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THE DIFFERENCES IN SCORES AND SELF-EFFICACY BY STUDENT GENDER IN MATHEMATICS AND SCIENCE

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ABSTRACT. Typically, mathematics and science are seen as linked together, where both subjects involve numbers, critical thinking, and problem solving. Our study aims to develop a better understanding of the connections between student's achievement scores in mathematics and science, student gender, and self-efficacy. We used the Trends in International Mathematics and Science Study 2007 eighth grade data to answer our research questions and were able to demonstrate that when controlling for self-efficacy, there is a statistically significant difference in the achievement scores between males and females by subject, where females score higher Algebra, but males score higher in the other mathematics subjects. Likewise, we were also able to demonstrate that there is a statistically significant difference in the achievement scores in Earth Science, Physics, and Biology, between males and females where males score higher in science subjects. In both mathematics and science examinations, we controlled for self-efficacy where in mathematics females hold lower self-efficacy then males and in science there is no difference between females and males in terms of self-efficacy. We conjecture that mathematics and science classrooms that consider self-efficacy may impact student's achievement scores by subject, which can ultimately impact career choices in mathematics- and science-based fields.

KEY WORDS: achievement scores, differences by gender, self-efficacy, subject differences, TIMSS 2007

Introduction

Students often have a variety of achievement levels and self-efficacy concerns in mathematics and science. These fundamental subjects are taught at all grade levels to all students across the USA and the world. Our study aims to develop a better understanding of the connections between student's achievement scores and their self-efficacy in these subjects so that ultimately teaching and learning can be improved. For this study, we examined the US eighth grade data from the Trends in International Mathematics and Science Study (TIMSS) 2007 national survey to explore the differences in achievement scores and self-efficacy of students by gender in both mathematics and science, where the subjects for each discipline were separated out and combined for a more in-depth examination of the topic. We used quantitative techniques in our research and found that there are indeed differences between males and females when mathematics and science are broken out by subject.

Literature Review

The President's Council of Advisors on Science and Technology (2011) warn that the USA is positioned to lose its competitive edge within the market place due to the lagging numbers of students choosing careers in science, technology, engineering, and mathematics (STEM) (Stuart, 2000). Our elementary and secondary student's achievement scores in mathematics and science consistently place the USA among the middle or lower rungs when compared to the other nations of the world. In addition, the council reports that various groups, such as minorities and women, are under-represented in the STEM fields (Stuart, 2000). To counter this trend, mathematics and science partnerships have been initiated to support new national level programs that encourage students to enter the STEM disciplines (Merrill & Daugherty, 2010). Examining mathematics education and science education communities in greater detail reveals the efforts that have been made to understand the lackluster achievement scores and the dwindling number of students preparing for STEM careers, as they relate to gender (Merrill & Daugherty, 2010). These reports and findings serve as the motivation for our work. As the USA moves forward, additional information about mathematics and science performance is needed so that improvement and enhancements can be made to curricula, but there is still a question as to the differences between males and females in these subjects which must be understood so that choices to pursue STEM careers can be improved as a whole.

Over the last 25 years, the mathematics education community has explored the reasons for the under-representation of various minority groups, most notably females (Hyde, Fennema, Ryan, Frost & Hopp, 1990). Research showed that the gender gap associated with the achievement scores for mathematics may be partly mediated by female's attitudes toward mathematics (Ma & Cartwright, 2003; Brush, 1985; Hyde et al., 1990) or by social economic status (Anyon, 1980; Chiu, 2009). Many of the early research focused on a single component of attitude, mathematics anxiety (Stuart, 2000; Ma, 1999; Satake & Amato, 1995; Greenwood, 1984). Zakaria & Nordin (2008) explored mathematics anxiety and motivation using 88 matriculating students in Malaysia, where 82.95% were females. Their study showed mathematics anxiety was correlated to both motivation and mathematics achievement, but they did not address mathematics anxiety according to gender. Other studies explored the gender difference based more broadly on student's experiences with mathematics using dichotomous terms: positive or negative experiences (Ma & Cartwright, 2003; Brush, 1985). Hyde et al. (1990) took a broader approach by performing a meta-analysis to explore the role student affect and attitude has on mathematics achievement scores based on many attributes held by students from kindergarten to college. They found that student's attitudes toward mathematics, while significant, have small effect sizes (Hyde et al., 1990). Our study aims to fill a gap in the literature by exploring the differences by gender in mathematics and science by subject while accounting for self-efficacy differences.

Hyde et al. (1990) explains that in their study, they separated the terms attitude and affect specifically to accurately represent the psychological meanings associated with the terms held by many social psychologists. Many incorporate affect within attitude, where attitude typically consists of three parts: beliefs, affect, and behavior. The term *affect* relates to the affective process that regulates the emotional states and the production of emotional responses (Bandura, 1994). The affect process is separate from the term self-efficacy, people's belief in their ability to produce results, but affect does influence a person's self-efficacy (Bandura, 1994). For this project, we focus on self-efficacy, a persons' belief in their abilities, as our theoretical framework because the survey tool used to collect the data specifically asks for students' beliefs on their abilities or self-efficacy. See "Appendix 1" for the TIMSS questions we examined in this study. It should be noted that some of the questions in the original survey do refer to students' general attitudes toward mathematics and science, but for our research, we specifically analyzed the questions relating to belief of success (self-efficacy), not general attitude toward the subjects. One could argue that self-efficacy is a part of overall attitude, but for our work, we are only interested in that small subset of attitude, self-efficacy. Also the self-efficacy questions relate to individuals' perception which again is our interest in this work. We want to know how students view their ability to succeed compared across male and female groups.

More recently, Frenzel, Pekrun & Goetz (2007) studied the gender differences in mathematics from a novel perspective with fifth graders in Germany, based on the emotions the students experience, which extended beyond anxiety to include feelings of pride, hopelessness, shame, and enjoyment. Their results showed girls experiencing lower levels of enjoyment and pride with mathematics while concurrently experiencing higher levels of anxiety, hopelessness, and shame when compared to boys without there being a gap between their achievement scores. In another research project, Beaton, Tougas, Rinfret Huard & Delisle (2007) developed two studies with 66 Canadian undergraduate women pursuing various fields of study. The research was initiated to determine the reason for women's continual avoidance of mathematics and mathematical-based careers. Their study confirms earlier research findings that links higher levels of mathematics anxiety among women to their decline in mathematical performance.

Finally, researchers have specifically examined sources of self-efficacy with middle school students in mathematics (e.g. Usher, 2009; Usher & Pajares 2009). Skaalvik & Skaalvik's (2006) with a two part longitudinal study of middle school and high school mathematics students showed self-perceptions, which include self-concept and self-efficacy, predicted subsequent achievement more accurately than prior achievement. They found that self-concept and self-efficacy mediated academic achievement in both parts of their study. On the other hand, they did not find evidence to support the impact of self-perception on later achievement that was mediated by student's interests in mathematics, goal orientation, or their self-esteem. These studies seem to suggest that mathematics achievement is influenced significantly by student's attitudes and self-efficacy, which differ by gender.

Yet, what is self-efficacy? In our study, we were informed by Albert Bandura and his work that focuses on self-efficacy. Grusec (1992) solidified a historical account of the legacies of Sears and Bandura and explains Bandura's self-efficacy theory where "people develop domain 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" (Grusec, 1992, p. 782). She goes on to explain that self-precepts provide the framework, which information is judged so that if someone has a negative self-precept about a situation, where they believe they will fail, this in turn causes the person to become self-focused and emotionally aroused, which hinders their ability to perform well (Grusec, 1992). A person's self-efficacy is molded by past experiences in addition to observing what others have accomplished, motivation provided to them by others, and their own psychological state when engaged in an activity (Grusec, 1992), which does tie into the studies addressing mathematics anxiety but is one component of our notion of self-efficacy.

Turning our attention to science, we find that the connection between mathematics and science is widely accepted. Yet the reason for the connection extends beyond the ability to perform calculations. Rutherford

(1997) reminds us that scientists want people to understand mathematics so that they can understand scientific concepts and processes. Fundamentally, understanding the nature of mathematics supports the understanding the nature of science.

Taasoobshirazi & Carr (2008) explored the gender differences for students in the sciences with an emphasis on physics. They cite two studies where the authors explored gender differences. The first study showed that difference between the genders appears in grade 4 and continues through school for the life sciences and the physical sciences (Beller & Gafini, 1996). The second study suggests the reasons for the gender differences in science achievement for K–12 may be linked to lower performance on standardized tests, which may hinder females from pursuing careers in the sciences (e.g. Katz, Allbritton, Aronis, Wilson & Soffia, 2006). However, perhaps another issue lies below the surface, self-efficacy.

Britner & Pajares (2006) report from their earlier studies (e.g. Pajares, Britner & Valiante, 2000) that for the middle school students science self-efficacy predicted higher science achievement scores for girls and Caucasian students than the achievement scores for boys or African American students as the former two groups had higher self-efficacy ratings than the latter two groups. In addition to the research presented specifically focused on mathematics and science, other research shows that higher academic achievement is linked to higher levels of self-efficacy especially in STEM fields (e.g. Pajares & Valiante, 1999), which is important as STEM education begins to take hold in K–12.

In conclusion, Britner & Pajares (2006) state that according to Bandura (1986), student's self-efficacy beliefs are more accurate in predicting student's success in academics than other objective assessments that focus on the student's abilities. Bandura, Barbaranelli, Caprara & Pastorelli (2001) explain that perceived self-efficacy is crucial because "unless people believe they can produce desired outcomes by their actions, they have little incentive to act or to persevere in the face of difficulties" (p. 185). This underlying belief impacts the choices students make concerning their field of study in college, which determines their career choice (Zeldin, Britner & Pajares 2008).

Therefore, informed by the research, our study controls for self-efficacy to explore the relationships between mathematics achievement scores and gender and science achievement scores and gender. We explore this relationship for each of the subject area within mathematics and science including overall mathematics and science achievement scores. Typically, studies focus on comparing overall mathematics scores or overall science scores with self-efficacy (Chen & Zimmerman, 2007) or total mathematics and total science scores with self-concept (Wilkins, 2004) when comparing country performances. We unpack the overall mathematics and science scores to explore the relationship between each of the subjects within mathematics and science and the student's gender, while controlling for self-efficacy. The purpose of our study is to understand the differences between gender for mathematics and science when the topics are analyzed as a whole and by subject. Our research questions are:

1. Does gender impact achievement scores for each of the mathematics disciplines: Algebra, Geometry, Data, and Number?
2. Does gender impact achievement scores for each of the science disciplines: Biology, Chemistry, Earth Science, and Physics?
3. Does gender impact overall achievement scores for mathematics and sciences?

We expect to find Algebra scores to be impacted by self-efficacy in both gender groups due to the attention placed on this subject by the National Council of Teachers of Mathematics. They indicate that it is a gateway to higher levels of mathematics courses taken in high school, which positions a student for college and STEM fields. Concerning the science courses, we expect physics to be more negatively correlated due to its stronger connection to mathematics formulas and physical properties.

Methods

This research involved data from a national data set collected from a cross-sectional non-experimental study using US TIMSS 2007 public data resources. For the study, we focused on examining data related to eighth grade US students. We chose to focus on only the US students because there is a body of literature that questions the use of TIMSS to compare countries and even TIMSS data in general (e.g. Holliday & Holliday, 2003). By restricting our study to US eighth grade students only, we are able to remove concerns related to cultural, language, and country differences across nations. Specifically, we used data from a student survey instrument and plausible value scores as they both relate to mathematics and science. The plausible value is an estimate of the score based on item response theory (IRT) addressing item difficulty, which is a more recent technique used to more accurately measure student ability than the techniques used in classical test theory that were developed in the early twentieth century (Baker, 2001). It should be noted that IRT is simply a measuring technique, not a theoretical framework for this research. The data were obtained from the international data base (Foy & Olson, 2009) but can also be found at http://nces.ed.gov/timss/results07.asp.

Participants

As stated in the TIMSS 2007 Technical Report (Olson, Martin & Mullis, 2008) and reiterated in the user guide (Foy & Olson, 2009), the US sample of TIMSS 2007 includes both public and private schools, randomly selected through a two-staged sampling process (first at the school level, then at the classroom level) and weighted to be representative of the nation. In total, 239 eighth grade schools and 7,377 eighth grade students participated in the TIMSS study, and weighting was used to adjust for the complex sample design in order to obtain accurate population estimates (Olson et al., 2008).

Population and Sample. According to the technical report (Olson et al., 2008), the first stage of the sampling design considered the schools and focused on the profile of the proportion of public and private schools in the country and the proportion of the schools within four regions: south, west, north central, and the northeast of the USA. The second stage was the classroom where the size was set to a minimum of 20 students; if the number of students in a classroom was less than 20 students, then a pseudo-classroom was constructed by joining the small classroom to another classroom (Olson et al., 2008). This process allowed the collection the TIMSS 2007 data to obtain a representative sample of students. The school level sampling frame was used to attain a self-weighting student sample (Olson et al., 2008). The schools were selected in proportion according to their private and public status as well as their region in the country and size (Olson et al., 2008).

Instruments

In total, each TIMSS cycle gathers data relating to four separate surveys/assessments which were developed by all countries participating in the study (Olson et al., 2008). The first was a student achievement assessment in mathematics and science, the second was a student survey, the third was a teacher survey, and the fourth was a general school survey (Olson et al., 2008). Each of these items was administered by trained personnel, and the results were recorded nationally (Olson et al., 2008). Each item asks a variety of questions relating to mathematics and science. For the purposes of our research, we focused on questions relating to students' self-efficacy toward mathematics and science along with students' mathematics and science achievement scores.

Assessment data for TIMSS 2007 were collected through pencil-and-paper assessments administered to the students and through surveys where the eighth grade assessment had four scales that described the four content areas for mathematics: Number, Algebra, Geometry, and Data (which included Chance), in addition to the four domains science: Earth Science, Physics, Biology, and Chemistry (Olson et al., 2008). To accommodate the missing data from surveys that were not completed, plausible values were estimated based on the students who were participating in the assessment, where the plausible values are assigned values (Olson et al., 2008). The plausible values are estimated from five random draws from an empirically derived distribution of score values based on the student's observed responses to assessment items and on background variables (Olson et al., 2008). The plausible values were used in this study.

Data Analysis

A variety of tests were performed on the data to help answer the research questions. The first tests were a series of reliability analyses to ensure that constructs could be properly created. The second set of tests involved analyses of variance (ANOVAs) comparing gender and self-efficacy scores and gender and overall mathematics and science scores. The final set of tests involved two multivariate analyses of covariance (MANCOVAs) where the differences between gender and subject scores were examined while controlling for self-efficacy concerns, where controlling means statistical control where variations from one construct or variable are taken into account before the variations of another construct or variable are determined (Keith, 2006). Each of these tests helped to answer the research questions.

Assumptions. Three assumptions were addressed during the data analysis of this study: normal distribution, homogenous variance of errors, and independence of responses. For normality, a visual inspection of all the constructs' histograms was conducted and confirmed that the data were relatively normally distributed. For homogenous variance of errors, multiple tests were performed alongside the other statistical tests above to address this concern. Finally, the independence of responses was addressed through the sampling technique employed by the agency collecting the TIMSS data. It should be noted that approximately 5% of the student data were double counted because a few of the students were linked to two different mathematics classrooms or science classrooms. This is mostly due to enrollment in two courses in one subject. Due to this small percentage, the sample data remained intact and overall independence was not violated.

SES Considerations. An extensive effort was applied to creating an appropriate socioeconomic status (SES) construct since a constructed variable was not included in the data set. The attempts included various combinations of items such as mother and father highest education level achieved separately and mother and father highest level of education achieved as one item, race, and selecting items found in the home, such as a computer, and internet service. However, the identification of the items owned in the home was dichotomous data, and the parental educational achievement was student reported and showed that 28% of the students lacked knowledge of their parents' highest level of educational achievement. The numerous attempts to create a suitable SES construct resulted in reliability Cronbach's alpha values severely below the 0.80 desirable levels. Therefore, we decided it best not to create a faulty SES construct.

Constructs. Two major categories of constructs were created for the analysis. The first major category of constructs focused on the student achievement scores associated with each of the four subjects within mathematics and science and the student's overall mathematics and science scores. The eight subject constructs were created by averaging the plausible values of the student's achievement scores for each of the four subjects in mathematics (Algebra, Geometry, Data, and Number) and the four subjects in science (Biology, Chemistry, Earth Science, and Physics). The last two constructs used the average of the five plausible values to generate an overall construct for mathematics and science. This resulted in the final ten constructs: overall mathematics, overall science, Algebra, Data, Number, Geometry, Chemistry, Earth Science, Biology, and Physics.

The second construct used the student attitude survey items as a means to address self-efficacy for each discipline, mathematics and science. A construct was created with four of the survey items from one question for each discipline (mathematics: questions 9 a, c, e, and f; science: questions 12 a, c, e, and f) to create a general mathematics self-efficacy construct and a general science self-efficacy construct. All of the items used a Likert-type four point scale where 1=agree a lot, 2=agree a little, 3=disagree a little, and 4=disagree a lot. Questions 9 and 12 had items c and e reversed coded to match the scale of the other items. In addition, all missing cases were addressed before the analysis began. A reliability analysis using Cronbach's alpha showed all of the items in the constructs were suitable to represent student mathematics self-efficacy, α = 0.838, and student science self-efficacy, α = 0.824. The item scores were averaged to create the two self-efficacy constructs for mathematics and science. See "Appendix 1" for the self-efficacy questions used from the survey.

Results

Multiple tests were conducted with the various constructs to help answer the research questions. Two ANOVAs were performed comparing gender and self-efficacy scores and gender and overall mathematics and science scores. Also, two MANCOVAs were performed to analyze the differences between gender and subject scores while controlling for self-efficacy.

Analysis of Gender and Self-Efficacy

First, the descriptive statistics for the self-efficacy scores in mathematics and science by gender show overall that males have a stronger self-efficacy than females. Specifically, the mean self-efficacy score for males in mathematics was 2.0281; for females, it was 2.1760. The mean self-efficacy score for males in science was 2.4063; for females, it was 2.4214. The questions in the survey used Likert-type responses where 1=agree a lot, 2=agree a little, 3= disagree a little, and 4=disagree a lot so the lower the score, the higher the self-efficacy. See "Appendix 1" for the exact questions.

Next, two ANOVAs were performed to determine whether there was a difference between males and females based on their self-efficacy for mathematics and science. The first ANOVA assessed the difference between gender and self-efficacy in mathematics. This test revealed a statistically significant difference between male and female self-efficacy in mathematics (F = 63.026, p < 0.001). The second ANOVA evaluated the difference between gender and self-efficacy in science. This test failed to show a statistically significant different between male and female self-efficacy attitudes in science (F = 3.088, p = 0.079).

Analysis of Gender and Overall Scores

The next step in the study assessed the gender differences in the overall mathematics and science achievement scores. Two ANOVAs were conducted, where the first ANOVA evaluated the gender difference with the overall mathematics achievement scores. This test results failed to show a statistical significant difference between male and female mathematics achievement scores (F = 2.811, p = 0.094). The second ANOVA evaluated the gender differences with the overall science achievement scores. The test revealed a statistically significant differences between male and female achievement scores in science ($F = 36.274$, $p < 0.001$). In both cases, males scored higher than females. In mathematics, the male mean achievement score was 509.278 while the female achievement score was 506.412. In science, the male mean achievement score was 524.874 while the female achievement score was 513.981. Next, we explored the achievement scores for each of the subjects in mathematics and science.

Analysis of Gender and Subject Scores

The final step in the analysis of the data involved conducting a set of MANCOVAs where gender was the independent variable and the achievement scores by subject were the dependent variables, where self-efficacy was the covariate or control. The first MANCOVA explored these relationships with mathematics, which focused on the subjects: Algebra, Data, Number, and Geometry. The Box's *M* value was 30.821 ($p = 0.001$), which indicates a lack of homoscedasticity between the variance–covariance matrices with the dependent variables. Therefore, the Pillai's trace was used for the analysis instead of the Wilk's lambda. The Bartlett's test of sphericity was significant ($p < 0.001$) with an approximate chi-squared of 39,928.190, which indicates a sufficient correlation exists between the dependent variables, the mathematics achievement scores for each subject. This finding allowed the analysis to continue. The Pillai's trace for this analysis had an *F* value of 24,728.563 ($p < 0.001$) which indicated there was a difference between the achievement scores for each of the mathematics subjects. The Levene's test showed that no items were statistically significant indicating the assumption of equal error variance across groups for the dependent variables held true. See "Appendix 2" for the SPSS output.

Finally, for the tests of between-subjects effects, there was a statistically significant difference in the achievement scores for Algebra ($F = 56.838$, $p < 0.001$) between males and females. It should also be noted that based on the graphical output from the analysis, we see that in every mathematics subject, males scored higher than females except in Algebra; however, the differences for the other subjects were not statistically different (see "Appendix 2" for all of the SPSS results). Before we began the analysis, we hypothesized that females would score lower than males in Algebra so this was a very surprising result.

The second MANVOCA focused on science with the subjects Chemistry, Earth Science, Biology, and Physics being explored in detail. The Box's *M* value was 23.709 ($p = 0.008$) indicating a lack of homoscedasticity between the variance–covariance matrices with the dependent variables. The Pillai's trace needed to be used for the analysis instead of the Wilk's lambda. The Bartlett's test of sphericity was statistically significant ($p < 0.001$) with an approximate chi-squared of 56,955.289, which indicated a sufficient correlation existed between the dependent variables, the science achievement scores for each subject. The Pillai's trace for this analysis had an F value of 7,870.000 ($p < 0.001$) indicating there was a difference between the achievement scores for each of the science subjects. The Levene's test showed that no items were statistically significant indicating the assumption of equal error variance across groups for the dependent variable held true.

Finally, the tests of between-subjects effects determined that by gender there was a statistically significant difference between achievement scores in Earth Science ($F = 100.527$, $p < 0.001$), Biology ($F = 12.605$, $p < 0.001$), and Physics ($F = 193.997$, $p < 0.001$). Chemistry failed to show a statistically significant difference. Based on the graphical output, we see that males scored higher than females in all science subjects, yet only in Chemistry was the difference not statistically different. See "Appendix 2" for all of the SPSS results.

Discussion

Similarities and Differences Between Mathematics and Science

Our results show a variety of similarities and differences between self-efficacy and scores in mathematics and science. Some of the results we found paralleled past literature with regard to analysis conducted on mathematics and science as a whole, but some of the results produced new and interesting findings when mathematics and science were examined by subject.

Self-Efficacy by Gender. Upon inspection, we found differences between male and female students' self-efficacy in mathematics and science. We found that males exhibit statistically significant higher self-efficacy levels when compared to females in mathematics. This finding is also supported in the literature where other authors also found similar results that showed there are indeed differences in the attitudes of males and females concerns mathematics (Ma & Cartwright, 2003; Brush, 1985). In science, the self-efficacy levels between male and female students were not statically different. Our study does not address the reasons for the differences since it is strictly quantitative in nature. Future research may address the reasons for the differences.

Achievement Scores by Gender. The results comparing gender with the student's achievement scores found differences between gender for mathematics and science; however, the differences for mathematics were not statistically significant. This is supported by the literature that states that gender gaps by scores in mathematics are diminishing (e.g. Hyde & Mertz, 2009). On the other hand, the analysis found a statistically significance difference in the science achievement scores between female and male students, where the males achievement scores were higher. Again, our study does not address the reasons for the differences or lack of difference found between gender and the achievement scores in mathematics and science. Future research may explore the reasons for the differences.

Overall Observation. The most interesting observation for the set of ANOVA tests revealed that the mathematics self-efficacy scores were statistically significantly different by gender, but the mathematics achievements scores were not statistically significantly different by gender. However, the opposite was found with science. That is, the self-efficacy scores by gender were not statistically significantly different in science, but the achievement scores in science were statistically significantly different by gender. The reasons for this difference are unknown at this time, but this finding does suggest that males and females do perform differently in science compared to mathematics even though the subjects are often linked when references are made to STEM careers (e.g. Merrill & Daugherty, 2010).

Similarities and Differences Between Mathematics and Science by Subject

Based on the MANCOVA analyses, the individual subjects associated with mathematics and science revealed the achievement scores differed by gender when controlling for self-efficacy. For mathematics, Algebra showed a statistically significant difference in the achievement scores between females and males, where female's achievement scored were higher than males. The ANOVA exploring the overall mathematics achievement scores showed no difference by gender, which was consistent with the other mathematics subjects, Data, Number, and Geometry. In science, the achievement scores were statistically different between female and male students for three of the subjects, Earth Science, Biology, and Physics where male's achievement scores were higher than females. The ANOVA examining the overall science achievement scores showed a statistically significant difference between males and females achievement scores. Only Chemistry showed a non-statistically significant difference between the achievements scores of males and females while controlling for self-efficacy.

These results help support the notion that examining overall mathematics and science scores does not present a complete picture of a student's level of knowledge for mathematics or science. To better understand a student's achievement scores, it is best to unpack mathematics and science by subject while concurrently addressing self-efficacy. As shown by these results, when the achievement scores are separated by subject, we find that females are statistically significantly higher achievers in Algebra. Likewise, we find males statistically higher achievers in Earth Science, Biology, and Physics. These subjects may suggest instructional and curricular changes are in order to address the differences between males and females achievement scores when viewed through the lens of self-efficacy.

Limitations

There are several limitations to our research. The first set of limitations deals with our particular work. The first is the absence of an appropriate SES construct. An extensive effort was made to create an appropriate SES construct since a SES variable was not included in the data set, but as discussed in the "Methods" section, no such construct could accurately be created. The second limitation concerns the nature of using large-scale data bases. Inherent to the large size, we are aware of the small effect sizes that result. However, our intent was to identify statistically significant relationships associated with student self-efficacy and the impact gender has on achievement scores in mathematics and science by subject so small effect sizes are acceptable and expected.

The second set of limitations relates to using TIMSS data in general. First, given the nature of our data, national data set, we were unable to ask or supply questions that pertained to our specific research questions, which reduced the robustness of our self-efficacy construct and subsequently rendered an SES construct obsolete. Second, we are aware that using the TIMSS 2007 data is quickly becoming outdated, but the TIMSS 2011 data were unavailable at the time of this study. Finally, there is a body of literature that discredits the use of TIMSS data (e.g. Holliday & Holliday, 2003; Brown & Brown, 2007; Wang, 2001) which cannot be ignored. Most of the issues surrounding TIMSS data relates to its' use for country comparisons and general assessment, ranking, and evaluation of education. Since our study focuses on the difference between males and females, not on differences between countries or using the data for strict evaluations purposes, these arguments should be considered, but we feel they do not discredit our work. Despite the various limitations in our research related to the analysis itself and TIMSS data in general, we feel we effectively addressed our research questions and have provided information that is valuable to the literature.

Future Work

The results of this study produced interesting and unexpected findings, but the *why* remains unanswered. We believe a future qualitative study offers a better methodology to address the reasons underlying the statistically significant differences we found between males and females according to their achievement scores in the subjects in mathematics and the subjects in science including the differences in the self-efficacy levels we found between males and females. Another avenue for future work may be to study the results using correlations to see if any connections between the constructs can be understood. At this point, this is beyond the scope of this project as this research is the first step in understanding if any relation even exists between the constructs of interest when mathematics and science scores are separated by subject. Also for this work, we were specifically concerned with group differences which lends itself to analysis using ANOVAs or MANCOVAs.

Additional work could be completed that addresses research to practice issues and remediation and prevention actions. Our work has shown that there are differences by subject in mathematics and science between genders. This could lead to future work that aims at closing the gap between genders for various subjects. Again, this is beyond the scope of this work due to resource and time limits, but our hope is that work in that area would be supported by our findings.

Conclusion

Mathematics and science are subjects that are closely related as they both contribute to STEM education, but when examined by various subjects, the achievement scores between males and females in mathematics and science exhibit different trends. Based on the TIMSS 2007 data, eighth grade males seem to show higher achievement scores in mathematics and science when compared to females. However, in mathematics, Algebra is the subject where the differences between males and females are statistically different, and in this case, females show higher achievement scores than males. In science, males show statistically significant higher achievement scores in Earth Science, Biology, and Physics. These results confirm the notion that evaluating achievement scores of students in terms of mathematics and science as a whole may not provide an accurate picture of education and achievement. To truly improve middle school education for both males and females, each of the content areas must be separated apart and evaluated. Each subject within mathematics and science should be scrutinized to explore and identify the differences that exist between male and female students. We conjecture that instructional and curriculum changes by subject may increase the self-efficacy and achievement by subject of students in mathematics and science, which in turn has the potential to increase career choices in STEM-based fields.

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Appendix 1
Grade 8 Student Questionnaire

The Likert-type scale:

1: Agree a lot 2: Agree a little 3: Disagree a little 4: Disagree a lot

9. How much do you agree with these statements about learning mathematics?

    (a) I usually do well in mathematics
    (b) I would like to take more mathematics in school
    (c) Mathematics is more difficult for me than for many of my classmates
    (d) I enjoy learning mathematics
    (e) Mathematics is not one of my strengths
    (f) I learn things quickly in mathematics
    (g) Mathematics is boring
    (h) I like mathematics

12. How much do you agree with these statements about learning science?

    (a) I usually do well in science
    (b) I would like to take more science in school
    (c) Science is more difficult for me than for many of my classmates
    (d) I enjoy learning science
    (e) Science is not one of my strengths
    (f) I learn things quickly in science
    (g) Science is boring
    (h) I like science

Appendix 2: SPSS Output

Self-Efficacy Construct Reliability

TABLE 1

Math reliability statistics

Cronbach's alpha	*N of items*
0.838	4

TABLE 2

Science reliability statistics

Cronbach's alpha	*N of items*
0.824	4

ANOVA for Gender and Self-Efficacy in Math

TABLE 3

MathAttitude

	Descriptives							
					95% confidence interval for mean			
	N	*Mean*	*Standard deviation*	*Standard error*	*Lower bound*	*Upper bound*	*Minimum*	*Maximum*
Girl	3,831	2.1760	0.81712	0.01320	2.1501	2.2018	1.00	4.00
Boy	3,719	2.0281	0.80040	0.01312	2.0024	2.0539	1.00	4.00
Total	7,550	2.1031	0.81224	0.00935	2.0848	2.1215	1.00	4.00

TABLE 4

MathAttitude

	ANOVA				
	Sum of squares	*df*	*Mean square*	*F*	*Sig.*
Between groups	41.244	1	41.244	63.026	0.000
Within groups	4,939.395	7,548	0.654		
Total	4,980.640	7,549			

ANOVA for Gender and Self-Efficacy in Science

TABLE 5

ScienceAttitude

	Descriptives							
					95% confidence interval for mean			
	N	*Mean*	*Standard deviation*	*Standard error*	*Lower bound*	*Upper bound*	*Minimum*	*Maximum*
Girl	3,829	2.4214	0.35243	0.00570	2.4102	2.4326	1.00	4.00
Boy	3,715	2.4063	0.39347	0.00646	2.3936	2.4189	1.00	4.00
Total	7,544	2.4139	0.37325	0.00430	2.4055	2.4224	1.00	4.00

TABLE 6

ScienceAttitude

	ANOVA				
	Sum of squares	*df*	*Mean square*	*F*	*Sig.*
Between groups	0.430	1	0.430	3.088	0.079
Within groups	1,050.454	7,542	0.139		
Total	1,050.884	7,543			

ANOVA for Gender and Scores in Math

TABLE 7

Avg_PV_Math

	Descriptives							
					95% confidence interval for mean			
	N	*Mean*	*Standard deviation*	*Standard error*	*Lower bound*	*Upper bound*	*Minimum*	*Maximum*
Girl	3,855	506.4116	73.17520	1.17862	504.1009	508.7224	284.19	703.11
Boy	3,764	509.2777	76.02192	1.23915	506.8482	511.7071	265.33	721.45
Total	7,618	507.8276	74.60405	0.85473	506.1521	509.5031	265.33	721.45

TABLE 8

Avg_PV_Math

	ANOVA				
	Sum of squares	*df*	*Mean square*	*F*	*Sig.*
Between groups	15,642.478	1	15,642.478	2.811	0.094
Within groups	4.238E7	7,616	5,564.744		
Total	4.240E7	7,617			

ANOVA for Gender and Scores in Science

TABLE 9

Avg_PV_Science

	Descriptives							
					95% confidence interval for mean			
	N	*Mean*	*Standard deviation*	*Standard error*	*Lower bound*	*Upper bound*	*Minimum*	*Maximum*
Girl	3,855	513.9810	76.14188	1.22641	511.5765	516.3855	259.31	734.13
Boy	3,764	524.8744	81.68024	1.33138	522.2641	527.4847	290.12	755.50
Total	7,618	519.3628	79.10920	0.90635	517.5861	521.1395	259.31	755.50

TABLE 10

Avg_PV_Science

	ANOVA				
	Sum of squares	*df*	*Mean square*	*F*	*Sig.*
Between groups	225,981.248	1	225,981.248	36.274	0.000
Within groups	4.745E7	7,616	6,229.756		
Total	4.767E7	7,617			

MANCOVA for Gender and Subject with Self-Efficacy in Math

TABLE 11

Multivariate tests

Effect		*Value*	*F*	*Hypothesis df*	*Error df*	*Sig.*	*Partial eta-squared*	*Noncentrality parameter*	*Observed power*[b]
Intercept	Pillai's trace	0.926	24,728.563[a]	4.000	7,876.000	0.000	0.926	98,914.253	1.000
	Wilks' lambda	0.074	24,728.563[a]	4.000	7,876.000	0.000	0.926	98,914.253	1.000
	Hotelling's trace	12.559	24,728.563[a]	4.000	7,876.000	0.000	0.926	98,914.253	1.000
	Roy's largest root	12.559	24,728.563[a]	4.000	7,876.000	0.000	0.926	98,914.253	1.000
MathAttitude	Pillai's trace	0.247	647.073[a]	4.000	7,876.000	0.000	0.247	2,588.292	1.000
	Wilks' lambda	0.753	647.073[a]	4.000	7,876.000	0.000	0.247	2,588.292	1.000
	Hotelling's trace	0.329	647.073[a]	4.000	7,876.000	0.000	0.247	2,588.292	1.000
	Roy's largest root	0.329	647.073[a]	4.000	7,876.000	0.000	0.247	2,588.292	1.000
ITGENDER	Pillai's trace	0.058	120.981[a]	4.000	7,876.000	0.000	0.058	483.925	1.000
	Wilks' lambda	0.942	120.981[a]	4.000	7,876.000	0.000	0.058	483.925	1.000
	Hotelling's trace	0.061	120.981[a]	4.000	7,876.000	0.000	0.058	483.925	1.000
	Roy's largest root	0.061	120.981[a]	4.000	7,876.000	0.000	0.058	483.925	1.000

Design: Intercept+MathAttitude+ITGENDER
[a]Exact statistic
[b]Computed using alpha = 0.05

TABLE 12

Tests of between-subjects effects

Source	*Dependent variable*		*Type III sum of squares*	*df*	*Mean square*	*F*	*Sig.*	*Partial eta-squared*	*Noncentrality parameter*	*Observed power*[a]
Corrected model	dimension1	Avg_PV_Algebra	8.889E6	2	4,444,503.907	1,192.586	0.000	0.232	2,385.172	1.000
		Avg_PV_Data	7.589E6	2	3,794,651.441	699.498	0.000	0.151	1,398.996	1.000
		Avg_PV_Number	9.630E6	2	4,815,128.303	1,060.545	0.000	0.212	2,121.090	1.000
		Avg_PV_Geometry	7.357E6	2	3,678,479.766	1,064.698	0.000	0.213	2,129.396	1.000
Intercept	dimension1	Avg_PV_Algebra	3.499E8	1	3.499E8	93,889.422	0.000	0.923	93,889.422	1.000
		Avg_PV_Data	3.776E8	1	3.776E8	69,603.765	0.000	0.898	69,603.765	1.000
		Avg_PV_Number	3.648E8	1	3.648E8	80,348.538	0.000	0.911	80,348.538	1.000
		Avg_PV_Geometry	3.166E8	1	3.166E8	91,623.612	0.000	0.921	91,623.612	1.000
MathAttitude	dimension1	Avg_PV_Algebra	8,854,765.099	1	8,854,765.099	2,375.983	0.000	0.232	2,375.983	1.000
		Avg_PV_Data	7,434,931.763	1	7,434,931.763	1,370.539	0.000	0.148	1,370.539	1.000
		Avg_PV_Number	9,448,940.293	1	9,448,940.293	2,081.155	0.000	0.209	2,081.155	1.000
		Avg_PV_Geometry	7,286,516.583	1	7,286,516.583	2,109.007	0.000	.211	2,109.007	1.000
ITGENDER	dimension1	Avg_PV_Algebra	211,824.198	1	211,824.198	56.838	0.000	0.007	56.838	1.000
		Avg_PV_Data	19,128.935	1	19,128.935	3.526	0.060	0.000	3.526	0.467
		Avg_PV_Number	19,286.016	1	19,286.016	4.248	0.039	0.001	4.248	0.540
		Avg_PV_Geometry	193.317	1	193.317	0.056	0.813	0.000	0.056	0.056
Error	dimension1	Avg_PV_Algebra	2.936E7	7,879	3,726.779					
		Avg_PV_Data	4.274E7	7,879	5,424.823					
		Avg_PV_Number	3.577E7	7,879	4,540.239					
		Avg_PV_Geometry	2.722E7	7,879	3,454.952					
Total	dimension1	Avg_PV_Algebra	2.007E9	7,882						
		Avg_PV_Data	2.263E9	7,882						
		Avg_PV_Number	2.089E9	7,882						
		Avg_PV_Geometry	1.844E9	7,882						

TABLE 12

(continued)

Source	*Dependent variable*		*Type III sum of squares*	*df*	*Mean square*	*F*	*Sig.*	*Partial eta-squared*	*Noncentrality parameter*	*Observed power*[a]
Corrected total	dimension1	Avg_PV_Algebra	3.825E7	7,881						
		Avg_PV_Data	5.033E7	7,881						
		Avg_PV_Number	4.540E7	7,881						
		Avg_PV_Geometry	3.458E7	7,881						

[a]Computed using alpha = 0.05

MANCOVA for Gender and Subject with Self-Efficacy in Math

TABLE 13

Multivariate tests

Effect		*Value*	*F*	*Hypothesis df*	*Error df*	*Sig.*	*Partial eta-squared*	*Noncentrality parameter*	*Observed power*[b]
Intercept	Pillai's trace	0.550	2,403.876[a]	4.000	7,870.000	.000	0.550	9,615.503	1.000
	Wilks' lambda	0.450	2,403.876[a]	4.000	7,870.000	.000	0.550	9,615.503	1.000
	Hotelling's trace	1.222	2,403.876[a]	4.000	7,870.000	.000	0.550	9,615.503	1.000
	Roy's largest root	1.222	2,403.876[a]	4.000	7,870.000	.000	0.550	9,615.503	1.000
ScienceAttitude	Pillai's trace	0.007	12.889[a]	4.000	7,870.000	.000	0.007	51.558	1.000
	Wilks' lambda	0.993	12.889[a]	4.000	7,870.000	.000	0.007	51.558	1.000
	Hotelling's trace	0.007	12.889[a]	4.000	7,870.000	.000	0.007	51.558	1.000
	Roy's largest root	0.007	12.889[a]	4.000	7,870.000	.000	0.007	51.558	1.000
ITGENDER	Pillai's trace	0.191	463.766[a]	4.000	7,870.000	.000	0.191	1,855.066	1.000
	Wilks' lambda	0.809	463.766[a]	4.000	7,870.000	.000	0.191	1,855.066	1.000
	Hotelling's trace	0.236	463.766[a]	4.000	7,870.000	.000	0.191	1,855.066	1.000
	Roy's largest root	0.236	463.766[a]	4.000	7,870.000	.000	0.191	1,855.066	1.000

Design: Intercept+ScienceAttitude+ITGENDER
[a]Exact statistic
[b]Computed using alpha = 0.05

TABLE 14

Tests of between-subjects effects

Source	*Dependent variable*	*Type III sum of squares*	*df*	*Mean square*	*F*	*Sig.*	*Partial eta-squared*	*Noncentrality parameter*	*Observed power*[a]
Corrected model	Avg_PV_Chemistry	114,532.583	2	57,266.291	11.598	0.000	0.003	23.195	0.994
	Avg_PV_EarthScience	804,017.529	2	402,008.765	62.938	0.000	0.016	125.876	1.000
	Avg_PV_Biology	158,636.224	2	79,318.112	13.606	0.000	0.003	27.212	0.998
	Avg_PV_Physics	1.162E6	2	580,823.217	108.983	0.000	0.027	217.967	1.000
Intercept	Avg_PV_Chemistry	4.409E7	1	4.409E7	8,929.806	0.000	0.531	8,929.806	1.000
	Avg_PV_EarthScience	4.488E7	1	4.488E7	7,025.797	0.000	0.472	7,025.797	1.000
	Avg_PV_Biology	4.749E7	1	4.749E7	8,145.410	0.000	0.509	8,145.410	1.000
	Avg_PV_Physics	4.152E7	1	4.152E7	7,790.079	0.000	0.497	7,790.079	1.000
ScienceAttitude	Avg_PV_Chemistry	78,889.120	1	78,889.120	15.977	0.000	0.002	15.977	0.979
	Avg_PV_EarthScience	173,630.977	1	173,630.977	27.183	0.000	0.003	27.183	0.999
	Avg_PV_Biology	87,987.885	1	87,987.885	15.093	0.000	0.002	15.093	0.973
	Avg_PV_Physics	141,072.277	1	141,072.277	26.470	0.000	0.003	26.470	0.999
ITGENDER	Avg_PV_Chemistry	37,559.433	1	37,559.433	7.607	0.006	0.001	7.607	0.787
	Avg_PV_EarthScience	642,106.608	1	642,106.608	100.527	0.000	0.013	100.527	1.000
	Avg_PV_Biology	73,481.968	1	73,481.968	12.605	0.000	0.002	12.605	0.944
	Avg_PV_Physics	1,033,901.471	1	1,033,901.471	193.997	0.000	0.024	193.997	1.000
Error	Avg_PV_Chemistry	3.887E7	7,873	4,937.761					
	Avg_PV_EarthScience	5.029E7	7,873	6,387.374					
	Avg_PV_Biology	4.590E7	7,873	5,829.715					
	Avg_PV_Physics	4.196E7	7,873	5,329.472					
Total	Avg_PV_Chemistry	2.083E9	7,876						
	Avg_PV_EarthScience	2.210E9	7,876						
	Avg_PV_Biology	2.251E9	7,876						
	Avg_PV_Physics	2.026E9	7,876						

Corrected total	Avg_PV_Chemistry	3.899E7	7,875
	Avg_PV_EarthScience	5.109E7	7,875
	Avg_PV_Biology	4.606E7	7,875
	Avg_PV_Physics	4.312E7	7,875

[a]Computed using alpha = 0.05

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