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Fragile Strength: Math Self-Efficacy of High Achieving Girls

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This thesis, written under the direction of the candidate's thesis advisor and approved by the department chair, has been presented to and accepted by the Master of Science in Education Program in partial fulfillment of the requirements for the degree of Master of Science in Education. An electronic copy of of the original signature page is kept on file with the Archbishop Alemany Library.

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Abstract

Math gender gap research shows girls’ math self-efficacy to be correlated with their interest in pursuing higher levels of math education and STEM career opportunities. Most math gender gap studies have used only quantitative approaches, thereby missing the opportunity to gain deeper perspectives directly from girls who are steadfastly facing the math gender gap. This study centered around two small focus groups of girls attending a unique secondary school where every afternoon is fully dedicated to deep engagement with higher-level mathematics. Additionally, parents of girls at the school were surveyed to provide further insight into possible sources of their daughter’s math self-efficacy. The research aimed to identify common experiences that had contributed to the girls’ math self-efficacy to inform strategies that parents, teachers, administrators, and educational policymakers can implement to increase math self-efficacy for girls. The findings unexpectedly revealed that these girls had experienced obstacles to their math self-efficacy during elementary school, which created a disinterest or dislike of math within school. However, the findings also showed the foundational significance of family math experiences and role models towards building the girls’ math self-efficacy. Importantly, only through nonstandard opportunities beyond regular math in school did the girls begin to identify their math self-efficacy. Furthermore, the crucial insight gained through the study was how fragile math self-efficacy is, even among girls who have a strong math foundation, and how important it is to create the opportunities and environments to nurture girls’ math self-efficacy throughout their education.

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Chapter 1: Introduction

At a time when STEM job growth continues at a rapid pace, we need to support all girls' interest and confidence in their math abilities in order to keep these opportunities open for them. Gender-based stereotypes about math abilities have been undermining females' confidence in their abilities for over a century in the United States. Research has shown that girls' math self-efficacy is correlated with their interest in pursuing higher levels of math education and STEM career opportunities (Bandura, Barbaranelli, Caprara, & Pastorelli, 2001; Schwery, Hulac, & Schweinle, 2016). Psychologist Albert Bandura (1994) defined self-efficacy as the belief in our abilities to perform at levels to achieve success in an activity. Unfortunately, many girls lose their self-efficacy and interest in math, particularly during adolescence, leading to narrowed opportunities for their future education and careers.

In the United States, between 2009 and 2015, the number of STEM jobs grew by 10.5 percent, compared to 5.2 percent for non-STEM jobs, and projections forecast that these percentages will continue to increase (Fayer, Lacey, & Watson, 2017). The math-intensive fields of computer occupations and engineers were among the occupations with the highest job gains. Additionally, the average wage for all STEM occupations was almost double the average wage for non-STEM occupations. The gender gap in pay has not decreased much in the past fifteen years, and full-time working females earn only 80% of what their male counterparts earn according to the Census Bureau in 2017 (Graf, Brown, & Patten, 2019). Considering that our country has a shortage of STEM workers, and women are underrepresented in the math-intensive STEM fields, it is imperative to increase and maintain girls' interest in math to open more opportunities for them and to completely close the gender gap.

Statement of purpose

While there has been a significant amount of quantitative research analyzing various aspects of the math gender gap, there has been minimal qualitative research examining the early math experiences of high achieving middle and high school girls in order to understand the development of their positive self-efficacies in mathematics. The present study aimed to explore the experiences that have contributed to the high math self-efficacy of girls who have chosen to attend a secondary school where all students immerse themselves in a math culture. The students are challenged with high-level math courses and are surrounded by others who also have a passion for math. The research examined how math-related activities influenced the girls' thoughts and feelings about math. This included inquiring about their memories regarding math during various time periods in different learning environments. The research also examined the influence of teachers, families, social groups, math role models, and math gender stereotypes.

Overview of the Research Design

An emphasis on qualitative data within a convergent mixed methods approach was chosen in order to delve deeply into the experiences of girls within a unique math community. Two rounds with two small focus groups, one consisting of middle schoolers and the other of high schoolers provided the time for the participants to share the stories of their experiences and opinions. Parent surveys offered additional data about girls within the school community. The research site was an independent private secondary school with an intentionally designed math culture. Students commute from all over the San Francisco Bay Area to attend the school, which is academically selective. More importantly for this research in self-efficacy is the fact that the school selects students who identify as loving math and who have the desire to enthusiastically engage in math with teachers and other students who share their passion. The students spend their entire afternoons exploring, problem solving, communicating, and collaborating in a wide range of high-level math classes. The researcher acknowledges a possible bias as a parent of a current male student at the research site, which could influence analysis due to familiarity with some of the experiences of the participants. However, the researcher’s child was not a participant in the study. The researcher also acknowledges a possible bias regarding the influence of learning environments on girls' math self-efficacy through experiences with her daughter.

Significance of the Study: Research Findings

The research revealed the unexpected finding of obstacles the girls experienced during elementary school created a disinterest or dislike of regular math within school. However, also revealed was the importance of the family math experiences and role models that had been very influential in building strong foundations for the girls’ math self-efficacy. Additionally, an important finding was that only through nonstandard opportunities beyond regular math in school did the girls begin to identify their math self-efficacy. The crucial finding was that even girls who seem to be good at math and have strong family math support can lose their math self-efficacy fairly easily. Furthermore, ongoing reinforcement of their math identity through supportive and engaging environments including their current school was important in solidifying their math self-efficacy.

Significance of the Study: Implications

The end goal of the study was to identify sources of these girls' math self-efficacy to determine if there are conditions that can be implemented and supported by teachers, parents, and educational policymakers to increase and maintain the math self-efficacy of more girls. As these girls currently have high math self-efficacy and attend a school with a strong math culture, one would assume they had attained their math self-efficacy early on and have loved math all throughout their education. However, the findings show how math self-efficacy is fragile even among girls with strong foundations in math. This led to the realization that there are likely many girls who have lost their math self-efficacy due to experiences involving typical math instruction in school, similar to those identified as negative by the girls in the study including environments with boring, competitive, and closed-ended math instruction. These findings suggest that many more girls could also be experiencing the joy of math like the girls in this study if given appropriate instruction in a supportive environment. Besides the fact that this would enrich their lives from an educational and psychological perspective, this could also lead more females into STEM careers, thereby closing the gender gap.

Chapter 2: Literature Review

With math gender gap research showing the correlation between girls' math self-efficacy and their interest in pursuing higher levels of math education and STEM careers (Bandura, Barbaranelli, Caprara, & Pastorelli, 2001; Schwery, Hulac, & Schweinle, 2016), it is important to focus attention on understanding the sources of girls' self-efficacy. Self-efficacy is one's belief in their ability to perform at levels to achieve success in an activity (Bandura, 1994). Rather than avoiding difficult tasks, people with high self-efficacy levels approach these tasks as challenges to be mastered, which leads to intrinsic interest, motivation, and commitment to the related activity. Various social and environmental factors contribute to the differences in math self-efficacy levels between the genders. This study investigates whether there are commonalities among the sources of math self-efficacy within a group of secondary school girls, who have chosen to attend a school with a focus on the deep engagement and enjoyment of mathematics.

The following literature review begins with the historical context of the math gender gap including the negative influence of math gender stereotypes, as well as recent statistics regarding the gender gap in STEM fields. Next, Bandura's (1986) self-efficacy beliefs within his social cognitive theory are provided, which have been influential in much of the gender and math research for several decades. Then, an overview of Dweck's (2006) growth mindset theory provides an additional lens to view strategies for increasing self-efficacy. Lastly, findings from the research literature regarding various strategies and interventions designed to help close the gender gap are presented, which are organized using Bandura's (1986) four categories of primary sources of self-efficacy beliefs: mastery experiences, vicarious experiences, social persuasions, and physiological and emotional states.

Gender Gap and Gender Stereotypes

Gender-based stereotypes and biases regarding math ability contribute to the negative impacts on girls' and women's STEM performance and career choices (Wang & Degol, 2017). There has been extensive research for the past several decades to determine the causes of the math gender gap. Boaler & Sengupta-Irving (2006) argued that some research has inadvertently done damage by positioning girls as maladaptive and the responsibility for change is placed on girls rather than analyzing the broader social system. These studies have perpetuated ideas of the girls' inadequacy by presenting anxiety, lack of confidence, and lower achievement as properties of the girls rather than their responses to their particular working environment. It is important to analyze these responses while also analyzing the teaching environments and societal influences.

It is promising that the gender gap in STEM fields has narrowed over the past several decades in some ways. For example, in 2012, women's representation at the graduate level in the U.S. increased to 54% of biological, 54% of biomedical, and 48% of medical degrees (U.S. Department of Education, NCES, 2014; Wang & Degol, 2017). However, in that same year, the gender gap continued to persist in math-intensive STEM fields with women representing only 19% of computer and information sciences, 23% of engineering, 29% of mathematics and statistics, and 34% of physical and technological sciences doctoral degrees. According to the U.S. Congress Joint Economic Committee (2012), it is essential to increase the participation of women in the STEM workforce to help alleviate the shortage of STEM workers. The committee's report states that the percentage of bachelor's degrees awarded to women in 2009, as compared to 1993, declined by 4% in mathematics and statistics and by 10% in computer science. The report also revealed that only 14% of engineers and 27% of workers in math and computer science positions are women.

Historical background of the math gender stereotype. Many American adults and children still hold the belief that males are more naturally equipped for math than females (Schwery, Hulac, & Schweinle, 2016). An influential source of this stereotype goes back to 1894 in a book by social philosopher, Havelock Ellis, who popularized the greater male variability hypothesis among psychologists. His work encouraged the idea that genius was a peculiarly male trait based on his observation of the prominence of men in positions of prestige and power (Shields, 1975; Weatherall, 2002), and also that males had a natural disposition for math (Schwery, Hulac, & Schweinle, 2016). While Ellis' hypothesis was deftly challenged as a "pseudo-scientific superstition" by statistician Karl Pearson, many proponents of his theory liberally borrowed from Ellis' work (Shields, 1975). His work received social acceptance since the general assumption of scientists at the time was that women were both physically and intellectually inferior to men. Researchers, such as Shields (1975), have noted that in the new scientific age of the 1800s, the religious age's previous explanations for women's subordinate societal position were replaced with a search for biological accounts of gender differences to justify women's secondary status in society (Weatherall, 2002).

The math gender stereotype was reinforced by the Benbow and Stanley (1980) report, which reported a major gender difference in math reasoning ability within a large sample of gifted middle school students (Boaler & Sengupta-Irving, 2006). Articles appeared in popular magazines shortly after the release of their report exaggerating the research with titles such as "The Gender Factor in Math: A New Study Says Males May Be Naturally Abler then Females" in which the authors concluded “males inherently have more mathematical ability than females” (Time, 1980, p. 57). The 1980 Benbow and Stanley report has been widely discredited, but its negative impact on the math gender stereotype has been widespread (Boaler & Sengupta-Irving, 2006). An example of this impact was revealed through empirical research by Eccles & Jacobs (1985). The researchers found that prior to exposure to the Benbow and Stanley report, it was popular to express a belief in equal math abilities for both genders, but after exposure, it became acceptable to express the belief that males are better than females in math. The findings also revealed that mothers are prone to projecting their own lack of math self-efficacy onto their daughters as they significantly lowered their expectations of their daughters’ math abilities and potential after exposure to the report. Fathers of sons who were exposed to the report increased their opinions that males do better than females in math. Interestingly enough, fathers of daughters who were exposed to the report became sensitized to the importance of math and defended their own daughter’s math abilities.

Gender stereotypes persist. The math gender stereotype continues to persist, and studies have consistently shown that these stereotypes have continued to result in parents expressing the same gendered beliefs that boys are naturally better in math than girls when evaluating their own children’s abilities in math. In a study of 914 adolescents and their parents that was part of a larger longitudinal study, Frome & Eccles (1998) found that children’s perceptions of their math abilities were as highly correlated with their parents’ (especially mothers’) perceptions of their abilities, even more than their own grades. In addition to academic and demographic data, the students and parents completed questionnaires three times during the students' sixth- and seventh-grade years. During this time, the girls achieved significantly higher average math grades than the boys. However, boys reported significantly higher self-concepts of math ability. Additionally, it was found that mothers of girls underestimated their daughter's math abilities and attributed the girls' higher math grades to effort rather than ability, whereas mothers of boys overestimated their math abilities.

Recent research surveyed 44 teachers and 121 eleventh grade students at a high school to examine gender role biases (Hand, Rice, & Greenlee, 2017). Both the teachers and the students reported the belief that boys tend to perform better in STEM subjects and girls perform better in humanities subjects. Along gender stereotype lines, both groups attributed more masculine traits to the typical scientist and feminine traits to the typical humanities professional. These same students were also surveyed about their self-efficacy in math and science with the results supporting previous findings of girls having lower self-efficacy in these subjects. In fact, research consistently shows that girls report lower levels of self-efficacy in math than boys when they have similar and even higher academic skills (Bandura, 1986; Frome & Eccles, 1998; Schwery, Hulac, & Schweinle, 2016). A frequently referenced study in math gender literature is Cvencek, Meltzoff, & Greenwald's (2011) research on math gender stereotypes in elementary school children. They studied 247 American children, aged 6-10, using Implicit Association Tests and explicit self-reported measures in which they assessed the association of three areas: gender identity (e.g. me with male), math gender stereotype (e.g. male with math), and math self-concept (e.g. me with math). The study indicated that math gender stereotypes emerged during grades 1–2 following the emergence of children's gender identity. Girls at this age were found to already have a decreased math self-concept prior to any difference in math achievement.

Gender differences and similarities. In regards to academic skills, there have been repeated research findings of similar achievement by females and males on indicators of math performance. Hyde (2016) reviewed seven meta-analyses with ages ranging from children to adults regarding gender differences in three areas: mathematics performance, spatial skills and 3D mental rotation, and verbal skills. Among the younger ages, a meta-analysis of seven million American children in grades 2-11 synthesized data from state assessments of math performance and found no gender difference (Hyde, Lindberg, Linn, Ellis, & Williams, 2008). While Hyde, Fennema, & Lamon's meta-analysis from 1990 found some evidence of gender differences in mathematics performance, the difference had disappeared by the time that more recent meta-analyses were completed (Lindberg, Hyde, Petersen, Linn, 2010; Else-Quest, Hyde, & Linn, 2010). Hyde noted that a factor that may have affected the change was that girls now take as many math courses in high school as boys, which was not as likely to be the case prior to 1990.

Hyde (2016) also referred to the gender stratification hypothesis, which states that gender difference outcomes are closely related to the variations in opportunity structures within a girl or women's culture. Else-Quest, Hyde, & Linn's (2010) meta-analysis examined data from two major international data sets, Trends in International Mathematics and Science Study (TIMSS) and the Program for International Student Assessment (PISA) testing 14-year to 16-year-olds in 69 countries. Overall, there was very close to zero difference in math performance with some nations favoring males and others favoring females. There were larger differences favoring males in nations where gender inequality is higher, which was measured through variables such as women's representation in research occupations and higher government positions.

While the findings from the recent meta-analyses show that the gender difference in spatial skills has decreased since the 1990 meta-analyses, a moderate gender difference is still present favoring boys. In particular, 3D mental rotation skills showed the largest difference. Hyde discussed the lack of spatial curriculum in American schools and indicated that these differences may result from extracurricular learning experiences, such as sports and video game playing. Hyde suggested that this gender gap could be eliminated if spatial skills were specifically taught in school with a well-designed curriculum. A research study focused on boys' higher exposure to video games showed success in nearly eliminating previous gender differences in spatial attention, which supports higher-level spatial cognition, with just ten hours of training using an action video game (Feng, Spence, & Pratt, 2007). The results also showed a decrease in gender differences in 3D mental rotation skills after the relatively short amount of training. It was notable that the control subjects who played a non-action video game did not show an improvement, therefore emphasizing the need for research-informed curriculum development. Additionally, an important finding was that follow-up testing suggested that the improvements were persistent.

The final area analyzed in Hyde's (2016) review were verbal skills, which had previously shown larger gender differences favoring girls. However, the meta-analyses have shown that the differences are now close to zero or small depending on the type of verbal skill. For example, in Hyde's earlier meta-analysis of children and adults, there were no differences for reading comprehension, vocabulary, or essay writing, but there was a difference of effect size -0.33 favoring females for verbal fluency. In another meta-analysis included in Hyde's review (Hedges & Nowell, 1995), most effect sizes of gender differences in verbal skills were close to zero. These small differences lead to a refocusing on similarities instead. An important hypothesis for gender-related research is Hyde's Gender Similarities Hypothesis proposed in 2005, which states that females and males are similar on most, but not all, psychological variables. Evidence for this hypothesis was a result of a synthesis of 46 meta-analyses of research regarding psychological gender differences. Various tests of cognitive abilities and other psychological qualities, such as personality, self-esteem, and communication within the 46 meta-analyses were analyzed, and a total of 124 effect sizes were extracted from the data. The results showed that 78% of the effect sizes were small or close to zero, with more of the exceptions to this pattern occurring in areas such as aggression and aspects of motor performance. Other researchers tested the Gender Similarities Hypothesis in 2015, synthesizing 106 meta-analyses with similar results where 85% of the effect sizes were small or close to zero (Zell, Krizan, & Teeter, 2015). The overall idea of the hypothesis is that contrary to gender stereotypes, females and males are more similar than different.

Social Cognitive Theories

Bandura's self-efficacy beliefs. The math self-efficacy beliefs of girls have been an important factor to examine throughout much of the math gender gap research. Within Bandura's social cognitive theory, he described perceived self-efficacy as "people's beliefs about their capabilities to produce designated levels of performance that exercise influence over events that affect their lives" (Bandura, 1994, p. 71). These beliefs determine how we feel, think, and motivate ourselves, which then affects our behavior. He identified that people with high levels of self-efficacy approach difficult tasks as challenges in which to attain proficiency rather than threats to avoid. Bandura also observed that this approach leads to intrinsic interest, engagement, and sustained commitment to the associated activities. Bandura (1986) theorized that self-efficacy evolves quickly during elementary school years and it is developed and revised based on the person's interpretation of information from four primary sources. These sources are: mastery experiences — interpretations of our own performances, vicarious experiences — observations of others' actions, social persuasions — evaluative feedback from others, and physiological and emotional states — feelings often interpreted as indicators of our capabilities. Bandura (1986) suggested that mastery experience was generally the most influential factor on a person's self-efficacy. However, Usher & Pajares (2006) also found that social persuasions are predictive of the self-efficacy beliefs of middle school girls, but not of middle school boys. They suggested that girls may be more aware of feedback from other people when they are forming their beliefs about their capabilities.

Dweck's growth mindset theory. As with Bandura's model, Dweck's (2006) growth mindset theory is concerned with how people perceive their abilities, which play a key role in their motivation and achievement. Dweck focused on the neuroplasticity of the brain and her research findings revealed how a growth mindset with an understanding that the brain is malleable, led to increased motivation and achievement in people. Growth mindset encourages learning from challenges, taking risks, and learning from mistakes. Dweck suggested that teachers should increase their students' understanding that math ability is not a fixed trait. According to this theory, math ability can grow by persisting through challenging work, which will increase students' math self-efficacy. More recently, Dweck (2017) stressed that growth mindset has often been misinterpreted. Some have focused only on certain aspects of the growth mindset theory. It is frequently simplified as having an open-minded approach with praising effort or telling children they can do anything without the support needed. Instead, Dweck suggested focusing on the process of learning by teaching for understanding and working with students through challenges — allowing time for revisions and giving children the opportunity to show their increased understanding.

Strategies and Interventions

In reviewing some of the research on strategies to close the gender gap, including the lower levels of girls' math self-efficacy, Bandura's (1986) primary sources of self-efficacy lend a helpful framework. While strategies in the research literature may be useful to more than one source of self-efficacy, the following are given as examples under each of the four sources.

Mastery experience. Self-efficacy in a particular area is formed as people interpret their own previous success or failure on similar tasks. As Bandura indicated within his theory of self-efficacy, young children expand their knowledge of their capabilities by developing and assessing these capabilities within broadening areas (Bandura, 1994). He points out the importance of parental responsiveness to an infant's behavior in order to create successful experiences. These interactions increase cognitive competence and expanded capabilities, which lead to greater parental responsiveness, creating a positive cycle. This could also apply to other family members or close caretakers who are highly invested in the development of a child. These efficacy forming experiences build upon each other throughout a child's development. Peers and teachers also have a significant influence on a child's self-efficacy as their social world grows.

Researchers have found a connection between very early STEM engagement and increased development in STEM subjects over time (Master, Cheryan, & Meltzoff, 2017). Considering that the self-efficacy of girls in STEM can be formed early in their educational experience, it is problematic that girls have fewer experiences than boys with programming and robotics, and that they report less interest in these activities. In a recent study, Master, Cheryan, Moscatelli, & Meltzoff (2017) found that first graders already held the stereotype belief that boys are better than girls at programming and robotics. However, the researchers designed an intervention to develop girls' motivation in STEM, which resulted in the findings that the first-grade girls' interest in technology was easily changed through interventions.

In a longitudinal study on school-age girls, a promising strategy was found to substantially increase girls' math achievement through pretend play (Wallace & Russ, 2015). A positive correlation was found between the girls' early pretend play activities and their divergent thinking skills. Imagination in play and the amount of positive affect in the story was found to predict their math achievement. Children who use symbolic substitutions by pretending to play with an object not really in the physical world may have a shift from concrete to symbolic thinking, which is the kind of thinking used to understand written symbols in math and reading. The study also found a significant connection between girls with better divergent thinking skills (generating a greater variety of ideas) and their higher scores on math concepts/applications and math computations tests. According to the authors, the combination of pretend play and divergent thinking was responsible for 31% of the variance in math achievement over time.

Physiological and emotional states. According to Hill et al. (2016), girls have been found to display higher math anxiety than boys at both the elementary and middle school levels. In their study, there was a correlation between higher math anxiety and lower math performance for the middle school girls, but not for the elementary school girls. This finding raises the question of when the connection between higher math anxiety and lower math performance surfaces in the educational timeline. Dweck's (2006) growth mindset theory emphasizes the importance of communicating to children the value of learning through mistakes, challenges, and efforts. Recent research using electroencephalography (EEG) has shown the benefits of learning through mistakes among a sample of 123 school-aged children (Schroder et al., 2017). The study also used a questionnaire to assess the level of children's mindsets ranging from fixed- to growth-oriented mindsets. A full range of mindset endorsements was found within the sample. Using the neurocognitive methods, the researchers found that greater levels of growth mindset were correlated with greater attention to mistakes and better accuracy after mistakes. The results demonstrate the benefits of learning with a growth mindset involving problem-solving methods, which teach a positive response to mistakes rather than an anxiety-producing response.

Ganley & Vasilyeva (2014) used both cognitive and affective factors to test the relationship between college students' math anxiety and their performance on difficult math tests. Previous research has shown that math anxiety negatively affects visuospatial working memory, which has been shown to lead to poorer performance on difficult math tests. The study used math problems proven to be challenging from prior large-scale assessments in order to have a higher chance of creating math anxiety for the participants. Significant gender differences were found in the levels of worry (math anxiety) and visuospatial working memory, which they suggested possibly led to differences in math performance. Individuals often interpret anxiety as indicators of their capabilities, leading to further physiological effects including a decrease in self-efficacy.

What if these signals could be interpreted as enthusiasm instead of anxiety? Anderson, Boaler, & Dieckmann (2018) used Dweck's growth mindset approach to design part of their Mathematical Mindsets professional development program for teachers. Research has found that teachers overwhelmingly display a fixed mindset about the subject of math. This includes having a fixed mindset about both their own abilities and their students' abilities. Anderson, Boaler, & Dieckmann pointed out that having a fixed mindset with the belief that only some people can be successful in math creates math anxiety, consequently reducing a student's performance. Among 30 subjects, math professors were found to have the most fixed mindsets in regards to believing that students needed a "gift" to be successful in their field (Leslie, Cimpian, Meyer, & Freeland, 2015). Boaler (2016) proposed that the cultural construct that some people are "math people" while others are not is at the core of the widespread math anxiety in the United States and some other countries. Anderson, Boaler, & Dieckmann's (2018) studied a group of 40 teachers from eight school districts for one year examining the impact of their Mathematical Mindset Approach professional development program on teacher and student learning. The program centered around a growth mindset approach, but also focused on changing teaching strategies to support this way of thinking. Oftentimes, teachers will have good intentions by encouraging students to have a growth mindset and to challenge themselves, yet they do not give students the support and tools to do so. An example of a change in teaching strategies is to use math questions that are not closed with only one correct answer. Creating more open questions with many entry points and various ways of working lead to more positive math experiences and increase math self-efficacy in students. The program also taught the teachers about neuroscience (e.g. neuroplasticity), mindset, mathematics education research and how to translate that knowledge into new ways of teaching math. It helped change teacher beliefs about their own mathematical learning potential, which helped change their views about the potential inherent in all their students.

Vicarious experiences. Observation of the behaviors and consequences of role models in similar situations is also important in forming high levels of self-efficacy in a subject. Research has shown that exposure to same-gender role models who are successful in mathematics minimizes the negative gender stereotype effect, but it is important that the student believes that the success of the role model is attainable (Bagès, Verniers, & Martinot, 2016). Research has shown a lack of female role models presented within math classes (Hand, Rice, & Greenlee, 2017). Gender-balanced teaching initiatives can be introduced, such as exposure to a balanced number of females and male role models. Other research has shown that exposure to a hardworking role model whose success is believed to be attainable rather than one who purportedly has natural math abilities (regardless of their gender), increased both girls' and boys' math self-efficacy and exam performance (Bagès, Verniers, & Martinot, 2016).

Social persuasions. Social and environmental factors including encouraging or discouraging messages from others can be an important source of self-efficacy, especially during one's formative years. Research indicates that girls' disengagement from STEM during the middle school years may be partially due to being less likely to receive support from family, teachers, or peers to pursue STEM disciplines (Aschbacher, Li, & Roth, 2010). Their study found that the feedback from significant others helped form the students' perceptions of their abilities and their choices for their career options. Also, their relationships and interactions within their home, school, and wider communities were important factors in forming their STEM identities, activities, and aspirations. Through social interactions within these communities, students learn the common language, conventions, and histories needed to begin to develop their identities and their perceptions of what they are capable of achieving.

Parental influences. Casey, Dearing, Dulaney, Heyman, & Springer (2014) found that the supportive interaction of mothers during a spatial skills activity with their first-grade daughters mediated a negative link between the mothers' lower spatial skills and educational levels and their daughters' spatial skills. Providing exposure to spatial materials and toys was not a sufficient intervention. Instead, the findings suggested the importance of focused experiences with parental guidance for the development of spatial skills for young girls. Additionally, it was found that the improved spatial skills of the girls created a pathway to improving their arithmetic skills. The findings led the authors to suggest that more guidance should be given to students to systematically develop spatial skills in addition to the training and support given in developing arithmetic skills.

Gladstone, Häfner, Turci, Kneißler, & Muenks' (2018) study found that although both mothers and fathers perceived their daughters and sons as having equal math abilities, nevertheless both parents believed that math was more useful for their boys than their girls.

The authors referred to research that had shown how this perception can be easily changed through simple interventions with the parents. Also, in this study, both of the parents' beliefs contributed to their child's beliefs and grades, but the association was stronger between same-gender parent and child. Interestingly enough, they found a stronger association between math utility value and girls' achievement when the parent was the opposite gender.

Peer influences. Peer interactions and opinions can have a particularly strong impact on early adolescents. Robnett and Leaper (2012) investigated whether being part of a close-knit friendship group that values STEM would predict a high school student's STEM career interest. They found that girls who belong to a friendship group that values STEM pursuits have been shown to overcome negative gender stereotypes regarding STEM achievement and that these girls have a strengthened interest in a STEM career path. The strength of the impact of friendship group norms on STEM career interest was correlated with the strength of the students' identification with their friendship group. The study reported that the girls who belonged to friendship groups that were not perceived to support STEM and were made up of same-gendered members had a particularly low interest in STEM careers.

Supportive and collaborative learning environments. Social cognitive theory considers the learning environment to have a significant effect on an individual's self-efficacy (Joet, Usher, & Bressoux, 2011) and, as mentioned earlier, social persuasions can be an especially important source of self-efficacy for girls (Usher & Pajares, 2006). Master, Cheryan, & Meltzoff (2017) even found that preschoolers persisted longer on math and spatial tasks when they felt they belonged to an assigned group. The preschoolers were randomly assigned to groups that were not based on academics but were instead associated with a color. They were given a particular shirt color to wear at the same color table with various items of the same color including a poster with photos of all group members. The preschoolers were assessed about their identification with their group while working on math or spatial tasks in multiple conditions including group and individual conditions. In addition to persisting longer on the tasks, the preschoolers working in a group where they had a sense of belonging, correctly completed more, felt they did better, and were more interested in the tasks. The authors also referred to other research that has shown how people are more motivated to work toward a group's goals if they strongly identify with the group. However, when a group is identified with a fixed ability, children are less motivated and achieve less within the group. The researchers also caution teachers to be careful that they do not create out-groups within their classrooms.

Research about growth mindset has shown how the concept that we learn and progress through our efforts helps girls see math abilities as a developed skill. Research has shown how environmental influences can especially effect girls' math attitudes, therefore a classroom environment with a growth mindset can encourage girls as everyone is expected to learn through challenges and mistakes (Dweck, 2006; Tichenor, Welsh, Corcoran, Piechura, & Heins, 2016). In contrast, a fixed mindset is detrimental in that girls tend to see boys' math successes as the result of natural ability, and they tend to give up when the math gets challenging as they think they do not have the same abilities. Instead, Tichenor, Welsh, Corcoran, Piechura, & Heins (2016) suggest communicating to girls that math ability is developed by everyone through learning, which includes a natural process of working through challenging setbacks and confusion. In their study, 95% of the elementary school girls in single-gender classrooms versus 70% of the girls in mixed-gender classrooms drew female mathematicians when asked to draw what they think a mathematician looks like. Most of the drawings of women mathematicians were of teachers. They suggested that the girls in the mixed-gender classrooms begin to form a fixed mindset and believe the gender stereotypes that boys have natural abilities in math, while the girls in single-gender classrooms saw the relevance and usefulness of math.

Research has shown that girls have more positive attitudes about math when they can create their own knowledge as they connect with the knowledge of other students (Cantley, Prendergast, & Schlindwein, 2017). Their study found an increase in girls' enjoyment of math when an approach with collaborative cognitive-activation strategies was used when teaching math. These strategies taught the students to formulate problems for each other in which multiple methods towards a solution were encouraged. The students were also taught how to reflect, summarize, question, and conjecture in order to feel more empowered while solving the problems within a supportive group where risk-taking was encouraged.

Recently, Ogle, Hyllegard, & Rambo-Hernandez (2017), designed a collaborative and hands-on STEM enrichment summer program for underserved middle school girls to explore whether their participation would build their self-efficacy and knowledge in STEM subjects for continued interest and motivation. The program used team-based learning where they were encouraged to take intellectual risks in a supportive environment, and STEM community building was established. After just two weeks of the program, which was built around fashion manufacturing projects, their findings showed positive effects on the girls' math and science self-efficacy as well as their knowledge in math.

Conclusion

There has been a considerable amount of research in the field of gender and mathematics since researchers first identified a gender gap in mathematics in the 1970s (Fennema, 1974). The positive impact on the achievement of girls and women in mathematics due to interventions based on gender gap research creates optimism that additional well-designed strategies can continue this positive trend. Despite the suggestion that there may no longer be a math gender gap due to improvements in the math achievement gap, most of the literature demonstrates how societal math gender stereotypes continue to undermine girls' self-efficacy in math and their opportunities in higher level math and career opportunities. As the research on girls' self-efficacy within the gender and mathematics literature continues to be refined, new techniques can be utilized in educational and home environments to reach more girls to increase their math self-efficacy.

Although there is substantial quantitative research studying the persistent gender gap in mathematics, there is very little qualitative research examining the foundational math experiences of middle and high school girls in order to understand the development of their positive self-efficacies in mathematics. Therefore, the purpose of this study is to explore the perspectives of a group of mathematically high achieving girls about the early math experiences that shaped their positive math self-efficacy. By listening directly to these girls, the research hopes to add crucial voices to the body of gender and math research.

Chapter 3: Methods

Research Questions

The aim of this research was to help identify sources of girls' math self-efficacy among a group of high achieving girls in order to determine if there are strategies that parents, teachers, administrators, and educational policymakers can implement to increase math self-efficacy for girls. The central research question of the study asked: What common experiences have contributed to the math self-efficacy of girls who have chosen to attend a secondary school with a focus on the deep engagement and enjoyment of higher-level mathematics? The sub-questions associated with the central research question follow:

- Mastery experiences and identity: Do the girls identify as someone who likes math, and when did they first show an interest in math-related activities?
- Vicarious experiences through role models: Did the girls have any positive role models who influenced their interest in math?
- Physiological and emotional states: How did particular math-related activities influence the girls' thoughts and feelings about math?
- Social persuasion and feedback: Were there teaching strategies or environments that increased the girls' engagement with math?
- Perception of gender stereotypes: What are the views of the parent and student participants about the math gender stereotype?

Description and Rationale for Research Approach

I chose a convergent mixed methods approach to concurrently gather and analyze perspectives from both qualitative and quantitative data. The research methods of focus group discussions provided qualitative data while survey responses provided quantitative data. An emphasis was placed on the qualitative data, which explored the factors of a central phenomenon through an inductive process. This process encourages participants to share their experiences and perspectives to help construct meaning. My analysis made use of a phenomenological approach as I strove to identify and build a thematic understanding of the fundamental nature of the girls' experiences with math through the girls' reflections of their lived experiences (Creswell, 2018).

My research approach reflects a constructivist worldview as it seeks to understand the context of the participants' views of their situation. Following a constructivist perspective, I used open-ended questions to help the participants construct subjective meanings of their experiences, which have formed through various social, historical, and cultural influences (Bazeley, 2013; Creswell, 2018). My research stems from an interest in the impact of math gender stereotypes upon the math self-efficacy of girls. Gender stereotype is a socially constructed phenomenon; therefore, the use of the research method of small focus groups allowed for the exploration of this phenomenon with individuals who seem to have defied the influence of this stereotype. The small focus groups encouraged participants to build upon each other's responses as memories of their own experiences were triggered through the discussions. The young participants are still living in the midst of the math gender stereotype phenomenon, so the intention of the focus group method was to step out of the "stream of flowing action” in order to reflect, reconstruct, and make meaning of their lived experiences (Seidman, 2013, p. 17).

The majority of research studies regarding the gender gap in mathematics have used only quantitative data. The addition of qualitative data through a mixed methods approach brings another level of insight through student voice, thereby obtaining direct perspectives from those who are steadfastly facing the math gender gap phenomenon. While the focus groups were guided with the same questions, the qualitative focus group data was varied due to the discussions going in different directions within the two focus groups. The open-ended question design allowed for the participants to help guide the discussion and to emphasize certain factors. The addition of surveys provided specific quantitative information about girls within the school community as observed by their parents. The use of open-ended questions in the parent survey provided further data on topics in the focus groups as well as other topics. The data from the surveys was merged with the qualitative data during analysis to enable an integrated interpretation of the data.

Research Design

Research sites. The research site is an independent private secondary school (grades 6-12) in an urban area of the San Francisco Bay Area with nearly 100 students including 35 girls. The school has been in operation for just a few years and has striven for a gender balance, and their current enrollment for the upcoming year in each middle school grade is now 50% girls and 50% boys. The school offers an unusual approach with the afternoons dedicated to math, which allow the students to complete two and a half courses of math instruction per year. Each student is individually assessed and placed for each of their courses to ensure an appropriate level of proficiency and interest. The wide range of math courses provides in-depth learning that goes beyond typical secondary school courses, such as algebraic combinatorics, advanced Euclidean geometry, discrete probability, as well as individually customized courses. Each year, the school runs two student-led math festivals as well as other math events for the public. Students commute from all over the San Francisco Bay Area to attend the school for its exceptional learning environment. Exact demographic data is not available since the site is not a public school, however, the student body reflects the multicultural diversity of the San Francisco Bay Area and the school provides financial aid to many students.

The Head of School granted permission to conduct the research study among the school's female students in grades 6-12 and their parents. I coordinated with the school regarding the participant solicitation and consent process as well as the schedule for the focus groups. The school also reviewed the student focus group questions and parent survey questions.

Participants.

Students. The focus group participants were volunteers from the female student body in grades 6-12. Two focus groups were formed – the first group consisted of three students from ninth, tenth, and twelve grades, who are referred to as "high schoolers" and the second group consisted of two students from seventh grade, who are referred to as "middle schoolers." Student admission to the school is academically selective and is also dependent on students having a positive disposition to engage enthusiastically with a full range of subjects that emphasize collaborative learning and communication skills. Each of the students has gone through a thorough application process to ensure a good match and dedication to joining an intentionally designed learning environment with a strong math culture. The students are asked to reflect on their own growth and goals five specific times throughout the year in coordination with each of their teacher's evaluations including in-depth narratives, which offers them an active role in their academic path. The students structure their own proposals and plans for long-term projects, and they have many opportunities to challenge themselves with meaningful and open-ended problems.

Parents. The survey participants are parents of girls in grades 6-12 at the school. Eight mothers and one father from the 32 families of girls responded to the survey (some of their daughters participated in the focus groups). Five of those parents had high schoolers and the other four had middle schoolers at the school. When asked whether either parent in the family has a math-related occupation, the survey responses were: both parents in four families, the mother in one family, the father in one family, and neither parent in three families.

Sampling procedure. The parents of all grades 6-12 female students at the school received an email with consent forms and a letter of introduction including a description of the research study and an invitation for their and their daughter's participation in the research study. The parent and student participants did not receive compensation. The email message also included the parent survey questions (see Appendix A) as well as a link to the actual Google Forms to complete the parent survey and the list of questions to be discussed in the student focus groups (see Appendix B). The letter of introduction explained that if the parents and students chose to participate in the study, they would electronically sign the parent and student consent forms. The parents also had the option to participate in the surveys even if their daughters did not participate in the focus groups, and vice versa. The procedures of the study were approved by the Dominican University of California Institutional Review Board for the Protection of Human Participants, and all participants provided signed informed consent forms prior to participating in the study.

Instruments for Data Collection.

Focus groups. The student participants participated in a 2 or 3 person focus group that consisted of discussions with open-ended research questions (see Appendix B). They explored potential sources of their own math self-efficacy through reflection with others in the focus group about their math experiences. For example, in order to provide potential data for sources of math self-efficacy through vicarious experiences, the girls were asked to "Think of your strongest math role model and share a small story or a favorite thing about that person." They were asked to describe early memories of enjoying math and describe experiences with math in school and in extracurriculars to provide data for the research sub-questions. The focus groups were also asked to reflect upon math gender stereotypes with the question, "Describe how girls and women are portrayed in our society regarding whether they like math or are good at math — how do these portrayals make you feel?" Each focus group met for 30 minutes each time on two different days during their free-choice activity time period at a time and date chosen by the School Leadership. The student participants were divided into two focus groups in order to keep the focus groups small enough for all participants to have sufficient time for reflection and input. Focus group discussions were audio recorded on the researcher's password-protected iPhone and written notes did not include any names or identifying information. Pseudonyms were used for all focus group participants.

Survey. The parent participants answered an anonymous 20- to 30-minute online survey via Google Forms (see Appendix A), which provided data regarding their daughter's experiences with math-related activities and environmental influences. This provided additional insight into possible sources of girls' math self-efficacy from parents' perspectives. An example of a survey question to provide potential data for the research question, particularly the mastery/identity sub-question was "Did your daughter show an interest in math-related activities before age 5?" The results of the online survey were kept on the researcher's password protected computer and did not include any names or identifying information.

Data Analysis

Using a convergent mixed methods design, the qualitative and quantitative data was gathered concurrently. Qualitative data analysis methods were used to analyze the focus group discussions. All focus group discussions were audio recorded and completely transcribed by the researcher. The researcher wrote field notes directly after the group discussions to capture data about the focus group interactions. The quantitative data from the parent survey was downloaded as a spreadsheet document as well as a written document with pie charts.

The transcribed discussions and survey data were open coded by hand by identifying both expected and unexpected codes in the data. This initial coding process was begun inductively with segmenting the text data by identifying key words, phrases, and ideas. These segments were then labeled with expected codes from the literature review including identity, role models, emotions, social feedback, and gender stereotypes or with unexpected codes emerging from the focus group discussions. The quantitative data from the survey was also open coded initially. Concept mapping was utilized for further exploration of the data by sorting the codes into categories to search for associations, conflicts, or gaps in the data. Themes emerged through the analysis of the concept map and written reflections on the findings.

After concept mapping, the qualitative and quantitative codes were indexed using spreadsheets to organize the data and expedite pattern searching. Further patterns were found to connect and merge the smaller amount of quantitative data into the qualitative data, which enabled an integrated interpretation of the data (Bazeley, 2013; Creswell, 2018). The researcher wrote descriptions of the characteristics and contexts of the themes identified to clarify their relevance to the research question and sub-questions. At this point, all of the data was analyzed further through focused coding and any additional relevant codes were sorted into the themes. During the additional analysis of the data, the researcher also searched for significant statements from the participants for analysis to develop a description of the focus group participants' experiences and to examine any commonalities among them.

Validity and Reliability

The validity and reliability of the data were initiated by using a convergent mixed methods research design. This method was selected to obtain in-depth perspectives from students about the phenomenon that is being studied, while also broadening the range of the phenomenon by obtaining additional data from the perspective of parents through surveys. The qualitative data was obtained from multiple student participants through two rounds of focus groups to increase the reliability of the findings. The reliability of the quantitative data was also increased by gathering perspectives from multiple parent participants. The researcher wrote detailed analysis based on dense and rich data from the transcription of the focus groups discussions merged with the parent survey data.

While the student participants are currently part of a unique school community having nontypical experiences with math, their previous experiences in mostly typical elementary schools inform our understanding of girls as a wider group. These are girls who have common experiences for girls of their generation in numerous non-math activities as well as math activities, which contribute to the generalizability of the research findings. The exploration into their previous experiences with math in school broadened the context of the findings by revealing the fragility of math self-efficacy even among a group of high achieving girls who would appear immune to the effect of negative math experiences on their self-efficacy. Through the realization that these common experiences could be turning numerous girls away from math and therefore narrowing opportunities for their futures, the implications of this study are extended to girls as an overall group. The findings and implications may also be generalizable for other underrepresented groups in STEM who may have similar negative experiences with math in school leading to decreased math self-efficacy.

Research positionality. The researcher acknowledges a possible bias as a parent of a current male student at the research site, which could influence analysis due to familiarity with some of the experiences of the participants. As the student participants in this research study are girls, the researcher’s child was not a participant in the study. Prior to the research study, the researcher had only briefly interacted with a few of the participants in previous years at social events but had not previously met most of the participants. The researcher aimed to create a focus group environment without a researcher-versus-participant approach, but rather as a “researcher-as-participant-as-listener-as-learner-as-advocate” environment as suggested by Kinloch and San Pedro (Paris and Winn, 2013, p. 28). With this in mind, the researcher designed the focus group questions to support Kinloch and San Pedro’s approach of using a dialogic spiral. In this approach, the conversation moves back and forth among the participants and the researcher where knowledge and meaning are co-constructed through the interactions among the whole group. This approach came naturally to the focus group participants who described similar dynamics in collaborative classroom experiences with their classmates and teachers at their current school.

The researcher also acknowledges a possible bias regarding the influence of learning environments on girls' math self-efficacy through experiences with her daughter. She had loved math, but then she started to dislike it for two years while using an online curriculum during middle school offering no interactivity with a teacher. After a change in learning environments to a 1:1 teacher to student ratio, she regained her love of math and increased her math self-efficacy. With an awareness of these biases, the researcher strove to make conclusions based on what the participants said rather than any personal bias. It is also possible that student or parent participants may have certain biases just by the fact that they are in a school community with a strong math-culture, but the researcher believes that their unique perspectives are a vital source of insight into the topic of this study.

Chapter 4: Findings

Research on the gender gap within mathematics continues to show girls’ math self-efficacy to be of vital importance in sustaining the desire to pursue higher levels of math education and STEM careers. Given most of the research uses quantitative approaches by studying a specific variable, such as math anxiety, the present study chose a less common approach in examining girls' math self-efficacy by gaining an understanding directly from the personal viewpoints of a group of girls who were likely to have high levels of math self-efficacy. As previously discussed, these girls have made a considerable effort to attend a unique school with a focus on creating an engaging math culture. The school strives to find students who are passionate about math and who seek higher levels of math for themselves. Early in the focus groups, all of the student participants responded with a confident "yes" when asked, "Do you consider yourself to be a person who likes math?" Many of them relayed stories of enjoying math-related activities when they were young. Additionally, the parent surveys reported that 78 percent of their daughters showed an interest in math-related activities and 89 percent showed an interested in spatially related activities before age five.

Three central themes emerged within the data from the focus groups and parent surveys. The first theme identified obstacles to the math self-efficacy of the focus group participants and the daughters of the parent survey participants. These included the unexpected obstacles they experienced during elementary school, which created a disinterest or dislike of regular math within school. Also included are the expected, yet resisted, obstacles of math gender stereotypes and general societal stereotypes about math. The second theme to come out of the data was the significant importance that supportive family and influential family role models had on building the foundation of the girls' math self-efficacy and uniquely positioning these girls to pursue math. The third theme to emerge was the pivotal role of nonstandard opportunities beyond regular math in school. Only through participation in these nonstandard opportunities did the girls begin to identify their math self-efficacy. Furthermore, ongoing reinforcement of their math identity through supportive and engaging environments including their current school was found to be highly influential in cementing their math self-efficacy.

Obstacles to Math Self-Efficacy

Dislike of school math and non-supportive learning environments. Each of the focus group participants had obstacles that could have created a permanent disinterest or dislike of math. Even though high schooler, Sonia, had positive early experiences with her family doing problem-solving puzzles, her eventual high math self-efficacy was delayed and almost extinguished through negative experiences in elementary school and middle school with math. She explains:

> *I always saw school as more of a social space during that time than an educational space, mostly because I came there for the friends and then I went home for education, right? So, I'm not sure I can comment a lot on the math at school. I always remember the fact that math at school was always focused on how quickly you can do arithmetic and I cannot do arithmetic quickly. Like I will see a times and I will assume it's plus or vice versa. It was like my brain just gets mixed up on these things. I just can't do it very quickly. So, I hated that.*

Sonia expressed that she had not thought she was good at math at that time mainly because she thought math was equivalent to speed arithmetic. She had not connected the fact that the puzzles she was doing at home were math and that the speed math at school was just arithmetic until eighth grade. Sonia said what really bothered her was that the teachers focused on giving “lots of the same types of problems” where there was a pressure to “get as many problems right in as short amount of time as possible.” Sonia “got turned off with anything with the name math on it," so she and two other kids just did their math homework in class quickly and slept for the rest of the class.

Her sister, Tara, became discouraged in math when they changed schools when she was in first grade. She found the new school’s math curriculum easier than the math she had done in a Montessori kindergarten class where students were able to work at their own pace. Tara remembered, “being really shocked at the difference in level between public school and private school.” Her older sister, Sonia added, “You complained about it a lot more. I just became quiet.” Tara said, “Our parents got concerned because I was complaining about public school so much and the math curriculum.” She went on to explain her thoughts about math at that time, “For some reason, in elementary school, I always thought I was pretty good at math because I felt like the concepts they were teaching us weren't really hard,” and then she added, “But then I didn't really get good grades because I used to make a lot of silly mistakes and then not really think about or pay attention to anything.” The lack of challenge in school math created enough disinterest in Tara, so this otherwise very mathematically capable girl could have then appeared less capable to the teacher or to future teachers.

The middle schooler focus group also discussed how a lot of kids did not like math in their elementary school classes because teachers either went too fast or too slow, thereby creating either math anxiety or disinterest. They added that smaller classes like they have at their current school, are much better for the teacher to be able to adjust more easily to individual students. Ava disliked the way that math was taught in her old school, which made her feel pressured to always focus on getting high scores. She contrasted this with her current school, which focuses on understanding and encourages a trial-and-error type of problem solving.

Middle schoolers, Isabelle and Ava, also experienced some other challenges to the development of their math self-efficacy that were similar. In both girls' cases, they were in group situations where they felt shy about asking people to explain something. Isabelle explained how at her elementary school there was "just a big test at the end of a course" rather than "mini quizzes in between to see how you were doing." The format of the class was to work with a partner, who in her case "understood it perfectly," so the teacher would assume that she also understood the material until the test. She added that she likes how math classes at her current school have practice quizzes that do not count towards one's grade, so she can evaluate how she is doing and whether she truly understands it.

Ava's similar experience was during fourth grade in what should have been a fun math experience. She described it as "a separate little thing out of school and we could do sewing or whatever, and you paid for it," and it turned out to be a non-supportive environment that she "actually really disliked." She explained how the teachers gave them problems in which they would be expected to know how to solve them quickly rather than abstract problems to be explored. Ava said, "So, the other kids did [know how to solve them], and I just sat there like what's going on?" She went on to explain, "And they (the teachers) didn't…" she paused, and then continued, "They helped the other kids. But I was always too shy to ask because I was already kind of nervous, so it wasn't great." In both of these learning environments, the girls felt that the teachers had not created an environment where they felt comfortable to be part of the math conversation and ask questions.

The responses to the parent survey question "Throughout elementary school, in what ways, if any, did your daughter's teachers support/challenge her in math class?" were mixed between positive and negative experiences. The supportive situations usually pointed to a particular teacher who gave their daughter higher level or more engaging math opportunities. An example of one such teacher was described as, "an excellent math teacher who had majored in Math at UC Berkeley, and is passionate at teaching." However, other girls were less fortunate in that their teachers did nothing to appropriately challenge them in math class even when parents tried to advocate for them. An example of this is illustrated by a parent's response:

> *It was a bit of an uphill battle to get her elementary school to recognize her math talents. Her math was mostly supplemented at home and once she was able to test into the higher levels and demonstrated strong AMC 8 [American Mathematics Contest 8] scores as a 5th grader, the teachers began to recognize her math abilities. This was the impetus for moving to [this school] for middle & high school.*

Math was their realm and not hers. For high schooler, Mari, the obstacles to her math self-efficacy were milder due to fewer negative experiences with math during elementary school. However, despite her strengths in math, she had identified with her less STEM-oriented interests in order to differentiate herself from her brothers who strongly identified with math. This was the case until her interest in math was reinforced through a female friend. Similar to the other girls in the focus groups, her enjoyment came from math beyond the typical math in the classroom. Another girl from her current school seemed to have a similar experience of realizing her math identity later than her brothers. In the parent survey, her parent described how she had two brothers who were “very strong” and “more eager” in math, so their daughter “tended to feel that ‘math’ was their realm and not hers.” The parent said that this changed when her daughter came to her current school and realized that “she was much stronger at math than the average student, boy or girl.”

Math gender stereotypes. It was expected that the parents in the survey and the girls in the focus groups would have encountered math gender stereotypes in our society to some extent, so this study aimed to survey the parents about their beliefs and explore the level of exposure and impact on the focus group of girls. The parents were asked, “Before having children, did you think that boys were usually better at math and girls were usually better at the humanities?” to which 89 percent of the responses were “no.” It is likely that their belief system, which went against the standard message in our current society, was passed along to their daughters, therefore having a positive effect on the girls’ math self-efficacy.

In the second round of focus groups with the high schoolers, they were asked to describe how girls and women are portrayed in our society regarding whether they like math or are good at math, and how these portrayals made them feel. After a pause, Sonia broke the silence with, “That's a big question. Hmm? I have to think about those for a little bit?” Tara asked for clarification on whether this was about the media or the common opinion, to which the reply was, “Maybe both. Oftentimes we see it through the media.” Sonia then expressed that she thought there were clearer stereotypes in movies and that the general public opinion is a little ambiguous. She gave the example of how often movies use the stereotype “with a glow up where the girl takes off her glasses, let's out her hair and suddenly becomes gorgeous where she was like a nerd earlier." Mari added an example of one of the many films with this stereotype and Sonia added comments about the ridiculous repetitive details like "they have to take off their glasses." All of the girls laughed. Sonia shared that at various times when she "revealed to others" about going to a math-related event, "people are surprised that someone *is good at math and not a loser at everything else*." The group added examples of how this was more the case with girls, who are supposed to be "a social butterfly of sorts and interesting," and to be "a math nerd" at the same time is a "very non-synonymous idea." Tara added that conversely, often male figures in the media who are very smart are portrayed as cool and fashionable.

Mari added further insight into math gender stereotypes within the media. She brought up the film *Hidden Figures*, which is on many lists of movies with positive female math role models (e.g. Common Sense Media's list of *Movies That Defy Gender Stereotypes*) and is set in the 1960s:

> *In media, whenever we see a girl in math, it's always portrayed as being a very rare occurrence. Like that movie Hidden Figures, it was a big deal because it was about women in math, so, in math and science. So, it's always portrayed as being rare and how they're not as recognized. Which I guess it is kind of conflicting opinions for me. Do I think that yes, it's true that everybody should be more recognized, or do I think that like, I don't know, it feels a little bit weird to, I don't know... [Sonia adds, "Make such a big deal of it?"] Yeah.*

Tara then added a single sobering statement, “And it does reflect the truth of our society. There are less women in STEM, but yeah.” It was noteworthy to observe how a film that is meant to inspire girls could also frustrate them that there is even the need to point out the “rare occurrence” of women. The film also highlights another underrepresented group in STEM of African-Americans. The girls realized the necessity of educating our society of the achievements of underrepresented groups, but they seemed to be particularly disappointed that there was the need to do so. When asked what they thought helped them not to be affected by the stereotypes, the high schoolers all said “family” and Mari also added the importance of her “good friend who was also a girl and we both did all the math together. I had that support and I didn't feel quite as isolated like stereotypically. So that helped me be more interested in it.”

Middle schoolers Ava and Isabelle also discussed the portrayal of girls and women in our society regarding whether they like math or are good at math. Ava felt that there have been a lot of messages that women should not be in math and science and that it “is for guys,” but she also felt “it is kind of quieting down.” She expressed that the efforts to make toys or games that are targeted at girls, which make learning STEM fun are a good way to get girls interested. Isabelle agreed with Ava’s sentiments and added that she *really did not like* how people thought that only men could be mathematicians, but she also felt that way of thinking was “going away.” She talked about how their current school had improved the ratio of girls to boys in a short time, so she felt that “it’s getting a lot better in schools too,” which showed how every effort towards gender equality can make a big impression on young people. When discussing what they thought might have helped them not be affected by stereotypes, Ava answered more in regards to the societal stereotypes about math. She said that although she “didn't quite understand” why other students did not like math, she felt, “Oh, okay, you don't like it, but I still like it, so that doesn't affect me.” Ava also pointed out the fact that having at least one or two other kids in class who really liked math (one being a close female friend) really helped. However, Isabelle expressed that it was more difficult in her experience. She explained:

> *At my old school there was one kid who really liked math, there was a boy. There weren't any other girls who liked math along with me. So, I wasn't entirely sure if I should have said, ‘Oh yeah, I really like math’ or fit in with my friends and say, ‘No, I hate math.’ But here, everybody likes math, so it's a lot easier to be like, ‘Oh yeah, I agree with you. I like this, I like that.’*

Ava explained that her friend group in elementary school was primarily girls, but most of them had a neutral to negative view of math besides one female friend and herself who “both really like math.” She went on to describe another group that she was a part of that seemed to have a more positive effect on her math self-efficacy as “They didn't go to recess together and they didn't eat together, but they all liked math, so in class, they would all be in a group together, and that was all boys except for me and (that same female friend).” Having at least one female friend to work with on math seemed to be an important factor to consider when students are working in groups. Tara explained how she felt in a math class of fifteen people when she was the only girl:

> *I remember in that class, in particular, it felt a little weird because I remember I didn't have a definite partner that I often grouped up with. So, I think something that often*

happens, especially for young girls and boys, is that the girls group themselves up and the boys group themselves up. And that becomes a problem when you get environments where there are so many boys and so few girls. So, I guess finding other girls or somehow breaking those gender divisions is really important in those kinds of classes.

Sonia and Tara had similar experiences with their elementary school friend groups. Their friends were mostly girls at that age, and those girls' views about math were generally negative. Sonia said she remembers that the groups of kids who did really well on the math pre-exams and were placed in higher achievement classes in math were pretty consistently girl-dominant groups. However, she explained, "There was still this weird negative association within my friends concerning math. Most people saw it as either boring or uninteresting or difficult or like one of the above. It was, it was strange, tedious." So even though these girls at her old school did well in their math achievement, they still had negative feelings about math, which would continue to reinforce low math self-efficacy.

Societal stereotypes about math. Early in the first focus group with the middle schoolers, they were asked to describe the way they feel about math compared to the general public. Both Ava and Isabelle thought that most people do not like math or think it is boring. Isabelle shared a story about her choir teacher:

I go to choir and my choir teacher says we have to have an expression, and when we're like this [makes frowning face] the whole time, it's our math face. And I don't really like it. When I do math, I have fun and I enjoy it. Not just like [makes frowning face] the whole time.

Ava also explained how she sees math from a “slightly different perspective as the general public, which allows me to enjoy it more or love it.” In the focus group with the high schoolers, Tara had expressed a similar feeling. Mari agreed and added that people their age are usually only exposed to specific types of math through the standard textbooks in school, whereas “we can see all of these cool applications at [this school] like number theory, graph theory, and all this other stuff that I didn't really know about until I came here.” Sonia excitedly conveyed how she had written her entire college essay on this idea. She described it as:

> *A lot of people see math as something more akin to arithmetic than math, which is a bunch of calculation and finding the right answer for the question. I prefer to see math as finding the simplest, most condensed answer or proof. You know, nice explanations for things, which I guess is just the way I see it. Because it makes it more interesting and less boring.*

Sonia really emphasized that it was important to convey to girls that math is so much more than just the arithmetic that is typically taught in school. All of the girls in the focus groups expressed how the math in school prior to their current school was not interesting like the experiences that they had outside of regular school.

Strong Foundations in Math at Home

Mastery experiences and vicarious experiences. Long before any of these girls attended school, the foundation of their math self-efficacy was being formed. The student participants shared many stories about their families including parents, grandparents, aunts, uncles, and siblings actively engaging in math-related activities and providing strong math role models throughout their childhoods. They spoke of how passionate about math particular family members were. Although two sisters in the focus group of high schoolers had their self-realization of loving math at very different ages, they both spoke excitedly about the enjoyment that they had playing math word games with their family. Sonia, who had thought she was not good at math until eighth grade due to negative experiences with math in school, said:

> *I don't know if you [toward her sister] thought of the same one but, our family is full of mathematicians, like both of our grandfathers were mathematicians. So, a lot of people in my family enjoy math, which means that a lot of the stuff we did at home ended up being suddenly math-related without me knowing it until much later on. My mom would give us, or at least me, I don't remember, "X and Y problems", she called them, where she'd say, "X plus Y equals something and X times Y equals something". And she'd be like, "What's X? What's Y?" This was when I'm in second grade, third grade. And I always thought of them as puzzles, not math, which is very weird, but I loved them. I used to bug her for more of them, and then as I got older the numbers that she used increased in size... but that was one of them [memories].*

Her sister, Tara, expressed that her memories were similar. She also thought that the puzzles their uncle gave them, which were "less numbery" but had "numbering solutions," were particularly interesting. She added, "But you don't really realize they were math until later on." Even though these students did not realize that they were learning math concepts, these playful interactions with family built a strong sense of efficacy in problem solving, which is a foundational skill for higher level mathematics. The exploration process of problem solving teaches how to engage with a problem and how to creatively persist to reach a solution.

Ava had a strong family role model who helped her build perseverance by working with Ava on math problems while expressing an interest in the subject. Ava explained, “When my mom would help me with my math homework or when I would do some math competition once in a while, I'd come home and we'd go over all the questions and that kind of thing. She always was super interested in it [math], in high school especially. That was one of her big things as well. So, I feel like we're very similar in that we both like math.” At another point in the focus group, she spoke affectionately about her mother as a role model explaining, “She always kept encouraging me and would go, ‘Hey, let's look at this thing, it's interesting,’ or like, ‘Do the extra credit just because you can,’ and that kind of stuff. She's super hard working.” Ava’s perceived similarity to her mother increased the impact of role modeling on her math self-efficacy.

When asked about her strongest role model, Isabelle said that it was her father. She described that he was always “very interested in math” and had gone to a school similar to her current school for high school (implying that there was a focus on math). Isabelle explained that “He was part of the reason I got interested in math and he helped me with a lot of stuff that was related to math.” In looking back, she relayed that while she “wasn’t against math” when she was younger, she “wasn’t really interested in it” until in third grade when her father got her excited about a math activity in school. She expressed her father’s enthusiasm saying, “He got me interested in it partly because he was like, ‘Oh yeah, let's check this out! Oh, do you want to redo the things you did in class today?’ and stuff like that.” Earlier during the focus group, Isabelle had joyfully explained the math activity when recounting an early memory of enjoying a math-related activity. She pointed out that "you were anonymous, so nobody knew what your name was, and then you'd take multiplication tests and you'd move up on this scale. I remember it being really fun." Her father's model of enthusiasm and encouragement to work on problems similar to those she would encounter in school helped Isabelle build more mastery experiences to increase her math self-efficacy.

Family was also an influential source of role models for Mari who was inspired by her well-respected physicist grandfather, chemist grandmother, and her economist father. Education is clearly a strong family value in Mari's family, and she went on to explain how all of her father's family were teachers and professors in their STEM fields and how her grandfather wrote physics textbooks and was involved in a national physics teachers' association. As with the other students, Mari's family has carved out a unique educational path for her including her current school that is the site of this study. Mari's schooling journey has included a small private school with grade and subject accelerations, homeschooling with online math through Stanford and Khan Academy (while on her father's sabbatical), additional online math through Art of Problem Solving, and finally moving across the country specifically to attend her current school. She explained that her father is a "big math person" and her mother is "also more of a numbers person," so she and her brothers were guided to be "more mathy."

Unique Math Opportunities Spark Math Self-Efficacy Realization

The parent survey indicated that two-thirds of the girls had one or both parents who were in a math-related occupation. This would increase the chances that these girls had a family role model who could work with them on higher level math and express enthusiasm while talking with them about challenging math concepts. Also, these parents would probably have greater insight into finding and evaluating opportunities in math outside of school. However, the parents in other fields within the participants' current school community also found opportunities to support their daughter's math self-efficacy — as is apparent by their daughters currently attending a school with a strong math culture. An example of this from the parent survey was:

> *Both of her parents and all relatives are in humanities related jobs, but she is interested in math. This was sometimes difficult to bend things for her, but we tried to find as many opportunities as we could. A huge part of this was summer camps as she finally got to talk to people who loved math the way she did and found teachers who were also interested in her success in math for the first time.*

The sense of belonging among other people who have similar interests is an important factor in promoting self-efficacy in the shared interest (Bandura, 1994). All of the focus group participants and all of the parent survey participants' daughters (some of whom were the same) were involved in math groups outside of school. Examples of these activities were math/STEM camps (Epsilon Camp, MathPath, Summer Institute for the Gifted), math clubs (afterschool programs and Math Circles), math competitions (Mathleague, MATHCOUNTS, Mathematical Association of America's American Mathematics Competitions), robotics teams (FIRST LEGO League), programming camps and online communities, science clubs, and online math programs/communities (Art of Problem Solving, Stanford math programs, Khan Academy).

In regards to how extracurricular activities influenced her thoughts and feelings about math, Tara spoke about her experience when she started going to Math Circle in fourth grade:

> *There was actually another girl from this school who was there. So, I met her before we went to [this] school. I remember that was the first time I was in an environment with other peers my age, where I actually felt motivated to work on math. It was always me independently with my sister and my parents, but there I started feeling kind of competitive and I wanted to answer first and stuff, but I never felt that kind of thing before, yeah.*

When asked whether there were other ways that it made her feel by seeing other people more interested in math outside of school, Tara went on to say:

> *It was really fun seeing those people, for one. At that time in elementary school, I was probably overconfident in my math skill. So, I think being there, it made me feel like there were people that were at my level, I guess. That was one of the feelings I got there. So, it was interesting to have a peer group where you felt like you were working with them. Yeah.*

In a later focus group, responding to the question of whether she remembered any moments when she had the self-realization of liking math for herself, Tara replied, “I think I grew up with it. I don't really remember personally because I was raised around math. So, I kind of always knew that I was interested in it, even though I didn't like school math.” When asked to expand on any moments where she thought, “I just love math,” she reiterated how she found everything that her parents and relatives gave her (e.g. the word puzzles) “super interesting.” Then Tara described another particular memory, and her sister added further details:

Tara: And then also when I was in fourth grade, I just randomly was doodling, I guess, but it was like math style doodling. And I was looking at differences between polynomials and I think I came up with like some things vaguely related to calculus [laughs].

Sonia: She figured out rate of change of polynomials without any knowledge beforehand of what she was doing. [Everyone laughs] It was kind of ridiculous.

Tara: [Laughs] I didn't know what terms were at that point.

Sonia: She's just tossing around with stuff.

Tara: I thought it was very cool.

This was the same year that Tara found her math peers through Math Circle.

As discussed earlier, Sonia had a varied path to math self-efficacy that she called a “late awakening.” She had positive experiences among family, but she had not seen a connection with math due to her perception of math being skewed by generally negative experiences at school. By seventh grade, when she had become uninterested with the repetitive style of teaching, Sonia reached a tipping point:

I was just like, okay, this is… I can do this. I know how to do this. This is ridiculous. And it's around then that I started realizing that I am what is considered good at math, even

> *if I didn't like it, again, no connection to the puzzles [with family]. And then my mom came up to me, and she's just like, do you want to go to this Math Circle? San Jose Math Circle for eighth grade. And I was just like, well, I mean it can't hurt to try it. And I went there, and instead of seeing math, I saw puzzles and this is the big revelation. Ooh, hah hah, ooh, yeah. That was, that was a big thing for me.*

Sonia explained that she actually learned about her current school from the Math Circle and that she went to her parents and told them that they needed to check it out. Her sister expanded upon this by saying, “she normally isn't super passionate about things, but she was really insistent about it and I think that was what motivated my parents.” Sonia later added, “I don't think I truly came to decide that I *loved* math until after I came to [this] school.”

Isabelle had a similar experience to Sonia in some ways. She also had strong family support for her math self-efficacy and felt that going to Math Circle really influenced her feelings about math. She said that Math Circle made her think of math differently. Previously, she had seen math as only arithmetic, but in Math Circle “it was more like logic and puzzles. So, I enjoyed that more.” She also had mentioned early on in the focus groups that she had found out about her current school through her Math Circle, so it was an important step toward her current math self-efficacy. Isabelle was also fortunate to have positive social feedback at school to reinforce her math self-efficacy during the last two years before she came to her current school. She had a teacher who created fun and engaging math activities and she had found a group of friends who were “all very interested in math, and it was all girls except for one boy.” She recalled, “We would go to recess and we'd have these math books and then write down all the cube roots. I still have all of them.”

Mari recalled that she started realizing that she really liked math around fifth grade when she was doing accelerated math and an extracurricular math club including math competitions with her friend. Her fifth-grade teacher had opened up opportunities for her with appropriate and enjoyable challenges to share while she also received positive social feedback from her peers. Mari's foundation of math self-efficacy was encouraged at that time by having: a creative and encouraging teacher, a female friend to share enjoyable and challenging math experiences, and a small school with kids that she had grown up with and she described as having a supportive rather than unhealthy competition between them.

Similar to the other focus group participants, Mari expressed that she enjoyed working on the type of math that she would encounter through these nontypical opportunities, such as math competitions. All of the participants spoke about this kind of math as interesting word problems or puzzles, unlike typical school math. Many of the participants expressed that they would try to quickly finish their regular school math, which was described as "boring." Mari further elaborated that unlike school math, the extracurricular math was not assigned to one particular genre. She described it as a mix of everything, which connected the dots for her. Similar to Sonia, Mari also expressed that coming to her current school was what really cemented her feelings about math. These experiences beyond the classroom exposed the girls to mathematicians similar to the teachers at their current school who enthusiastically teach interesting math concepts beyond what is commonly taught in school and share their passion for math.

Ava had early memories of being filled with "a lot of excitement and joy" when learning subtraction in kindergarten and that her mother was a strong source of her math self-efficacy.

When asked what she thought would be a good way to make math more interesting to young girls, Ava recommended exposing them to more abstract math that was fun like her mom had done “rather than just straight arithmetic”, which got “a little bit boring sometimes.” Ava described how she came to the realization of how she liked math:

> *It was a little like sparks of just really pure enjoyment. Just being like, wow, this is so cool. It was just a few times that I remember them very specifically and then I feel like in fifth grade I found that a lot more. And then I read this book, it was called "Love and Math," and it was definitely way too hard for me to be reading. I didn't really understand it. It's by a Berkeley professor, I think. But I remember the first thing was, “When I was younger, I didn't really like math. But then I had one teacher who really showed me what math was and I got to dive into it and it was just so different from what I'd learned in school and I got to feel this excitement.” I'm like, “Oh, I feel that excitement sometimes with certain situations that have happened a few times.” And I was like, "Oh, maybe not arithmetic.” I mean I do enjoy arithmetic because it's nice and it's just like even. Reading that, I was like, “Oh, okay, so this is a thing and people like math. Okay, cool.”*

Ava also spoke about how early on at her current school, she thought, “Oh yeah, I enjoy doing math.” And then after a couple of months, “At night I would fall asleep just thinking about math and I realize that it was just something that I really liked thinking about. So, I'm like, oh, I *really* enjoyed thinking about this.”

The girls in the focus groups described their current school environment as very supportive and “everyone’s kind of excited all of the time.” Tara expressed how everyone during class, including the teacher, is “extremely eager about the content and they’re happy to be learning or teaching it.” Sonia added, “Yeah, I think a lot of it also has to do with the fact that we're really close to the teachers here. It doesn't feel like you're asking a superior... I mean it's not like they're not in authority, but they're also friends on top of that. And that makes it a lot more comfortable.” The middle schoolers spoke about how they liked that they have more time with their teachers at their current school since they have small class sizes. Also, how much they like the student to teacher relationship, which “is more like friends and that makes learning math more fun.” Additionally, all of the girls in the focus groups spoke enthusiastically about how amazing their current school’s teachers are and about all of the mathematicians who visit and those who are involved with the school. This sense of belonging to a wider math community has built an even stronger math self-efficacy in the girls. Through their previous experiences during elementary school along with their positive experiences in their current school, the participants gained an understanding that seemed to inform the ways they inspire and support other girls through their community events, especially their math festival for girls.

Conclusion

The present study aimed to identify sources of math self-efficacy among a group of high achieving girls by identifying common experiences that had contributed to their math self-efficacy. Bandura’s (1986) self-efficacy beliefs within his social cognitive theory provided the theoretical framework to explore the sources, which guided the design of the research sub-questions. The first sub-question explored the self-efficacy source of mastery experiences to determine whether the girls identified themselves as someone who likes math and whether they had shown an early interest in math-related activities. The focus group and survey questions surrounding this line of inquiry not only confirmed their current positive math self-efficacy levels, but it also led to a significant number of stories about the importance of positive math experiences with their families. The second sub-question about math role models stemming from Bandura's self-efficacy source of vicarious experiences led once again to the girls' families as their main source. The third sub-question explored how particular math-related activities influenced the girls' thoughts and feelings about math to determine whether physiological and emotional states had been triggered by certain experiences. The focus group questions into this area as well as questions regarding the teaching strategies or environments within the fourth sub-question about social persuasions revealed the finding of math experiences in elementary school that had negative effects on their feelings about math. However, questions in these two areas also brought out the finding that nonstandard opportunities beyond regular math in school were the gateways to the girls' identifying their positive math self-efficacy, which led to their current school environment where they have conveyed how this further solidified their math self-efficacy. Additionally, the fifth sub-question about the girls and their parents' perceptions of the math gender stereotype examined whether stereotypes had impacted the girls' math self-efficacy. Although it was clear that the girls are very aware of these stereotypes and they have felt the emotional impact of them at times, it was also clear that they and their parents did not subscribe to these gendered stereotype beliefs, so the impact was minimized.

Chapter 5: Implications

Building and maintaining high levels of math self-efficacy in girls remains a crucial task for our society. This study set out to identify the common experiences of girls within a math community whom one would assume had attained their math self-efficacy at an early age and continued to build it through the present. The research findings connect with the theoretical framework of the social cognitive theories of Bandura’s (1986) self-efficacy beliefs and Dweck’s (2006) growth mindset in various ways. The finding that the girls had strong family support for their math interests early in their lives, including strong math role models, connects with all four of Bandura’s sources of self-efficacy. The fun math interactions the girls had with their families helped form their math self-efficacy through mastery experiences where they explored math problem solving within a supportive environment. They were likely to have experienced positive social feedback about their math abilities from extended family members and friends, which would then create positive physiological and emotional signals further supporting their self-efficacy.

Although Bandura (1994) emphasizes that a strong sense of self-efficacy is built through successes, he also warns that those who only experience easy successes can become easily discouraged by failure. Bandura (1994) and Dweck (2006) both stress the importance of building a resilient sense of efficacy through experiences of persisting through and overcoming challenges. Having these experiences of success through sustained efforts increases one’s self-efficacy that they have the capability to succeed, leading to greater levels of perseverance through obstacles and quicker rebounds from setbacks. Having a role model to demonstrate the attitude and behavior necessary to approach these types of challenges is an important factor for self-efficacy. The addition of strong math and educational role models within the girls’ lives created vicarious experiences to draw upon as they developed their own sense of math identity. Bandura (1994) explained that when these role models succeed through a sustained effort, the observer believes that they can also succeed in comparable activities. The greater the perceived similarity is, the more persuasive the role model’s behaviors are. All of the girls in the focus groups expressed the strong connections they had with the math role models in their lives.

The girls’ exploration of math concepts with their families (even when some were not aware that it was math) set the stage for the recognition of joyful math when they were exposed to it later in the unique math opportunities outside of standard school math. These nontypical experiences led to the girls’ identification of their math self-efficacy, which in turn, led to their current school providing further reinforcement. Additionally, while enjoying the fun and excitement of the math activities in supportive environments, the girls were likely to have interpreted their positive physiological and emotional states as signs of efficacy in math. Oftentimes, these positive or negative states enhance or diminish self-efficacy depending on how an individual perceives their physiological and emotional states. Since perception is key in the effect that these states have on one’s self-efficacy, teaching the skills necessary to understand and change one’s perceptions of these states is an important task for parents and teachers. For example, in a supportive growth mindset environment, the process of problem solving through exploration including becoming comfortable making mistakes along the way teaches how to engage with a problem and how to creatively persist to reach a solution.

Implications for the Literature

The unexpected theme in the research findings was that the girls had experienced obstacles to their math self-efficacy during elementary school, which had created a disinterest or dislike of regular math within school. One would have expected that all of these girls would have especially loved math in elementary school. While the research literature has revealed how levels of girls' math self-efficacy are much lower than boys, even when their academic achievements are equal (Bandura, 1986; OECD, 2015; Schwery, Hulac, & Schweinle, 2016), it was unexpected that girls who had really strong math foundations and who currently have high math self-efficacy would have been so negatively affected by math at any point in school. This finding led to the important insight of how fragile math self-efficacy is, even among students who have strong foundations for their self-efficacy. This revealed the implication that there are many other girls who could also be experiencing the joy of math, but who have lost their math self-efficacy due to environments with boring, competitive, and closed-ended math instruction at school. They have not been given the opportunity to experience the joy of math and reach math self-efficacy through an opportunity like the girls in this study. Therefore, it is particularly important to analyze how environments might create negative effects on the girls' math efficacy, or, conversely, spark math self-efficacy.

Implications for Practice and Policy

Teachers. The results of this study provide opportunities for teachers to reflect on the math learning environments in their classrooms. The understanding that girls' math self-efficacy can be easily damaged during their schooling years through common teaching techniques — even among girls with strong math ability and positive math role models — can help teachers adjust some of their practices. Teachers could increase their sensitivity to math learning activities that could create math anxiety, such as math speed skills activities or classrooms that inhibit quieter students from asking for help in understanding a concept. Instead, they could actively check-in with quieter students in sensitive ways to connect with them to effectively teach for understanding. During math classes, teachers can emphasize depth of learning over speed or performance. Another important opportunity for teachers is to be a good math role model for girls. This is especially important for plenty of girls who may not have math role models in their families. Potential role models can work on ways to connect with girls to increase the perception of similarity that the girls feel with them. These role models raise the observer's self-efficacy by expressing their positive ways of thinking and behaviors that show effective strategies while working on challenging tasks.

Schools. At the school level, teachers could be supported to attend professional development programs that teach strategies for increasing math engagement leading to high math self-efficacy for their students. An example of this is the Mathematical Mindsets professional development program for teachers using new brain research, Dweck's growth mindset approach, and an open approach to math (Anderson, Boaler, & Dieckmann, 2018). The research on this program showed that teachers significantly changed from fixed to growth mindsets, which positively affected their beliefs about math and their beliefs about their student and their own math potentials. Additionally, schools could support the development of afterschool math programs for school aged children in the community. Programs specifically designed for girls could interest more girls in extracurricular math-related activities and lead to increases in their math self-efficacy. The findings of the current study suggest that these programs can have a strong impact on girls' math self-efficacy and their realization of enjoying math. One model for a potential afterschool math program could be a Math Circle, which was an influential program for all of the focus group participants who had access to a Math Circle. Free resources, including an extensive handbook and a mentorship program for launching Math Circles are available from the National Association of Math Circles, which is a project of the Mathematical Sciences Research Institute.

Dweck (2017) stresses the importance of teachers and parents truly conveying growth mindset through their behaviors and practices rather than just endorsing it. It is suggested that teachers focus on the process of learning in a way similar to how the girls experienced it with their families, in their math opportunities outside the norm, and in their current school. The focus in this kind of learning environment is on working with students when they are stuck to increase their understanding and to giving them opportunities to revise work to show their increased understanding. This teaches that difficulty and confusion are not due to inabilities, but are instead a normal part of the learning process. The aim is for students to find deeper solutions and explanations why something is or is not working. Teachers in these environments focus on taking the time to explore the process of learning the concepts by guiding students to really delve into the math problems rather than just getting through the material. This method of teaching for understanding may take some time to adjust to as students may work on fewer problems. However, rather than just getting an answer and moving on or being passed over while your partner answers the question, the students will build upon their prior math knowledge to be prepared for higher levels of math.

Educational policies and contributions to social change. A priority for state and federal funding for high-quality afterschool programs could broaden the access to math for more students. These programs could be modeled after Math Circles or similar programs. The model of the program is to engage students in fun math activities that expose them to novel math concepts that they would not ordinarily be exposed to unless they were a math major in college. However, the problems are low-threshold, high-ceiling problems, which offer many entry points while leading to deep math concepts. The environments are collaborative and often the Math Circles bring in mathematicians from the surrounding communities to share their enthusiasm for math. The findings suggest that these programs can have a strong impact on girls' math self-efficacy and their realization of enjoying math. Having a sense of belonging within a supportive and engaging environment for math was shown to be very important factor in igniting and maintaining the girls' math self-efficacy in this study.

Additionally, programs specifically designed for girls with a collaborative and hands-on approach could interest more girls in extracurricular math-related activities leading to increases in their math self-efficacy. As the challenges to their math self-efficacy can often increase in the secondary school years and beyond, it is significantly important that girls are able to solidify positive levels of math self-efficacy through their daily school experiences. As shown in this study, funding for smaller class sizes or additional teacher assistants would help increase the effectiveness of teacher to student relationships. As our country recognizes the need for more STEM workers, hopefully, it will support programs that create more engaging, supportive, and inclusive math learning environments for girls and other underrepresented groups.

Limitations of the Study

The quantitative data was limited by the fact that the school size is small and only approximately 1/3 of the invited participants volunteered to submit parent surveys. The qualitative data focus groups had an appropriate number of participants for the time allotted and the groups discussed all of the focus group questions within the two rounds with each group. However, the limitation with the current qualitative data would be the limited amount of time for the overall study. If the study were extended, more details about the girls' current school experience would be useful. Of course, having additional perspectives of other girls within the school would be welcomed if there was additional time. While this particular study focused on hearing directly from the girls that were the topic of the study, interviews with teachers from both their current school as well as previous schools would add another important perspective. The teachers' perspectives could be useful in learning more about their math teaching strategies and their opinions on engaging more girls into the math community.

Also, the perspectives of the girls in this study are limited based on the participants coming from well-educated families who provided role models, math support, and access to unique math opportunities. In a longer study, the addition of another school site could provide perspectives of students who currently have low math self-efficacy to identify whether this stemmed from their experiences with math in school. It would also provide further insight into whether or not they had strong foundation in math at home and access to math opportunities outside of the norm. An additional missing perspective is that of boys, which could add data about their personal experiences with math and their viewpoints about math gender stereotypes.

The findings are specific to the research site in that it is an independent private school, which limits the findings by focusing on a group that no longer attends a public school or, in the case of one student, has never attended a public school. This may have created a bias against their prior learning environments. My own bias as a parent at the school may have guided the design of some of my questions. For example, I asked questions about the girls' families, so this could have revealed more about the impact of their families on their math self-efficacy. My own children had attended Math Circles several years ago, so that could create a bias in seeing the value of such a program. My familiarity also made it easy to understand what the participants were describing when they were describing the Math Circles. I did not interject any personal comments about it during the focus groups, but I did not overlook that part of the findings as someone may have done if the person was unfamiliar with Math Circles.

Directions for Future Research

Additional focus groups with boys at the research site would be useful to compare with the current study. It would add to the research literature to have qualitative data directly from the perspective of boys to determine whether they had similar or different experiences than the girls that led to their high math self-efficacy. Another productive area for further research would be analysis of the blatant and subtle messages from our broader social systems and how they impact both girls' and boys' perceptions about STEM careers. It would also be useful to conduct a longitudinal study of girls identified as gifted in math in early elementary school to identify when and under what conditions the girls' self-efficacy began to decline. Additionally, this study could research the impact of research-based interventions throughout adolescence.

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Appendix A: Parent Survey Questions

Is your daughter in grades 6-8 or 9-12? (If you have two daughters at the school, can you please submit a survey for each of them?)

- ❑ Grades 6-8
- ❑ Grades 9-12

Are you the mother or father?

- ❑ Mother
- ❑ Father
- ❑ We are answering the survey together
- ❑ Other

Did your daughter show an interest in math-related activities before age 5?

- ❑ Yes
- ❑ No
- ❑ Not sure

  If yes, what were some of the math-related activities that she enjoyed?

  ____

Did your daughter show an interest in spatially related activities (e.g. block building, puzzles, Legos, pattern blocks, drawing shapes, etc.) before age 5?

- ❑ Yes
- ❑ No
- ❑ Not sure

  If yes, what were some of the spatially related activities?

  ____

Did either parent actively engage in the spatially related activity?

- ❑ Mother
- ❑ Father
- ❑ Both parents
- ❑ Neither parent

When and how did you first notice your daughter had an interest &/or aptitude in math? Describe the type of support you provided your daughter to pursue her math-related interests?

____

Did your daughter participate in extracurricular math-related activities during elementary or middle school (e.g. math clubs/circles, math competitions, math camps, robotics, programming, STEM clubs/workshops/camps)?

- ❑ Yes
- ❑ No
- ❑ Not sure

  If yes, what were some of these activities?

  ____

Throughout elementary school, in what ways, if any, did your daughter's teachers support/challenge her in math class?

____

Does either parent have a math-related occupation?

- ❑ Mother
- ❑ Father
- ❑ Both parents
- ❑ Neither parent

Before having children, did you think that boys were usually better at math and girls were usually better at the humanities?

- ❑ Yes
- ❑ No

If so, did this perception change when your daughter started showing an aptitude for math?

- ❑ Yes
- ❑ No
- ❑ Not applicable

If you have other children, do you think any of their views about math affected your daughter's view about math?

- ❑ Yes
- ❑ No
- ❑ Not sure
- ❑ Not applicable

  If yes, please describe how.

____

Were there any role models outside of the immediate family who you think positively influenced your daughter’s interest in math?

____

Please add any other thoughts or stories that you have about possible sources for your child's interest, enjoyment, and/or confidence in math. Thank you very much for your participation!

Appendix B: Student Focus Group Questions

1. Imagine a mathematician in detail as if you're going to draw them. How would you describe that person?

2. Do you consider yourself to be a person who likes math? How do you think your math abilities compare to the general public?

3. Describe an early memory that you have of enjoying a math-related activity.

4. Describe a memory of a parent or sibling participating in a math-related activity. How does this person's interest in math differ from your own interest?

5. Describe an experience with math during elementary school (or middle school). What do you remember about your thoughts and feelings during that experience?

6. Did you participate in extracurricular math activities, and if so, how did those activities influence your thoughts and feelings about math?

7. Do you remember any teacher using games or illustrated books when teaching math? How did that affect your interest in learning math concepts?

8. What is the best way to make math more interesting to young girls?

9. Did your friends in elementary school have more of a positive, negative, mixed, or neutral view of math? Was your group of friends mainly girls, boys, or fairly evenly mixed?

10. What are some things that you like about the school culture at your current school?

11. How would you describe how girls and women are portrayed in our society regarding whether they like math or are good at math? Sometimes these portrayals are positive — are there examples that you can remember? Sometime these portrayals are negative — are there examples that you can remember? How do each of these portrayals make you feel?

12. Describe an activity or general teaching strategy used by one of your teachers that you think increased your engagement in math (this could be in the past or present, and could be in school or in extracurricular activities).

13. Do you enjoy math discussions and collaborative learning?

14. Do you like to feel a part of the wider math community through your current school? (What do the teachers or other students do to make you feel like you belong?)

15. Do you think the message of learning through challenges (and taking risks and making mistakes) was taught during elementary school math? How about at your current school?

16. Feelings about the general negative stereotype of math in our society? What do you think helped you not be affected by that negativity? What kind of advice would you give to girls in particular regarding math stereotypes?

17. Do you think that work in STEM fields, particularly more math-oriented work is seen as more is helpful and community-oriented or it is a solitary endeavor?

(Follow-up) Can you think of ways that might help society, and girls in particular, see work in math-related fields as more community-oriented?

18. When do you think you had the self-realization of liking math for yourself?
19. Think of your strongest math role model and share a small story or a favorite thing about that person.

Appendix C: IRB Acceptance Letter

DOMINICAN UNIVERSITY of CALIFORNIA

November 14, 2018

Tristan Tang
50 Acacia Avenue
San Rafael, CA 94901

Dear Tristan,

On behalf of the Dominican University of California Institutional Review Board for the Protection of Human Participants, I am pleased to inform you that your proposal entitled *Sources of Girls' Math Self-Efficacy Beliefs* (IRBPHP Application #10714) has been approved.

In your final report or paper please indicate that your project was approved by the IRBPHP and indicate the identification number.

I wish you well in your very interesting research effort.

Sincerely,

[redacted]

Randall Hall, Ph.D.
Chair, IRBPHP