Gender Differences in Mathematics

Colleen Foy

EMAT 7050

University of Georgia

20 November 2013

There has been a vast amount of research in the differences in performance among males and females in mathematics. One of the many reasons why gender differences in mathematical performance have been studied so much is because there is a lot of contradicting evidence. Perhaps one of the most controversial articles on this topic was by Benbow and Stanley (1980). Benbow and Stanley (1980) found that boys had consistently better scores on the mathematical portion of the SAT than girls, even when their course history was almost identical. They believed that the SAT-M is designed to test for mathematical reasoning ability. Benbow and Stanley (1980) also found that girls excel in computational tasks, while boys excel on tasks that require mathematical reasoning skills (p. 1262). The reason this article was so controversial is due to their conclusion that states: “we favor the hypothesis that sex differences in achievement in mathematics and attitude towards mathematics result from superior male mathematical ability, which may in turn be related to greater male ability in special tasks” (Benbow & Stanley, 1980, p. 1262). This article triggered an extensive look into the reasons why male mathematics scores are generally higher than female mathematics scores.

There have been recent studies that show that “males continue to outperform females on measures of mathematical performance, especially on more difficult items” (Ross, Scott, & Bruce, 2012, p. 278-279). However, there is also evidence that the gender gap in performance is declining, and that gender patterns are different among different countries. One study found that the gender gap in mathematical achievement in the United States was smaller than previously, but the gap grows larger as the students get older (Ross, Scott, & Bruce, 2012, p. 279). Studies in other countries did not necessarily produce the same results. Regardless of the current research, there is no doubt that one of the general stereotypes in mathematics is that boys perform better than girls. However, there is now substantial evidence to contradict Benbow and Stanley’s belief that this difference is caused by pure innate ability and aptitude. The focus of this paper is to shed light on the recent research on the causes of gender gaps in mathematics education, and the implications this outdated stereotype has had on females’ mathematical performance and future careers.

Again, the general consensus in the related research is that males do outperform females in mathematics achievement, but this difference does not really emerge until adolescence. The difference is also more prevalent when it comes to problem solving (Hyde, Fennema, Ryan, Frost, & Hopp, 1990, p. 300). Interestingly, females tend to have higher grades on report cards than males do (Hyde, Fennema, Ryan, Frost, & Hopp, 1990, p. 300). This may be due to the fact that teachers reward females higher test grades than warranted because of the belief that girls put more effort in than boys and that girls tend to have less behavioral problems than boys (Ross, Scott, & Bruce, 2012, p. 279). So then, what is the driving force behind males outscoring females on standardized achievement tests? Eccles and Jacobs (1986) argue that standardized performance tests are not true measures of innate mathematical ability due to many factors that can affect performance such as test anxiety, risk-taking preferences, cognitive style, and confidence in one’s abilities (p. 369). According to Eccles and Jacobs (1986), “sex differences in mathematical achievement and attitudes are largely due to sex differences in math-anxiety; the gender-stereotyped beliefs of parents, especially mothers; and the value students attach to mathematics” (p.370). Ganley and Vasilyeva (2013) found that females tend to be more anxious towards mathematics than males. It has been shown that anxiety may impact mathematical performance due to the relationship between anxiety and working memory. Prior research suggests that “individuals with high anxiety would perform less efficiently on tasks requiring working memory resources because their worrisome thoughts interfere with working memory, making them unable to fully utilize their working memory capacity for task performance” (Ganley & Vasilyeva, 2013, p. 2). Ganley and Vasilyeva looked at the two different types of working memory in their research study: visuospatial working memory and verbal working memory. They found that visuospatial working memory was more strongly related to both mathematical performance and gender than verbal working memory (p. 10). Their study requires future research because they used a meditational analysis which does not allow for casual claims. It would be interesting to see if the strong correlation found in this study actually constitutes that changes in anxiety and working memory could cause changes in mathematical outcomes.

It is natural to believe that one’s anxiety in mathematics could be affected by their attitude about mathematics. If one has a really good attitude in mathematics, they would probably experience less anxiety in the subject. Thus, attitudes may play an important role in mathematical performance. Generally, females tend to have more negative attitudes towards mathematics than males (Gunderson, Ramirez, Levine, & Beilock, 2012). Attitudes towards mathematics in adults can be traced back to childhood and tend to be more positive in younger age groups than in older age groups (Aiken, 1970). It is generally believed that people who have negative attitudes towards mathematics tend to avoid the subject all together and can be easily frustrated when doing mathematics. In contrast, people with positive attitudes towards mathematics are more likely to be motivated and enjoy doing mathematics more than people with highly negative attitudes. Thus it is natural to think that attitude influences mathematical performance. Aiken (1970) found that attitudes affect achievement and achievement in turn affects attitudes. Further research indicates that attitude only has an effect on performance at the extremities: that is either extremely negative attitudes or extremely positive attitudes (Aiken, 1970). Interestingly, one study showed that attitude is a predictor of mathematical performance among females more often than males (Aiken, 1970). This goes along with Eccles and Jacobs’ (1986) findings that social and attitudinal factors appear to have a much stronger direct effect on mathematical performance and belief in one’s ability than aptitude, especially among girls (p. 375).

Gunderson et al. (2012) proposed that “the development of negative math attitudes in young children, especially girls, sets the stage for lifelong behavioral and attitudinal patters, such as math anxiety and math avoidance, which can eventually lead to lower levels of STEM course-taking and career choices among women versus men” (p. 154). Thus it is important to investigate what factors have an impact on the development of a child’s attitude towards mathematics. A student’s attitude can be influenced by the attitudes of their peers, parents, and teachers. Children tend to develop similar attitudes to their parents, especially at younger ages. If a student’s parents have negative attitudes towards mathematics, it is likely that the student will take on some of those same beliefs. The same goes for positive attitudes. This also applies to math anxiety and math-self concept.

Not only do parents’ attitudes towards mathematics affect the student’s attitude, but a parent’s stereotyped beliefs also play an important role. In one study it was shown that “parents’ stereotyped beliefs are a key cause of sex differences in students’ attitudes towards mathematics” (Eccles & Jacobs, p. 375). When a parent believes the general stereotype that boys are better at mathematics than girls, they consequently apply the stereotype to their own children. These beliefs in turn affect children’s own self perceptions about mathematics and this then affects their mathematical ability (Gunderson et al., 2012, p. 155). Parents also affect their children’s attitudes by their expectations and encouragement. If a parent believes the gender stereotype that boys are better at mathematics than girls, they could potentially lower their expectations for their daughter. This could lead girls to lower their own expectations, and thus lower their belief in their own mathematical ability.

Teachers also have an impact on students’ attitudes. A teacher’s own attitude affects the way they teach the material. If a teacher doesn’t like a particular subject or struggles in a particular domain of mathematics, they can easily transfer these negative attitudes onto students. Teachers must be very careful in how they present material to their students. A teacher’s math-anxiety can influence their student as well. “Findings showed that female teachers’ math-anxiety was related to students’ mathematics achievement, but that this was only true for female students. Girls who had a higher-math-anxious teacher had lower math achievement at the end of the year than girls who had a lower-math-anxious teacher, even after controlling for girls’ beginning-of-year math achievement” (Gunderson et al., 2012, p. 157). In a way this perpetuates the math-gender stereotype. A teacher with low math-anxiety and high math-self-efficacy has the potential to reverse the math-gender stereotype.

The prevalence of the math-gender stereotype can have direct consequences for women. Good, Rattan and Dweck (2012) state that “negative stereotypes may have the power to disrupt more than performance; they may also carry a strong message that certain groups are less valued or accepted. That is, the gender stereotype in mathematics, when made salient, may lead women in particular to feel less like accepted members of the mathematics community and thus to have a lower sense of belonging to mathematics” (p. 701). To have a sense of belonging in the mathematics domain in particular means to feel welcomed and a part of the mathematical community. The math-gender stereotype may be compromising females’ sense of belonging in mathematics. It is natural to think that someone with a low sense of belonging to a particular domain may not port forth as much effort as someone who has a high sense of belonging in that subject. Someone who feels more accepted in the mathematical community would more than likely have higher confidence in their abilities than someone who disassociates themselves from the mathematics community. Someone with a higher sense of belonging to mathematics is more than likely going to have a more positive attitude towards it.

There are a variety of factors that affect one’s sense of belonging to a particular domain. A lot of it has to do with one’s theory of intelligence. One theory of intelligence is that intelligence is fixed, and you are either born with natural ability and talent or you aren’t. Others believe that intelligence is more malleable and can grow and improve as one advances in their education. According to Good, Rattan, and Dweck (2012) “students who hold the mindset that ability is a malleable quality are less focused on measuring and proving their abilities, and more focused on learning. They seek challenges that can result in better learning, and they remain highly strategic and effective in the face of setbacks even showing enhanced motivation and performance” (p. 702). Furthermore, when students have a fixed view of intelligence or are surrounded by individuals that support this idea, they may question their abilities and in turn question whether or not they belong to that particular community. In society, we are constantly hearing the phrases “I am not a math person” or “I am terrible at math”. People who believe this way are selling themselves short. Females in the presence of the math-gender stereotype may certainly feel this more than males. In contrast, if a female truly believes that “skills can be acquired through effort over time, then the stereotype of lesser underlying ability may become less credible and certainly will become less threatening for their sense of belonging because skill deficits can be overcome” (Good, Rattan, & Dweck, 2012, p. 702). In conclusion, their study showed that an individual’s sense of belonging to mathematics has an impact on whether or not they purse a mathematics career. Also, they found that people with a fixed view of intelligence had a lower sense of belonging than people who had a more malleable view of intelligence.

Not only do attitude, gender stereotypes, sense of belonging, and the other factors that have been discussed affect mathematical achievement, but they can also have a significant impact on an individual’s decision to pursue a career in mathematics. A research article by Smeding (2012) explores implicit gender stereotypes and their effect on mathematical performance in STEM women versus non-STEM women. Note that STEM stands for science, technology, engineering and mathematics and women in STEM represent women in these types of careers. This article classifies non-STEM careers as the humanities. It is thought that STEM women hold weaker stereotypes in mathematics than non-STEM women and also than males in both STEM and non-STEM fields. Smeding (2012) states, “regarding the implicit gender stereotype/performance relation, research has shown that for U.S. female undergraduates, the stronger their implicit gender-math stereotypes, the weaker their liking for, the lower their identification with, and the lower their performance in mathematics. The reverse was true for male undergraduates, for whom implicit math-gender stereotypes were positively related to math identification and performance” (p. 619). Again we see the impact that math-gender stereotypes have on performance, which in turn influences the amount of women we see in STEM careers. Currently, research shows that women are underrepresented in STEM careers relative to men. Smeding’s article gives one explanation for this, and there are many more out there.

A major concern for the lack of females in STEM relate careers is the fact that the United States is on track to lose its competitive edge within the market place due to the lack of students choosing careers in science, technology, engineering, an mathematics (Louis & Mistele, 2012, p. 1164). The United States has and continues to take numerous strides to help get more people in STEM careers. Louis & Mistele (2012) attempt to lessen the gap in the literature as to what may cause lower performance in mathematics by examining another factor: self-efficacy. The study took information from the TIMSS 2007 report, specifically, responses to questions dealing with self-efficacy. Recall that self-efficacy, as defined by Bandura is the collection of “specific beliefs about their own abilities and characteristics that guide their behavior by determining what they try to achieve and how much effort they put into their performance in that particular situation or domain” (as cited in Louis & Mistele, 2012, p. 1166). In other words, self-efficacy is related to one’s confidence in their abilities and can be molded by past experiences. Studies seem to suggest that self-efficacy differs by gender and can significantly influence mathematics achievement. In their study Louis and Mistele control for self-efficacy and attempt to answer the question of whether or not gender differences in self-efficacy impact achievement scores for each of the mathematics disciplines: algebra, geometry, data, and number. They found in their study that overall males have a stronger self-efficacy than females (Louis & Mistele, 2012, p. 1172). They also found that achievement scores between males and females were statistically significant in algebra, but not geometry, data, and number (Louis & Mistele, 2012, p. 1175). They found that females scored higher in algebra than males. Finally their study supports the fact that it is not enough to just look at scores when trying to explain gender differences in mathematics achievement scores. It is possible that changes in curriculum and instruction could increase self-efficacy and potentially increase the number of individuals who choose to pursue careers in STEM-based fields.

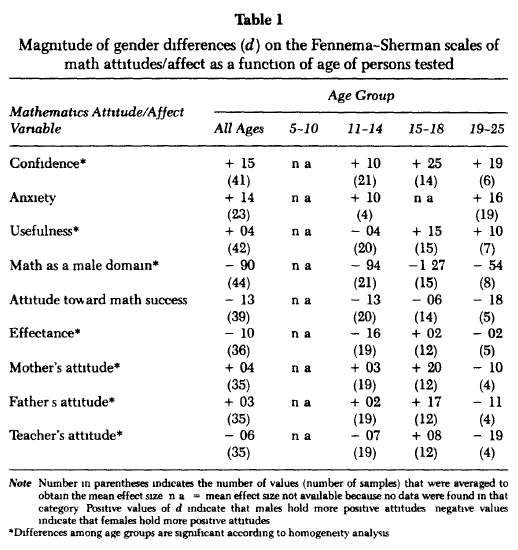
Further research on self-efficacy was done by Ross, Scott, and Bruce (2012). They address that the “key mechanisms linking self-efficacy and achievement are that students with high self-efficacy, in contrast with students with low self-efficacy, adopt mastery goal orientations, persist through obstacles, and maintain better control of their emotions” (Ross, Scott, & Bruce, 2012, p. 279). Students with a higher self-efficacy are less likely to be discouraged by failure because they believe they are going to be successful. This accounts for the reciprocal relationship between self-efficacy and achievement. It is believed that a student forms their self-efficacy beliefs based on their achievement. Furthermore, “since the relationship between self-efficacy and achievement is reciprocal, if the achievement gap disappears, it is possible that the confidence gap would decline and perhaps even disappear” (Ross, Scott & Bruce, 2012, p. 279). They tried to test this hypothesis, but failed to find anything statistically significant. The results of their research emphasize the importance of continuing to research to better understand the connection between student beliefs in their mathematics ability and their mathematical achievement. Regardless, there are still many advantages to reducing the confidence gap between males and females in mathematics.

Even if there isn’t evidence of a direct casual relationship between confidence and achievement, all students can benefit from increasing their self confidence in mathematics. Since many studies continue to show that men have more confidence in mathematics than women, Ross, Scott, & Bruce (2012) provide some strategies for reducing the confidence gap:

1. Continue efforts to make mathematics attractive to girls and women by overtly confronting stereotypical beliefs that mathematics is a male domain by presenting role models of female mathematicians; calling on females as frequently as males to give answers; providing equal time for males and females to explain their solutions; creating balanced gender cooperative groups in the classroom; and helping teachers recognize that some of their instructional strategies may contribute to stereotyping
2. Increase the likelihood that female students will interpret their performance as being successful by providing rubrics that enable students to reduce discrepancies between their self-evaluations and school standards
3. Provide attributional training in which students learn to attribute success to ability and failure to lack of effort
4. Confer status on female students by recognizing their achievements because respect from teachers is a stronger predictor of self-confidence for females than males (p. 285).

As teachers, we need to do everything we can to reduce the gender gaps in mathematics education. By following some of the steps above, we can potentially eliminate math gender stereotypes, gaps in self-confidence and self-efficacy, and perhaps increase the amount of females that choose to pursue STEM related careers.

Based on the vast amount of research in the past few decades in gender differences in mathematical achievement, there is no doubt that there are more factors at play than just natural ability. Gender differences in attitude, self-efficacy, sense of belonging, anxiety, and the math-gender stereotype all contribute to gender differences in mathematics. Hyde, Fennema, Ryan, Frost, and Hopp (1990) performed a meta-analysis of gender differences in attitudes and affect specific to mathematics. Specifically, they looked at a model proposed by Fennema and Peterson, which suggested, “failure to participate in independent learning experiences in mathematics contributes to the development of gender differences in mathematics performance” (Hyde et al., 1990, p. 301). In other words, the collection of factors discussed in this paper can partially determine what kinds of learning experiences a student has which in turn can affect a student’s performance. Again we see that attitudinal and affective variables are the ones contributing to the gender gap. Interestingly, the results of the meta-analysis indicate that gender differences in most aspects of mathematics attitudes and affect are small, except in stereotyping mathematics as a male domain (Hyde et al., 1990, p. 310). As indicated previously, the math-gender stereotype can have huge implications on a female’s future course selection and career paths. The following chart provides the results of the Fennema-Sherman scales in learning mathematics, mathematics anxiety, usefulness of mathematics, mathematics as a male domain, attitude towards success in mathematics, effectance motivation in mathematics, mother’s attitude, father’s attitude, and teacher’s attitude.



Note the magnitudes of the mathematics as a male domain results and how they are significantly larger than the rest of the results.

The articles addressed in this paper summarize the combined factors that attribute to the apparent gender gap in mathematics performance. In the conclusion, I would like to focus again on the apparent gender stereotype that males are better at mathematics than females. While I don’t necessarily believe that this is true, there is a common theme that this stereotype is a major dilemma for females. A study was done by Krendl, Richeson, Kelley, and Heatherton (2008) where they used “functional magnetic resonance imaging to indentify the neural processes engaged when women perform difficult mathematical tasks both in the presence and in the absence of stereotype threat” (p. 169). They looked at results on a mathematics test between two groups of females. One group was reminded of the stereotype before the test and the other group was not. They found that the group that was reminded of the sex difference performed worse than the group that was not reminded. These results indicate that “in the presence of stereotype threat, women experience heightened activation in the vACC, a region implicated in social and emotional processing, and subsequently fail to adopt effective mathematical learning strategies” (Krendl et al., 2008, p. 173). In conclusion, teachers must take all the emotional and psychological factors into account when trying to decrease the achievement gap between males and females in mathematics. They also must be careful not to perpetuate the math-gender stereotype because as it has been shown, these emotional and psychological factors can have detrimental effects on women’s performance in mathematics, and their future course work and careers as well.

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