades, thus supporting their hypothesis about gender stereotype theory. Skaalvik & Skaalvik (2004) supported this discovery by citing male students high self-motivation and self-concept about mathematics despite the absence of a clear difference among male and female grades. Their study concluded that gender differences in mathematics self-concept and performance expectations continued to exist and could be seen from early elementary onward. Furthermore, the study's authors were unable to connect this gap in performance expectations with actual performance, strengthening their argument that these gender-based differences are likely caused by gender stereotypes and socialization.

In Spain, Delgado & Preito (2008) studied the role of anxiety and mental rotation on gender differences and stereotype threat. The study took place at an *ensenanza secundaria obloigatoria* (a compulsory secondary education institution) and included 313 participants, aged fifteen to sixteen. Students were grouped by class and either assigned to perform tests under stereotype threat or without stereotype threat present The three tests included: a math test, a spatial test, and a math anxiety questionnaire. Participants tested under stereotype threat were told, “You are going to do some tests that are related to mathematical ability. Various research studies have found that boys have better math abilit[ies] than girls. We are trying to analyze whether this difference exists.” (p. 637). Participants were debriefed after the testing was completed.

What Delgado & Preito (2008) found was that stereotype threat correlated directly with gender and anxiety. In contrast, stereotype threat did not correlate with mathematical achievement on the mental rotation or math tests. Delgado and Preito found the interaction between gender, anxiety, and stereotype threat statistically significant. “Effects of stereotype threat in females are mediated by level of anxiety.” (p. 639). Delgado & Preito (2008) stated that previous studies were often contradictory, with results ranging from no impact, negative impact, to even a positive impact instigated by stereotype threat. Their research showed that there was in fact evidence of stereotype threat correlating directly to anxiety levels. Because they reached an altogether different conclusion using data sets similar to past studies, Delgado and Preito saw that a flaw with the current stereotype threat paradigm existed; and that a new paradigm based on the threat-related bias for anxious and non-anxious students should be researched.

The validity of Delgado & Preito's (2008) quantitative study was moderate because the duration of the experiment was brief (only one treatment), and the participants were grouped by classes (which could have tainted the results). Although their experiment had the lowest number of participants among similar studies, Delgado & Preito help highlight the important relationship between stereotype threat and anxiety.

Baloglu & Kocak (2006) studied the relationship between mathematical anxiety and gender. To study the differences in mathematical anxiety Baloglu and Kocak collected data from 759 volunteer college students from a state university in the southwestern United States Participants were selected using a convenient sampling method, with 554 female, 203 male, and two participants that did not indicate their gender. The mean age of participants was 26.1 years old, and the mean college GPA was 3.22. Participants completed a Mathematics Anxiety Rating Scale (MARS), a test of twenty-five items rated with the five Point Likert-scale, and demographic surveys. Three factors accounted for thirty-one percent of the variance on the MARS scores: mathematics test anxiety, numerical task anxiety, and mathematics course anxiety.

Baloglu & Kocak (2006) found that female students had higher mathematics anxiety than male students which was statistically significant, and that older students were significantly more likely to experience mathematics-based anxiety than younger students. Mathematical experience negatively correlated with mathematical test and mathematic course anxiety, but was only statistically significant with regards to mathematical test anxiety. Baloglu and Kocak found that male and female students differed significantly in numerical task anxiety, mathematical test anxiety, and mathematics course anxiety when mathematical experience was controlled. Male students reported more numerical task anxiety than female students, while female students scored higher on mathematical test anxiety. There was no statistical difference between males and females on mathematics course anxiety. For numerical tasks anxiety participants twenty-five years and older scored significantly lower than participants in the twenty-one to twenty-four year old range and the those under twenty-one years of age. The youngest group had the highest level of mathematics test anxiety while the oldest group of students had the highest level of anxiety about taking a mathematics course. Using this data set, Baloglu & Kocak (2006) concluded that females scored higher than males on their overall mathematical anxiety because of negative prior experiences with mathematics. Enrolling in a mathematics course or taking a mathematics test caused greater anxiety with age, but anxiety about performing numerical operations decreased with age.

The validity of Baloglu & Kocak's (2006) quantitative study was very high. Baloglu and Kocak explained the variables and methods used so that the experiment could be reproduced. There was neither multiple-treatment interference; nor evidence of the Hawthorne effect. The data analysis, measurement, and collection were effective, un-biased, timely, and consistent. The duration of the experiment was adequate, and the selection of participants was fine. There was no evidence of confirmation bias, nor was there any indication that the results found in this study would not be similar to the same study carried out by different researchers; the study allows for transferability but the time-scale required to support the age-scale requirements of this experiment makes it difficult to replicate.

What these studies conclusively show is that, although male and female students exhibit similar mathematical achievement levels, they have distinctly different emotional responses. Male students experience significantly more enjoyment and pride in mathematics, accompanied by less anxiety, hopelessness, and shame than female students. The results for stereotype threat were also fairly uniform, with male students experiencing stereotype threat less than female students and usually only in conjunction with race or stereotype lift. Additionally, stereotype threat causes more anxiety in female students than in male students and this anxiety, coupled with negative emotional responses to mathematics, can hinder achievement for female students. Research suggests, then, that, female students are more susceptible to negative impacts associated with anxiety and that this anxiety increases with age.

Teaching Practices and Interventions

The differences between male and female student highlighted above makes equitable mathematics education more difficult. Not only must educators take into account differing learning abilities and skill sets, but as previous studies have illustrated, they must also adapt their classrooms and curriculum to support equitable emotional support in mathematics education. It has become increasingly clear that the achievement gap amongst male and female students is not a function of unequal innate ability, but rather the differing socialization pressures emplaced upon each gender. It is important, then, for educators to address this imbalance by adjusting their teaching practices and interventions to help mitigate these gender-based discrepancies.

Differences in teaching practices, including types of instruction, courses of instruction, and types of school environments, affect gender and mathematical achievement. Traditional gender differences in learning styles have been argued as reasons for differences in mathematical achievement, and that specific teaching practices favor one group of students over others. Single-sex schools and classrooms, teaching methods and models, and areas of study are all believed to have an influence on mathematical achievement whilst specific interventions lessen negative factors that are associated with mathematical competency and achievement.

There exist a myriad of studies linking certain practices with increased mathematical achievement and more equitable mathematical education, both across genders and abilities. Chiu, Beru, Watley, Wubu, & Simson (2008) studied the influences of math tracking on seventh-grade students' beliefs and students' comparisons within or across tracks. They determined that ability tracks have a minimal effect on self-esteem while tracking did impact students' mathematical self-concept and ability. Craig (1999) studied the relationship between gender, instructional practices, and the use of technology and found that female students performed differently in single-sexed classrooms. Speilhagen (2006) investigated the effects of algebra on students and found that the completion of algebra courses in eighth grade led to additional mathematics courses being undertaken along with increased levels of college attendance. Timmermans, Van Lieshout, & Verhoeven (2007) studied the impact of direct instruction and guided instruction for low-achieving male and female students. Their study established that male students performed better with direct instruction and female students performed best with guided instruction. Van de gaer, Pustjens, Van Damme, & Munter (2004) studied the effects of single-sex education versus co-education on mathematical and language growth and their findings suggested that female students performed better in single-sexed classroom (although several other causal relationships were also proposed by the authors). Bernstein, Cote-Bonanno, Reilly, Carver, & Doremus (1995) studied the relationship of a specific intervention on the effects of mathematical anxiety for single-parent families, and found that these interventions did reduce anxiety. Falco, Crethar, & Bauman (2008) studied the effects of using 'skill-builders' curriculum on middle-school students' attitudes toward mathematical learning and found that 'skill-builders' positively impacted self-concept and attitudes toward mathematics.

Chiu, Beru, Watley, Wubu, & Simson (2008) studied the influences of math tracking on seventh-grade students' beliefs, students' comparisons within or across tracks, and gender differences. In addition, they investigated whether students on different tracks compared themselves to students on the same track as themselves or on other tracks, and if there was a difference between male and female students' self-esteem and self-concept within the same track Data was collected from seventh-grade participants from a mid-Atlantic school, consisting of 173 students. The study results showed that students compare more within tracks than across tracks and the influence of tracking was limited to students' school and mathematics self-concepts, but did not generally affect overall self-esteem.

With these results, Chiu et al. (2008) concluded that students first compare themselves upwardly within and then across tracks followed by downward comparisons themselves with lower-achieving tracks. This indicated direction of comparison was more important than the type of comparison. Students on higher tracks had higher self-concept than students on the lower tracks; students on lower tracks had lower self-concepts than those on the higher tracks. Grades had a stronger impact on students' self-concept than their math track. There was no correlation between upward, within and across track comparisons, on self-esteem, mathematics self-concept, or gender. There were no significant effects of downward, within and across track comparison on: self-esteem, mathematics self-concept, or gender.

Chiu et al. (2008) concluded that the influence of tracking on students' self-esteem was minimal or non-existent, but tracking could significantly influence mathematical self-concept and ability. Grades earned were cited as more important for students' self-concept and ability than which track the students were placed on. Unfortunately, due to the limitations imposed by their sampling size and methodology, it is unclear if grades effect self-concept or vice versa.

Craig (1999) set out to study the relationship between gender, instructional practices, and technology. Craig tried to answer three questions: could female students attitudes change regarding computers, science, and math, would female students behave differently in single-sexed environments as opposed to co-educational environments, and lastly, what practices would help teachers meet female students' mathematical education needs? To answer these questions, Craig studied qualitative data collected from observational field notes from a two-week summer program designed to help both students and teachers.

Craig (1999) found that female students behaved differently in single-sexed environments; asking for help more frequently from peers than the adult, and preferring to work in smaller groups than their male counterparts. Craig (1999) concluded that the attitudes of the participants did not change over the course of the study, but on a follow-up survey female students did change their perception that mathematics was a male domain. Another key piece of data was that every female fifth grade respondent preferred working in the single-sexed environments.[ix] Craig could not make a conclusion about teachers treating female and male students differently, but believed that educational philosophy was the biggest influence on teacher practices.

Craig's study, although important, has some serious limitations. The duration of the experiment was very short, and the selection of participants was not random. There was no evidence of confirmation bias, nor was there any indication that the results found in this study would not be similar to the same study carried out by different researchers, however, because of the sometimes contradictory nature of Craig's findings regarding single-sex environments, this study has more limited transferability value.

Speilhagen (2006) studied the effects of algebra on students. Speilhagen investigated questions about demographic compositions of existing algebra classes, whether the selection process for algebra was equitable, and what were the long-term advantages for students who studied algebra in eighth grade. Data used for this quantitative study was taken from a longitudinal study from a large school district

(60,000 students) and included mathematics courses taken, achievement tests, and college attendance after graduation.

Speilhagen (2006) found that the opportunity to be selected for eighth grade algebra was usually only for students already enrolled in upper-level or honors math courses. African American students comprised twenty percent of the school district's student population of the school, but only ten percent of students enrolled in algebra. A point increase for seventh-grade mathematics course grades was associated with being three times more likely to take algebra in eighth grade. There was a negative relationship between the socioeconomic status of each school and the number of students studying algebra in the eighth grade. Students that were enrolled in algebra exhibited higher achievement on all standardized tests than those students that did not take eighth grade algebra. Students that took eighth-grade algebra completed more mathematics courses after eighth grade and enrolled in more advanced courses than students that did not take eighth-grade algebra. Students who studied eighth-grade algebra attended college with higher frequency.

Speilhagen (2006) concluded that restricting access to eighth-grade algebra made no significant difference on standardized state tests (based on overlap groups), but studying algebra in the eighth-grade leads to additional mathematics courses being taken and higher college attendance. There is a disparity of access to eighth-grade algebra based on race, gender, and socioeconomic classes, which can adversely affect the opportunities of those students. "Eighth-grade algebra may be beneficial for greater numbers of students because it leads to increased mathematics literacy, as evidenced by the type and number of mathematics courses studied in high-school." (p. 57). Eighth-grade algebra can lead to more advanced mathematics courses being taken by students that would not have taken them before.

Speilhagen's (2006) conclusions are important for gender equality in mathematics education despite her focus on racial characteristics of mathematics achievement disparity. Her study may also been skewed by confounding variables, as other school districts often have mandatory student enrollment in eighth grade algebra while the examined district did not. Many of the same themes her research cited as evidenced of decreased African-American student participation—lack of positive mathematics education experience, and increase mathematics confidence—are the same factors attributed to participation gaps amongst high school and middle school female students.

Timmermans, Van Lieshout, & Verhoeven (2007) studied, "whether low performing students in a regular school show more performance gains when trained according to traditionally oriented DI (direct instruction) or when trained according to GI (guided instruction) based on constructivism" and "whether there is a difference in performance gains between girls and boys" (p. 43). Students were given 34 lessons in small gender-mixed training-classes comprising of four students each. In each school four of the participants received DI and four received GI. One trainer taught each group at that particular school (five trainers total). The first 10 lessons were the same for all children; the next 24 lessons were either DI or GI lessons. There were many pre- and post-assessments including performance strategies used, motivation measures, and power-tests containing addition and subtraction.

The results of this study showed that, female students in the GI group improved their performance, where as the performance of the female students in the DI group decreased. Performance of the male students decreased in the GI group and increased in the DI group. On average, the female participants in the GI group scored higher on strategy post-tests than those in the DI group, and there was a positive increase for emotions in the female GI group. Strategy choice depended more on individual characteristics of the problem solver than on the method of instruction. On the posttest both groups used a variety of strategies to solve problems (but this could be due to prior instruction and not from the study itself). “It cannot be concluded that GI is satisfactory teaching approach for low performing students in regular schools in general, for low performing girls, however, the approach seems to result in improved performance” (p. 52). This result could be due to the fact the low performing girls were not actually as weak in mathematics as the boys and suffered only less confidence before the intervention.

The study was long enough and with enough treatments to mitigate daily differences. The study used five different schools but only used eight students from each school. The fact that there were only a small number of students from each school (only two female and two male students for each DI or GI group is a small sample) seems to detract from the study in that it has small control or reference groups, but otherwise this study has high transferability.

Van de gaer, Pustjens, Van Damme, & Munter (2004) studied the effects of single-sex education versus co-education on mathematical and language growth. The quantitative study investigated the difference between the effectiveness of single-sex classes in single-sex schools and the effectiveness of single-sex classes in co-educational schools. The study tested four hypotheses; male and female students will make more progress in mathematics and language achievement in single-sex classes and schools, gender composition of classes will impact achievement but gender composition of schools will have no impact on achievement, differences between single-sex and co-educational schools cannot be explained by differences in pupil intake, and the type and location of schools cannot explain differences between single-sex and co-educational schools.

Van de gaer et al. (2004) used data from the *Longitudinaal Onderzoek Sedundair Onderwijs* (LOSO) project, which started in 1990 and followed a cohort of 6,000 students during secondary education. Questionnaires were completed by students, parents, teachers, and administrators. Van de gaer et al. found that female students did not make more progress in single-sex classes than in co-educational classes. Male students performed better in co-educational classes but did not reach statistical significance. No positive effects of single-sex schools were found for either male or female students, but that gender composition of the individual classes was more important than that of the schools gender composition. Lastly, Van de gaer et al. found that academic schools had a higher effect on mathematical achievement than vocational schools.

Van de gaer et al. (2004) concluded that male students do worse in single-sex classes, and that this may be caused by behavioral problems created by groups of difficult male students. Better achievement associated with single-sex classes and schools for female students was explained by the selective nature of those schools rather than from their separation from male students. Teachers were convinced, though, that single-sex teaching was better for female students because it reduced stereotype threat, increased confidence, and created a better learning environment. Although a valid study in terms of methodology, their conclusions rest on a lot of secondary conjecture, made by both students and adults on qualitative survey forms without quantitative evidence to back up their claims. What their study illustrates more than the relationship between single-sex instruction and achievement is that there still are overriding communally-acknowledged socialized norms concerning male and female students (this time focusing not on mathematical ability but rather on how each gender should best limit such discrepancies in education).

Bernstein, Cote-Bonanno, Reilly, Carver, & Doremus (1995) studied the relationship of a specific intervention on the effects of mathematical anxiety for single-parent families. Data was collected from participants from seven housing projects with single parents in New Jersey. Pre- and post- tests of math anxiety were collected from 177 adults, ninety percent female. Bernstein et al. (1995) found that through this intervention there was a significant decrease in the anxiety levels of female participants. Male participants did show a lower anxiety level, but this did not reach statistical significance.

Bernstein et al. (1995) concluded that this intervention did in fact lower math anxiety for non-traditional students, but that the effects of the duration of participation on math anxiety still required further study. Their conclusions also leads one to question whether parental anxiety toward mathematics can influence a student's achievement and perception of math-related tasks and skills (as has been previously discussed). Even more frustrating is the overall nebulousness of the Bernstein et al. study. The validity of Bernstein et al.'s (1995) study was poor because the intervention used was neither explained nor named. The variables and methods were poorly explained, making this study virtually impossible to reproduce. The collection, measurement, and analysis of the data were limited. The duration of the study was adequate and there were no problems with the selection of participants, but it would be irresponsible to cite only this study as proof of certain conditions and patterns even though it suggests that there are specific interventions that can help lower mathematical anxiety.

Falco, Crethar, & Bauman (2008) studied the effects of using ‘skill-builders’ curriculum on middle-school students’ attitudes toward mathematics learning. Data was collected from eight classrooms containing 228 sixth-grade students and included pre- and post-tests for attitudes toward mathematics. Four of the classrooms, chosen randomly, received the ‘skill-builders’ intervention taught by the counselor, and four classrooms were used as a control group. Falco, Crethar, & Bauman (2008) found that the interaction between ‘skill-builders’ intervention and attitudes toward mathematics was positive for both female and male students. Female students showed more gains in self-confidence, value of mathematics, enjoyment, total scores, and motivation. Male students showed less growth on all of the same items, and showed the most growth on value of mathematics and total scores.

Falco, Crethar, & Bauman (2008) concluded that the ‘skill-builders’ curriculum has the potential to impact students’ mathematical attitudes. ‘Skill-builders’ curriculum is associated with positive self-beliefs toward mathematics, self-confidence, the value of mathematics, enjoyment of mathematics, and motivation for mathematics. Using this intervention once may not be enough to maintain these positive attitudes and that follow-up lessons may be necessary until or through high school.

These articles allow one to make the argument that specific teaching practices and interventions can have a positive impact on students' mathematical anxiety and achievement. Math tracking affects student's mathematical self-concept, but not overall self-esteem. Both female and male students may exhibit different learning behaviors in single-sex classrooms but no overall achievement differences were found. Teachers' perceptions of student achievement, however, were greatly altered by such environments. Specific interventions can lower negative affective domains which can result in increased mathematical achievement, but the complex processes and factors contributing to such successful interventions remains the source of much-needed further study.

CHAPTER 4: CONCLUSION

Introduction

The first chapter of this paper described the importance of the question 'how should educators address gender differences to best support equity in students' learning and achievement in mathematics?' both personally and professionally. Personal reasons for studying perceived or actual gender differences were that I liked mathematics as a child and want to better understand why I was able to succeed in mathematics while so many of my friends experienced difficulties. Personal experience taught showed both ends of the spectrum—having fewer females in my upper-level mathematics courses taught exclusively by female instructors—of female participation in my own mathematical education. Professionally, as a perspective mathematics teacher I want to better understand the perceived and actual gender gap in mathematics so that I can use my findings to better serve portions of the population that may experience difficulties in mathematics. The importance of mathematics is increasing in the new global economy and while traditionally mathematics has been seen as a male domain, this trend needs to be reversed lest it exclude or hamper female participation in fields with the most growth, especially those dealing with technologies.

Chapter two of this paper attempts to highlight the progression of research and ideas concerning mathematical gender achievement gaps, creating a basis for the critical review of literature in chapter three. In the third chapter thirty research articles are critically reviewed starting with articles that try to illuminate the issue of whether or not there is a gendered achievement gap in mathematics. Next, research on stereotype threat and its effects are reviewed. Then investigations of influences from people on students' mathematical achievement and ability are reviewed, followed by articles concerning competency beliefs and attitudes. Emotions and anxiety research is studied, and finally specific instructional practices and interventions are examined.

This chapter will summarize the findings of the research articles from chapter three and then show possible implications for mathematics instruction. Further areas of research will be given along with potential questions for future mathematics instructors to consider when planning and implementing mathematical instruction for students of diverse backgrounds and experiences. Finally, this section will give on overall conclusion for the entire paper.

Summary of Findings

Gender Differences

Ai (2002) concluded that there was a small gender gap in mathematical achievement in favor of female students' growth rates that started lowest in mathematics. For female students that started in remedial classes, teacher encouragement was a positive influence on achievement while parental encouragement had a negative effect on achievement. Because his results showed no distinct difference based upon gender, Ai concluded that there is no mathematical achievement gap. Similarly, Ding, et al. (2006) concluded from their two studies that there is no difference in mathematical ability or achievement between genders. Female students did have a better mathematics GPA in both middle school and high school. In all groups, students that had lower initial achievement showed the most growth in mathematical ability and achievement measured through GPA and SAT-9 scores. Lachance & Mazzocco (2006) also concluded that no pattern of male or female advantage existed for all of the math tasks or all of the spatial skills tested.

Carr et al. (2007) on the other hand, concluded that by second grade, differences in strategies usage and fluency are present between genders. Male students exhibited higher confidence in mathematics, while female students showed lower mathematical confidence. Fluency, accuracy, and correct cognitive strategies predicted mathematical competency. Gierl et al. (2003) concluded that specific content and cognitive skills would produce gender differences in mathematical achievement and that male students routinely performed better on items that required spatial ability.

Between the extremes of no gender achievement difference and achievement gaps, Catsambis (1994) concluded that some similar patterns of gender differences in opportunity, achievement, and attitudes exist for all students. White, African American, and Latina female students do not experience an achievement gap and may have more learning opportunities. Catsambis (1994) stated that confidence and attitudes may not predict achievement and are probably a product of judging their performance by individual mathematical grades. Tsui's (2007) eighth grade study showed no difference between gender achievements on mathematical tests. There was no achievement difference between female and male students on the college entrance examinations, but for students scoring over the fiftieth percentile, male students scored higher than female students did. In the upper three percentile, the ratio of male to female students was twelve to one, showing a vast disparity between genders on both ends of the spectrum, if the averages were the same. Hall et al. (1999) concluded that there are significant differences for race, but not gender, in regards to mathematical achievement and performance in the early stages of schooling. The achievement gap between genders starts to occur at the end of junior high school or during high school.

With contradictory evidence finding both a lack and a presence of gender achievement disparity it is difficult to come to any solid conclusions. One conclusion that can most likely be made, because most of the research agrees, is that female students participate in higher levels of mathematics less frequently, which makes the findings of overrepresentation of males in the highest levels of mathematics and mathematical achievement a little less disturbing. Fewer females try to excel so there will be fewer females in the highest echelon of testing.

Stereotype Threat

Some studies showed negative effects from stereotype threat. The results from Smith's (2006) study showed that women endorse PAV-goals to a greater extent when experiencing stereotype threat, but since men were not part of the study there can be no comparison to how males would have reacted and how they might differ in regards to PAV-goals. Smith (2006) also found that women believed they would receive an excellent grade on the mock exam less frequently than they thought men would. Smith believed that higher PAV-goal endorsement led to lower performance expectations. Similarly, Delgado and Preito (2008) found that stereotype threat in female students correlated with anxiety levels. Delgado & Preito (2008) stated that previous studies were often contradictory and that a new stereotype threat paradigm based on the threat-related bias for anxious and non-anxious students should be researched.

Strategies exist that mitigate stereotype threat as seen by, Good, Aronson, and Inzlicht (2003) concluded that the typical gender gap in math standardized test performance was evident in the control group, but when given treatment about intelligence expandability the gender gap on mathematic standardized tests was removed. Students' test scores improved through learning attitudes that help contend with anxiety, addressing the stereotype threat of mathematical assessments. The two studies conducted by Rosenthal et al. (2007) showed that finding academic similarities between genders was the most effective means of improving performance expectancies. Thoman et al. (2008) concluded negative stereotype threat effects performance and can be nullified when the content is framed as an effort rather than an ability threat shifting the focus from natural ability towards effort created the effect that students feel more in control of changing their current level of achievement and have better hopes of higher achievement in the future.

The major problem with research into stereotype threat is that almost all of the studies use participants that are college-aged students attending college. Females in this scenario already for higher education, and may confound the data because of this. Similarly, transferability to younger students may be problematic for the same reasons. Delgado and Preito (2008) used the youngest participants in all of the stereotype threat research with the minimum age of fifteen years old.

External Influences

Friends, classmates, parents, and teachers influence mathematical success, ability and achievement. Crosnoe et al. (2008) concluded that friends' achievement had a stronger association with adolescents' future mathematics course-taking than did course mates' achievement. The study stated that per capita resources produced a much more profound effect in students who were already at the top of the achievement ladder.

Linver and Davis-Kean (2005) found that school grades declined for all groups from middle school to high school, but that female students in the highest tracking group had the highest grades overall. This study found that both a mothers' educational levels and accompanying educational expectations for her children, and that higher teachers' expectations, were associated with adolescents' performance in mathematics. For male students mathematical achievement was related to present mathematical achievement. Muller (1998) stated that parents influence their children's' mathematical achievement. Furthermore, Muller concluded that parental involvement did not appear to reinforce mathematical stereotypes, but that parental involvement did have limiting factors including: race, economic resources, and parental education levels.

Attitudes and Competency Beliefs

Estay & Snetzler (1998) concluded that females showed a more positive general attitude about mathematics but also reported more mathematics-based anxiety at all grade levels. Male students exhibited more confidence in learning mathematics, and in grades nine through twelve male students were more likely to consider mathematics as a male domain. The difference in positive attitudes favoring males is small, so students' attitudes toward mathematics may not fully explain gender achievement differences. Herbert & Stipek (2005) stated that students' self-perception of competencies and ability are strongly associated with their behavior in learning situations and that further research is needed to help understand the factors affecting student-held perceptions. Toward this end, Herbert & Stipek call for a more extensive search as to how parents might subtly convey gender stereotypes that lower perceptions of mathematical competency.

Brakatsas et al. (2009) concluded that students with high levels of mathematical achievement demonstrated high levels of mathematics confidence, strong positive levels of affective and behavioral engagement, and were not confident with using computers—but had positive attitudes toward learning mathematics with computers. Mathematics confidence and affective engagement were the two most important factors associated with the development of positive attitudes to learning mathematics with computers and these two factors were fairly gender-specific. Githua and Mwangi (2003) concluded that motivation was important for students and the learning process and that teachers could improve students' satisfaction with learning mathematics by considering students' needs and facilitating positive learning attitudes.

Competency beliefs are not always accurate; male students tend to over-evaluate their mathematical prowess and achievement while the opposite holds true for female students. These competency beliefs can influence later mathematical course enrollment, creating more mathematical opportunities (as shown above with decline in female participation in upper-level mathematics courses).

Emotions and Anxiety

Delgado and Preito (2008) found the interaction between gender, anxiety, and stereotype threat statistically significant, and that stereotype threat in female students correlated to anxiety levels. Baloglu and Kocak (2006) found that female students had higher mathematics anxiety than male students, and that older students were significantly more likely to experience mathematics-based anxiety than younger students. Mathematical experience negatively correlated with mathematical test and mathematic course anxiety, but was only statistically significant with regards to mathematical test anxiety.   Baloglu and Kocak found that male students reported more numerical task anxiety than female students, whilst female students scored higher on mathematical test anxiety. Baloglu & Kocak (2006) concluded that females scored higher than males on their overall mathematical anxiety because of negative prior experiences with mathematics and that mathematics course taking a mathematics test caused greater anxiety with age.

Teaching Practices and Interventions

Chiu et al. (2008) concluded that the influence of tracking on students' self-esteem was minimal or non-existent, but tracking could significantly influence mathematical self-concept and ability. Grades earned were cited as more important for students' self-concept and ability than the ability-track of the student. Speilhagen (2006) concluded that restricting access to eighth-grade algebra made no significant difference on standardized state tests, but studying algebra in the eighth-grade led to additional mathematics courses being taken and higher incidences of college attendance. This study is unclear, but assumes that eighth-grade algebra course completion would have similar effects (increased mathematics and college enrollment) for students that were not presently taking algebra.

Timmermans et al. (2007) found that, female students in the GI (guided instruction) group improved their performance, where as the performance of the female students in the DI (direct instruction) group decreased. Performance of the male students decreased in the GI group and increased in the DI groups. Van de gaer et al. (2004) concluded that male students do worse in single-sex classes, while female students performed better under the same conditions. Better achievement associated with single-sex classes and schools for female students was explained by the selective nature of those schools rather than from their separation from male students. Teachers believed that single-sex teaching was better for female students. Craig (1999) found that every female fifth grade respondent preferred working in the single-sexed environments.

Interventions help mitigate factors that can contribute to achievement disparity, but not every intervention will work for all students. Craig (1999) concluded that the attitudes of the participants did not change over the course of the treatment (computer based mathematical learning), but on a follow-up survey female students did change their perception that mathematics was a male domain. Bernstein et al. (1995) concluded that their specific intervention lowered math anxiety for non-traditional students, but they did not fully explain what or how they enacted the intervention. Falco, Crethar, & Bauman (2008) concluded that the 'skill-builders' curriculum has the potential to impact students' mathematical attitudes and is associated with positive self-beliefs toward mathematics, self-confidence, the value of mathematics, enjoyment of mathematics, and motivation for mathematics. This intervention seemed like it would be applicable to all students in middle school and beyond, helping mitigate factors of achievement disparity.

Implications for Teaching

From the research presented in chapter three, it is reasonable to conclude that there is the potential for achievement differences based on gender to exist. Accordingly, there must be educational practices one can use to minimize or eliminate gender achievement differences. I conclude that no single teaching method, model, or practice will be effective for all students, and therefore, as an—educator—I must incorporate several different practices within my mathematical pedagogy. One practice that I believe is key, especially taking into consideration current stereotype threat research, is teaching expandable intelligence theories. Along with expandable intelligence theories, I would set high expectations for my students and show models of all types and groups of people and their contributions in the field of mathematics. The idea that growth rates and achievement in mathematics declines with age means that the earlier educators can engage students in practices that help mathematical achievement, the more likely it is that those students gain mathematical competency and positive self-concepts. This means that teachers need to understand the mental models that each student uses while solving and practicing mathematics so that they can be synthesized into instruction. Another practice teachers should use is connecting learning in the classroom to actual skills that can be used in everyday life—especially with technology. Changing beliefs about self-concept or competency beliefs can impact students at the time of the treatment, and the effects can continue and encourage continued growth throughout a student's educational career.

Specific teaching practices that I will employ to combat specific factors which potentially affect gender achievement in mathematics are: involving parents, not to group by ability, providing multiple entries into mathematics, use multiple modes of instruction, give specific interventions or learning theories, and linking multiple correct problem solving strategies to each other. To involve parents, especially in non-intervention interactions—the interaction most associated with negative achievement gains—I propose to either call, email, or send home newsletters of what is happening in the classroom, allowing parents the opportunity to discuss actual events and instruction with their children. By sending home reports of positive behaviors and student learning I will be able to help create positive views of mathematics and help create positive parent-student interactions. By incorporating parental involvement I hope to gain positive emotional and competency beliefs in my students.

Research has shown that low achieving male and female students react differently to different modes and settings of instruction. This means that as an educator I must provide multiple entry points and multiple modes of instruction. I cannot just use guided instruction, nor can I only use direct instruction. I will need to use both models along with other models that incorporate group and individual work. For group assignments, I must be strategic in my groupings, since research showed that female students do better in single sex environments but male students do better in mixed groups, but could have been confounded by problematic behaviors in all male groups. I will not group by ability, so students do not see which tracks or ability group they are on, creating self-concepts that could be damaging to the student's achievement and mathematical beliefs. To combat stereotype threat, I would like to teach my students an effort based intelligence theory, instead of conforming to gender stereotypes and innate intelligence abilities. The effort based intelligence theories allow for students to have control over their intelligence instead of innate abilities, which are out of their control.

To reduce the affective emotions that hinder mathematical growth, I will teach my students anxiety reduction techniques and other high-stakes test taking strategies. Male students have more pride and confidence in mathematics, so I would like to help all of my students have positive emotions about mathematics. To do this, I will need to make the mathematics relevant for my students and help build upon prior successes. Teachers' and parents' expectations influence mathematical achievement. In my classroom every student is expected to achieve although at times specific tasks will be hard.

I need to require my students to press for justification and to make connections between correct cognitive strategies, correct manipulative strategies, and the explanations of the why of mathematics and not focus solely on how particular problems are solved. This strategy will help with mathematical transferability from the classroom to the real world. Since correct cognitive strategy use is more important than correct manipulative strategy use in regards to mathematical achievement and predicting future achievement, I want my students to be able to use and understand both strategies and be able make connections between the two. Also, connecting the correct strategies to verbal or written explanations will give my students more opportunities to make mathematical connections with subject area that they may feel stronger in. By providing students with opportunity and success in mathematics, I ca help them achieve more opportunities in higher education.

As an educator, I feel it is my obligation to ensure the highest degree of success and competency for each of my students. That means that some students will need more of my personal resources, creating an equitable but not identical education. There are potential mathematical achievement gaps; conversely there is the potential for equal mathematical achievement. To do this I must involve parents and children in the educational processes of my classroom, engage my students using multiple methods and strategies, and combat traditional views of male and female domains.

Suggestions for Further Research

One area that I did not find research in, and that would help shed light on some of the aspects of gender differences in mathematical achievement, was on the area of gender versus sex. What if the biological sex of the student is not in line with their identified gender? Another question along similar lines, what about the spectrum of male to female with students falling in the middle where gender identity is neither male or female? These issues could also be confounding variable for all studies if the percentage of students not identifying their gender with their biological sex was high enough or disproportionate across genders.

Another area of further study is what causes male students to have a higher mathematical confidence even if they have lower achievement than female students? What socialization issues contribute to mathematics as a male domain and what can I do to create a female mathematical domain? What are the effects of stereotype threat anxiety levels for anxious and non-anxious people? Does stereotype lift occur more frequently for male or female students and if so, what are the cause(s) of more frequent stereotype lift? Can stereotype lift occur without the negative impacts of stereotype threat in a diverse classroom?

What specific strategies can be used to diagnose why a particular student or group of students is not achieving at the same level as others students in the same grade? What are the relationships between multiple diverse factors; how does stereotype threat affect anxiety by gender, what is the effect of anxiety by gender on self-perceptions or achievement, and the opposite. Next, what is the relationship of achievement to these beliefs, and in what direction? Does achievement effect perceptions or vice versa or do they both affect each other? Many of the studies attempted to answer portions of these relationships, but I feel that the relationship is so complex they must be studied at length and in conjunction with each other.

Lastly, the research that would be most beneficial is a conclusive study on whether or not there are mathematical achievement differences. This study would have to be specific enough to focus only on mathematical achievement gaps, but also address the gender-sex issues stated above. A study of the biological differences in the brains between male and female sexed-students and gender identified students could also be quite helpful. If there is a physiological difference in the brains of male and females, then there might be specific strategies that are best suited for each type of student.

Conclusion

Mathematical gender achievement gaps, whether perceived or actual, have demonstrative effects on mathematics education. The importance of mathematics is increasing with the global economy and technological advances, and mathematical skills are becoming increasingly more important for all students to know and have. Many factors can affect mathematical achievement, including: stereotype threat, competency beliefs, parents, friends, emotions, anxiety, pride, enjoyment, prior success, intelligence theories, socialization, perceptions, and countless more.

The most alarming trend discussed in this paper is the decreased participation of female students in upper-level mathematics courses, and the disparity between genders at the highest-levels of mathematical achievement. Mathematics instructors need to consider potential causes and solutions to the mathematical gender achievement gaps.

While considering the quantifiable evidence on achievement gaps, trends begin to take shape, which can be extended to racial and economic minorities.

Although the exact causes of achievement disparity between groups may not be readily or easily defined, teaching practices that inculcate inclusion using positive learning theories and educational practices can help mitigate the perceived or actual mathematical gender achievement gap.

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FOOTNOTES

[i] Geist and King (2008) stated that during the 1970s, female students outperformed male students on all performance tests except in the twelfth grade using the National Assesment of Educational Progress 1978 (NAEP)(43); starting from the NAEP tests administered in 1999, female students were always outperformed by male students (50), and on the 2005 NAEP test twelfth grade female students were outperformed by an average of three percentage points (43).

[ii] Oberlin College would again make history as the first college to grant an undergraduate degree to an African-American woman in 1862.

[iii] For historical treatments on women and education, see: Lindquist (1942), Anastasi (1959), and Tyler (1965).

[iv] Sometimes referred to as the Schoolmaster to the Nation, lived 1758-1843

[v] For more information on stereotype threat and its outcomes, see: Stone, (2002), Good, Dwek, & Rattan, (2008), Steele (1997), and Gonzales, Blanton, & Williams, (2002).

[vi] For more studies concerning these and other hypotheses, see: Crosnoe, Riegle-Crumb, Field, Frank, & Muller (2008), Bryke, Lee, & Holland, (1993), and Crosnoe, Cavanagh, & Elder, (2003).

[vii] The sample size constituted of thirty-five Caucasian participants and thirty-nine African American participants (thirty-eight male students and thirty-six female students) .

[viii] Native American students—although seen as racially and ethnically distinct—were not included in this study because they comprised too small a sampling group.

[ix] Certain caveats need to be made for Craig's collected data: every fifth grade female student reported that they would not automatically eliminate all male classmates from a single-sex environment (despite the very nature of single-sex classes being homogenous) and that they would not preclude males from their groups and in fact may seek them for different classroom projects.