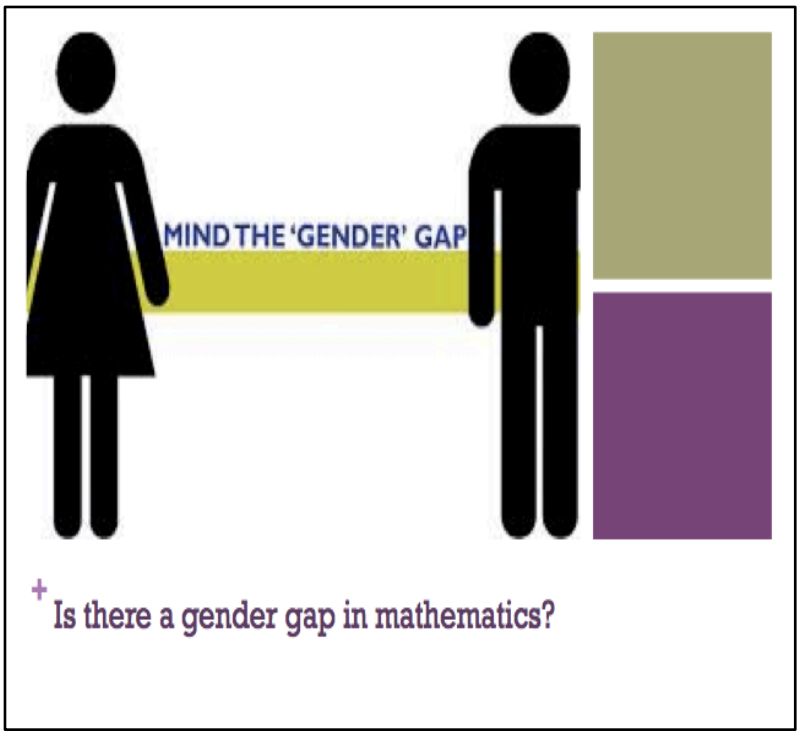
Breaking through the Math Ceiling

Kelly Day: Capstone Project

Capstone project as described in the Fulbright application: The purpose of this grant is to give girls the confidence in their abilities to think and express themselves mathematically. My objective is to study the causes of the gender disparity in mathematics education, learn best teaching practices from Finland, a country internationally acclaimed for supporting female development in mathematics, and after careful observation of Finnish education classrooms, combine all of my findings into a comprehensive study between the cause and effect relationship between teacher opinion and training in math and the corresponding student's opinion of mathematics.

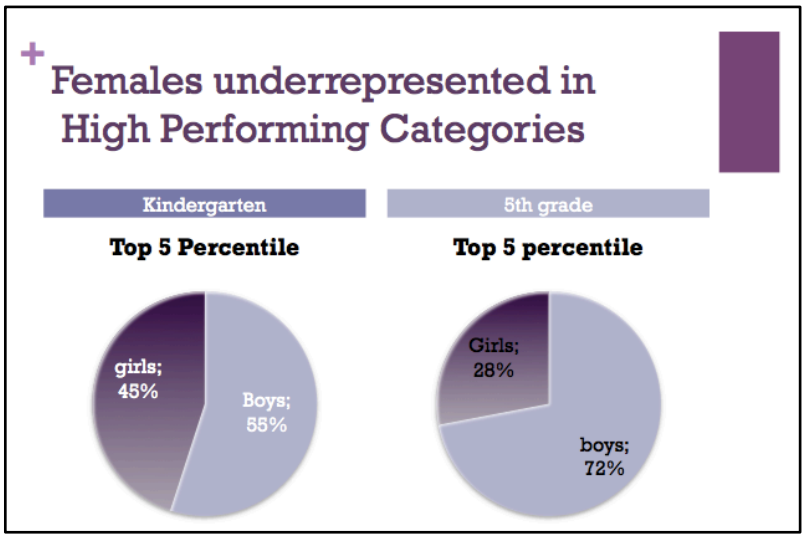


Is there a Gender Gap in Mathematics?

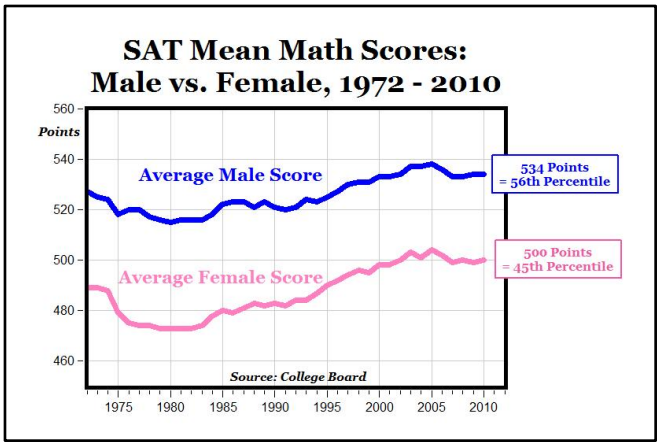
There are some that believe that the gender gap in mathematics is narrowing, however a recent Harvard University study states that, while girls may be outperforming the boys in the classroom, work still needs to be done in female achievement and understanding of mathematics.

The Early Childhood Longitudinal Study Kindergarten Cohort (ECLS-K) conducted a survey of over 20,000 students and 1,000 schools. This 10-year study evaluated the mathematical achievement and ability of students as they progressed through school (Freyer & Levitt, 2009). The study followed the same 20,000 students in their development from when they entered Kindergarten in 1998 to when they left eighth grade in 2008. They discovered that girls were consistently behind the boys in every age group, region, racial statistic and all socio economic statuses (Freyer & Levitt, 2009). The study found that while there is no statistical difference between genders in Kindergarten, by 5th grade, girls were .2 standard deviations behind 5th grade boys on every tested math concept (Freyer & Levitt, 2009). The Study goes on to report that by High School graduation there is .3 to .4 standard deviation gap between girls and boys and claims *"Girls are losing ground in math in every region of the country, every racial group, all levels of the socio-economic distribution, every family structure, and in both public and private schools"*(Freyer & Levitt, 2009).

Something that is even more alarming is that while there is no statistical gender gap between boys and girls at the low performing spectrum in mathematics there is a significant gap across all nations in high achievement in mathematics (Freyer & Levitt, 2009). According to the study, Kindergarten girls make up 45% of the top 5 percentile, but just a few years later they only account for 28%. (Freyer & Levitt, 2009).

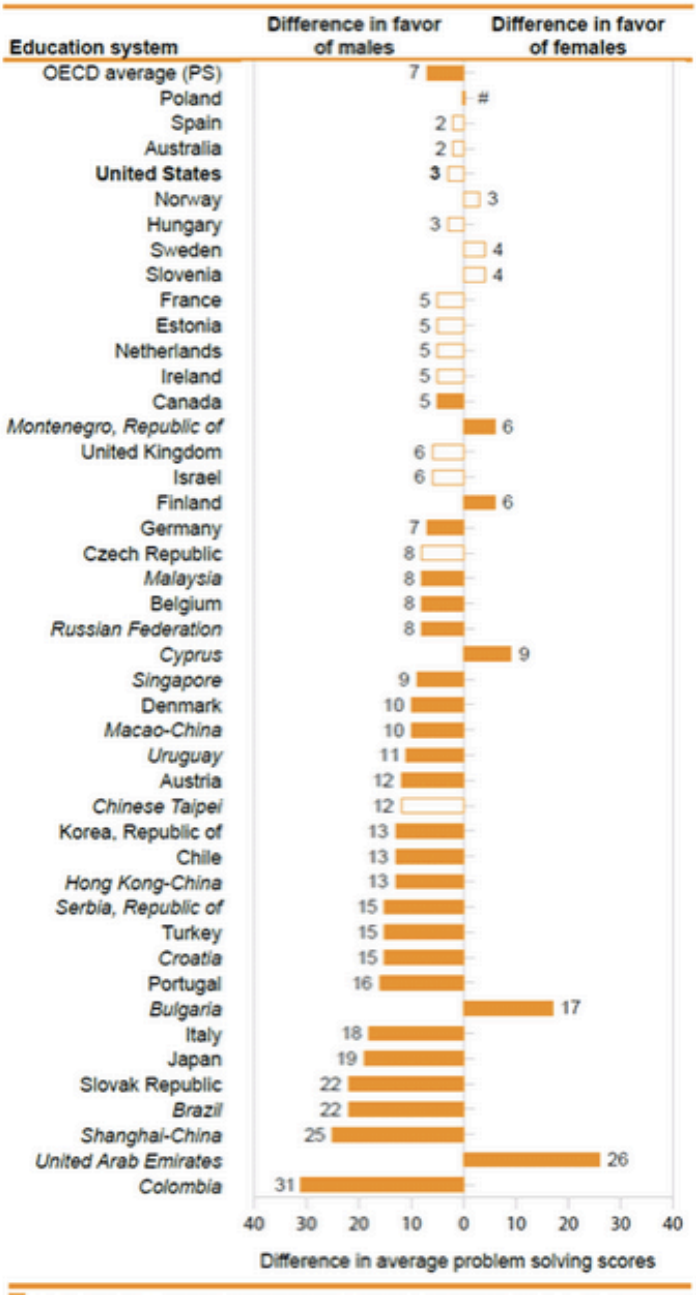


These findings are consistent across the globe. While there is an equal number of girls and boys present in the low performers of mathematics, boys do much better at the high end of the math achievement spectrum. This can be most effectively seen in the US's Scholastic Aptitude Test, referred as the SAT. This test, not unlike Finland's University Entrance exam, measures a student's ability to perform at the University level. Students who wish to attend a University elect to take the test to determine their placement in a University. According to the United States College Board the U.S male average score in math on the SAT test is about 30 to 40 points higher than the female average score. This phenomenon is unique to mathematics and does not happen on the verbal portion of the SAT exam.



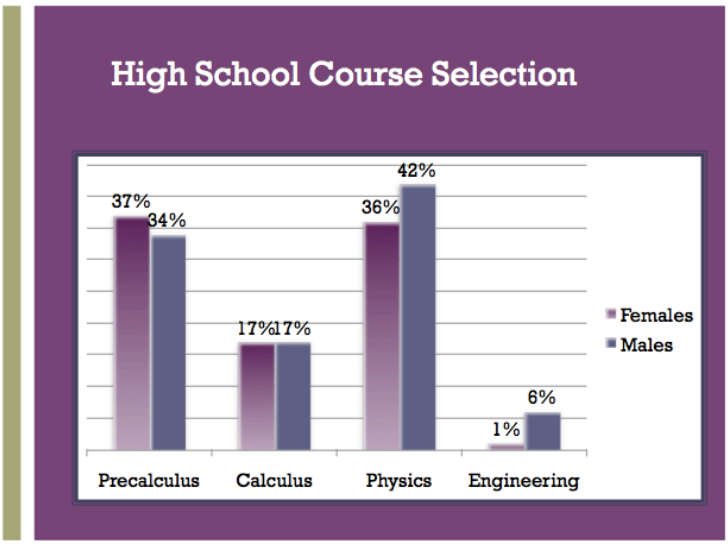
This is a Global Problem

This gender gap is a common problem throughout the world. This can be clearly demonstrated by looking at the PISA scores. The Program for International Student Assessment better known as PISA is an assessment of International education achievement that is operated by the OECD or the Organization for Economic Co-operation and Development (PISA, 2012). The test, which is administered every three years to students from countries all around the world, evaluates the mathematical abilities of students who are on average 15 years old. On this test boys outperformed girls in 54% of the countries who participated in PISA while only 8% had girls performing statistically significantly higher than boys (PISA, 2012). Ironically, most of the countries where girls tend to far outdo the males were societies where gender equality is less common. This has led to a growing theory that girls and boys both perform better in gender segregated schools. However, Finland, a country renowned for its dedication to gender equality, was one of the countries in the study to have girls performing just as well as the boys in math literacy. Finland had +3 points in favor of girls, the U.S had +5 points in favor of boys. Neither showed a statistically significant advantage to either boys or girls on math literacy (PISA, 2012).

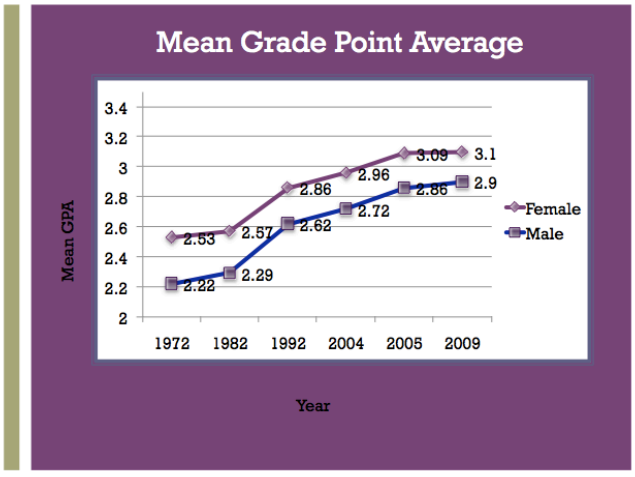


In problem solving, however, Finland's girls take a real lead. Finland's girls scored an average 6 points ahead of the boys. In the US the boys scored three points ahead of the girls. The only other nations where girls did better than Finland were Cyprus, Republic of Montenegro, Bulgaria, and United Arab Emirates (Countries where gender segregated classrooms are more common)(PISA, 2012). This shows that girls in Finland are doing a better job of problem solving than girls around the world. It also shows that there is still quite the global gender gap when it comes to international achievement in mathematics.

Some wonder if the difference in achievement has to do with course selection. According to recent statistics this does not seem to be the case. In recent years girls are taking the same level of advanced math courses as boys, with engineering being the exception. When engineering courses are offered in school, boys are 6 times more likely to take these courses as girls (National Girls Collaborative Project, 2015). However there is little difference between girls taking Pre-calculus, Calculus or physics at the High School level.



Data from National Educational Longitudinal Study and the US Department of Education show that girls are even performing at higher levels than boys in these courses (National Center for Education Statistics 1994, 1995, 2003, 2007) . From 1972 to present girls have consistently received higher grade point averages than boys. So, girls are taking the same courses in High school and doing better in these courses than the boys. According to a study by Duckworth and Selgman in 2006, this isn't surprising. Girls are more willing to work hard due to



their predisposed nature to please others and the intrinsic belief that efforts will be rewarded (Duckworth & Seligman, 2006).

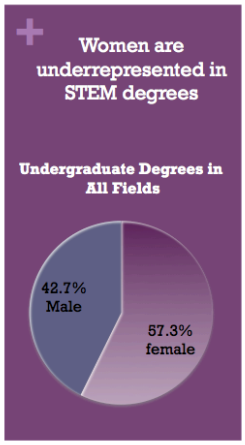
Girls also have a stronger inclination to please adults and have a genuine fear of disappointing those in authority roles (Duckworth & Seligman, 2006). According to this study, boys are less concerned in general about performance in school and pleasing adults. This could be a reason girls tend to outdo boys in school, while not actually achieving a higher mastery of skills. And even though boys receive worse grades in math than girls, recent research suggests boys score one third of a standard deviation higher than girls on self-concept and self-efficacy. This means that while boys may not be performing as well in the classroom, boys have much more confidence in themselves as mathematical thinkers and problem solvers (Duckworth & Seligman, 2006).

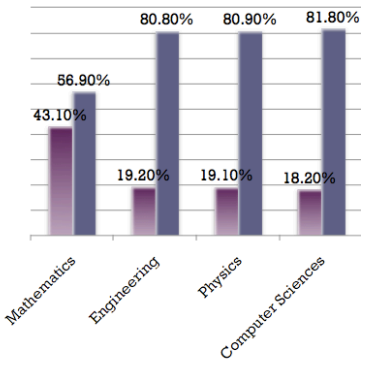
Beyond the construct of our society reside some very seriously stiffening math myths and conditioned beliefs. For example it is not uncommon in the US for someone to brag about how bad they were in mathematics. It is just generally accepted that math is hard, and you either have a brain that understands it or you do not. These stifling myths do not seem to exist in other subjects. A person is less likely to brag about being a poor reader or writer. However, being bad at math is seen as quite normal and something that can't be overcome through hard work and effort. Where lack of effort might be a cause for failure in other subjects, it is generally accepted that mathematics is a field where one either has the gift or doesn't. This type of cultural concept of mathematics is particularly dangerous to the female psyche.

Although girls tend to contribute academic success to work ethic, math seems to be the one discipline where girls feel that effort is not as important as ability (Ashcraft, 2002). There tends to be a highly engrained cultural belief that within the field of mathematics natural aptitude is a greater indicator of success than effort (Ashcraft, 2002). This is why it is socially acceptable for one to claim that they are not good at mathematics or that they don't have "a math brain". This

perception that in math ability is more important than effort is detrimental to the female student, who typically believes that success is correlated to how hard she works. However this socially constructed philosophy makes the female student believe that all of her efforts will be in vain in the mathematics classroom if she does not have the correctly wired brain. It makes her believe that math is the one unattainable mysterious subject that cannot be understood if one does not have the correct cerebral makeup. This is disheartening and extremely damaging to the confidence level a student has in the mathematics discipline.

Overall girls still fear mathematics and have lower self esteem when it comes to seeing themselves as mathematical thinkers. This can help explain why, even though girls make up more than the majority of bachelor degrees earned in the US. They are highly underrepresented in STEM degrees (National Girls Collaborative Project, 2015). While girls take the same level of math and science courses in high school, they are shying away from these courses at the University level. This I believe is a lack of confidence issue. Girls simply believe that they cannot perform as well at these higher level courses and therefore do not choose to even attempt them. This is in line with the recent research that suggests girls are far less willing to take a risk for fear of failure than boys, who are less fearful of failing. (Harris, Jenkins, & Glaser, 2006)





Girls are not willing to risk their futures on a subject like mathematics or physics in which they may hit an imaginary wall. Female students who have been otherwise successful in their mathematics courses in high school do not pursue the field at the university because they fear that eventually they will come to a point in mathematics that they will not understand. And they have been culturally

conditioned to believe that no amount of effort will allow them to break through this fictitious wall to the other side. Therefore they perceive subjects like mathematics and physics to be a risky field of study and therefore do not choose to pursue degrees that may be fruitless and futile. Instead females generally stick to professions in the social and biological fields. These fields are considered "safe" because they believe success in these fields of study can be attributed to effort rather than ability.

What are the Contributing Factors and Does Finland have the Answer?

While the gap may be closing in some areas, girls still lack confidence in mathematics. Math anxiety is high, self-confidence is low, females are not performing in the high achievement categories and they are not choosing to enter into the STEM professions. What may be the contributing factors to this problem?

- Classroom Environment
- Cultural Biases and Gender Stratification Hypothesis
- Learned math anxiety
- Teacher Training

Classroom Environment:

According to a study done by the University of Missouri, girls tend to be less willing to take risks in math because they fear wrong answers. Finland combats this by making female students feel comfortable with the subject and in making mistakes in general (Geary, Bailey, & LIttlefield, 2012) According to Finnish education expert, Pasi Sahlberg, Finnish Schools do this by developing "a variety of teaching methods, including cooperative learning,

American Classroom	Finnish Education
■ Quick to give answers	■ Cooperative Learning,
■ Instant rejection of wrong answers.	■ Problem Solving
■ Procedurally driven	■ Concept Attainment
■ Fast paced with several topics that are not integrated together.	■ Project Based Learning
■ Fear of being wrong/ Not willing to take risks	■ Fewer topics/ Shorter books and fewer problems
■ Timed Math Tests	

problem-solving, concept attainment, role playing, and project-based learning" (Sahlberg, 2011). My observations have shown that there is much less stress in a Finnish math classroom.

Finnish students are not given nearly as many topics as those presented in a typical American classroom. In fact Finnish students only have math a few times a week instead of daily. The anxiety Finnish students feel towards mathematics is lower because the subject is approached very differently in Finland. Student homework isn't usually taken for a grade. Students are allowed to learn the material in a no- risk way. They are not usually docked points for being wrong, and therefore there are fewer negative responses in math. This can generate a more positive overall feeling towards mathematics and more comfort and ease with a subject that tends to generate a lot of anxiety. This is especially helpful to female students who tend to care more about classroom performance and grades than their male counterparts.

The speed and level in which the math is presented is another major factor. From my observations in Finland, students are not really pushed to learn every single detail and topic in mathematics. Overall the amount of mathematics content covered in a single year in secondary education is much less than that covered in the United States. The overall pace is much slower and the content not as rigorous. Instead of learning a little about every topic, Finland focuses on a few topics and makes sure that every student masters those concepts before moving on. This may help with math anxiety and self-confidence.

The overall focus of the math classroom in Finland is also geared more towards application than calculations. Students do not spend hours upon hours learning how to factor and solve equations. Instead they learn how to use mathematics in their daily lives. They also use mathematics in physics classes and learn how math works in the real world. While this may appear to be less rigorous than the math presented to students in the United States, it serves its students well and Finnish students are well prepared for the real world.

Cultural Biases

Another contributing factor could be cultural biases. There is a deeply ingrained belief in American culture that boys are better at math than girls. The US has a continuing history of gender inequality along with a lack of female representation in leadership roles in the US society. There is a sociological theory proposed by researchers Baker and Jones called Gender Stratification Hypotheses that suggests that female lack of achievement in mathematics is directly connected to opportunities presented to females in society (Baker & Jones, 1993).

Finland is a very gender-neutral society. It was one of the first countries to give full voting rights to women and has some of the fiercest gender equality laws in the world. A female candidate has at one time held every elected position in Finland. The gender stratification theory suggests that the largest predictor of female success in academics is female representation in government. In Finland 43% of all elected officials are female compared to the US which has never had a combined number of over 20%. In Finland it is constitutionally illegal to have lower than a 40% representation from any given gender in government. This means that young girls in Finland often see women placed into leadership positions. This empowers them to become leaders in the classroom and overall gives them more confidence in themselves as logical mathematical thinkers.

In my interviews, however, I noticed that the older generation of Finnish people tended to have the traditional view on gender achievement in mathematics. Many Finnish adults I interviewed recounted stories of how their math teachers were all men and they looked down upon female math students. They talked about their lack of confidence in mathematics as a student and how that held them back in their studies and pursuit of careers. I was shocked to hear this was a common occurrence in Finland. It was not inline with what I had previously heard about the country that seemed so dedicated to gender equality.

Yet, when I interviewed current students these culturally conditioned beliefs did not exist. When I asked students about who is better in mathematics, boys or girls, they looked at me with utter confusion. They said it would depend on the person. "Sometimes girls are better and sometimes boys are better" said one Finnish 8th grade student. The Finnish students did not have a notion that boys were better than girls or vise versa. They thought of ability on an individual biases. These feelings of gender neutrality grew stronger as my interviewees grew younger.

So overall Finland is creating a generation of students who are blind to gender differences. And to some extent I see this happening in the United States. Most students I surveyed in both Finland and the United States stated that both boys and girls could be equal in mathematics. Perhaps the tide is turning in the correct direction.

Learned Math Anxiety?

However, I believe U.S. students (and female students especially) have been systematically trained to be fearful of mathematics. The education system in the U.S. has unknowingly bred a fear and distain for the subject. Students are trained at an early age to think of math as something that is difficult, tricky and unyielding. They see mathematics as an inflexible subject with only one correct process and answer and therefore the risk of failing is quite high. Females, who are more fearful of risky activities are also more perceptive other people's feelings, attitudes and anxieties. They can easily observe when someone is fearful of a given subject. This is especially true when that person is their teacher.

According to the McAnallen Anxiety in Mathematics Teaching Survey, there is a large percentage of elementary teachers in the U.S. that experience math anxiety (McAnallen, 2010). This study, using a research-developed instrument, took a sample of 700 teachers from various rural, urban and suburban communities in eight different states. It reported that Over 1/3 of all elementary teachers

demonstrated personal feelings of math anxiety (McAnallen, 2010). Most teachers were also self-professed to be bad at mathematics. This is a problem.

Female students are very perceptive. They also idolize their teachers. Therefore it can be extremely detrimental and disheartening when a teacher demonstrates an anxiety or distain for mathematics. It is not common for math teachers in the US to commiserate with their students. I have heard well-meaning teachers say "It is ok to be confused with math, I find it confusing myself."

This perpetuates the idea that math is an unsolvable riddle. Girls see that their teachers, who they believe are the smartest people in the world, struggle with mathematics. This trains them to think that math is difficult and unnecessary. If a student's teacher doesn't like math or isn't good at math, they feel as if they will never understand it and that they don't need to understand it. In my research I expected to find a correlation between the attitudes towards math of elementary teachers and their corresponding students. I believe that when a teacher at the elementary level of education has a fear and disdain for mathematics his or her students adopt a similar opinion.

In my research I surveyed 143 seventh grade students in the United States. In the survey 29% stated that they had a teacher who disliked mathematics and 55% of all students attributed their opinions of math to a previous teacher. I surveyed Jr. high students in Finland and 23% reported having teachers that didn't like math and only 35% attributed their own feelings towards math to the opinions of their teachers.

In my survey of middle school students there was a group of students who stated that they used to like mathematics, but bad experiences in school made them start to dislike math. For most of these students in the United States, the dislike of mathematics started in Elementary school. The majority of these students stated that 4th and 5th grades were the turning points for their perception and enjoyment of

the subject. Apparently something is happening in elementary school that is discouraging students in the United States from liking mathematics.

This same phenomena happens in Finland. However those who had a change of heart towards the subject claimed that their dislike of mathematics happened in 7th grade, not in elementary school. Finnish student's declined admiration for the subject of mathematics seems to start of when they switch from classroom teachers, who are highly trained in pedagogy and educational practices, to subject teachers who have high degrees in their content but very little training in pedagogy. Apparently highly traditional and formal secondary math classrooms of Finland are turning some students off of the subject.

Yet according to my survey of American students, those who changed their mind to a more favorable opinion of mathematics started to enjoy math more at 6th and 7th grade when they had subject teachers trained in mathematics. This was an interesting contrast in my study between Finnish students and American students.

Teacher Training?

Is teacher training in mathematics a problem? All teachers in Finland must receive their master's degree and conduct a formal research project that produces a master's thesis. In Finland it is extremely difficult to be accepted into the elementary education major and the job of a classroom teacher is a highly competitive and coveted profession. Only 10% of those who apply to become primary school teachers are allowed into the teaching program in Finnish Universities. Not only do the elementary education candidates have to have the best entrance exam scores, they also have had to pass a very rigorous interview process. Finland not only selects its best students to become teachers, it also makes sure that they have the aptitude, passion and ability to teach. Finland knows it produces a sound product that is fully trained in the art of education and it has reaped the benefits of only allowing the best of the best to train its children.

However, the US is going in the opposite direction. Some States, like Indiana, are actively discouraging teachers from earning their master's degree. There is also an increasing trend to promote alternative routes to the education profession without earning a degree in education.

There is simply not enough emphasis on mathematics in elementary education training. The typical elementary teacher, who is required to teach mathematics, has not received sufficient formal training in mathematics. Most teachers take Algebra I as their most advanced course, 40% enrolled in only one lower level math course at University (McAnallen, 2010). Therefore the education degree is attractive to those with math anxiety because it does not require mathematics courses.

During my time in Finland, I came across a survey that was given to Finnish students studying to become elementary teachers. I was able to translate this survey from Finnish into English and have some elementary education majors in the United States take the survey. The biggest difference I could see between the two groups was the ability to think mathematically. The confidence and anxiety levels between the two groups were actually fairly similar. It seems like both groups were relatively confident with their mathematical abilities, with the U.S. teachers being perhaps a little more confident than the Finnish teachers.

However, there was a big difference between the two groups in their actual mathematical abilities. Several of the U.S. education majors were not able to answer some simple arithmetic questions properly. When asked to compute (¾ ÷ 3), 18% of the U.S. Students got the answer wrong. When asked to compute (16.8 ÷ 2.4) over 35% of the U.S. students got the wrong answer.

What was even more alarming to me was the inability the U.S. student teachers had in creating story problems that accurately represent a situation. When asked to create a story problem that would demonstrate the calculation of (6 ÷ 24), many were not able to come up with a mathematically correct representation.

Only 53% of the U.S. elementary education majors were able to come up with a correct story problem representing the calculation of (6 ÷ 24). Below is an example of a correct story problem and answer.

There are 6 cups of ice cream to split between 24 people. How much ice cream does each person get?
Answer: ¼ a cup

Out of the responses 20% of the elementary majors came up with story problems that actually divided 24 by 6 instead of 6 by 24. An example of this mistake is the following story problem:

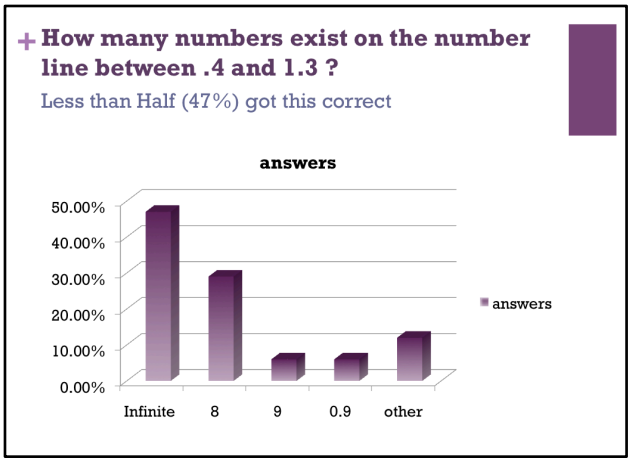
"Six girls need to divide 24 pieces of clothes between them. How many clothes will they each receive?"
Answer: 4 pieces of clothing each

And perhaps even more alarming was the fact that 27% of the responses had flawed story problems with inaccurate, confusing or missing information. An example is provided below.

The 6 Miller children brought bags of Easter candy to school. Unfortunately, the teacher said they could not eat the candy unless they had enough to go around the entire class. The children knew they had plenty so they proceeded to hand out candy to their classmates. If each Miller child had 10 pieces of candy and there were 24 other classmates, how many pieces would each Miller child give away (each child gives an equal amount)?

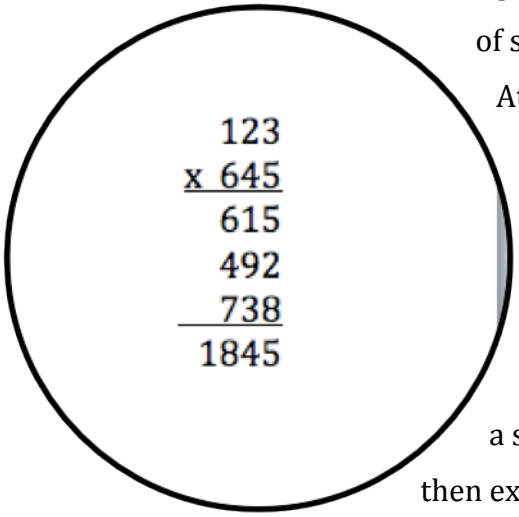
The answer provided by the student teacher was 4 pieces of candy because they divided 24 by 6. However the actual Answer to this question would be 60 divided by 24, which would be 2 and a half pieces of candy per child. Neither of which answer a question of what would be 6 divided by 24.

Overall U.S. teachers demonstrated a lack of understanding of the number line, the concept of infinity or a deep understanding of place value. When asked "How many numbers exist on the number line between .4 and 1.3", less than half of the student teachers knew that the answer was an infinite amount of numbers exist on the number line between any two given numbers. To the right is a display of the answers given to the free response question. It was surprising that there were consistent mistakes made.



Around 29% of the elementary education majors surveyed stated that there were exactly 8 numbers on the number line between .4 and 1.3. This means they listed the following numbers { .4, .5, .6, .7, .8, .9, 1, 1.1, 1.2, 1.3} and counted the 8 numbers in-between .4 and 1.3. Six percent of the students answered 9, which means they included 1.3 in their counting of the numbers in-between those listed above. Six percent answered that there were .9 numbers between the two given numbers, which means they simply found the difference between .4 and 1.3.

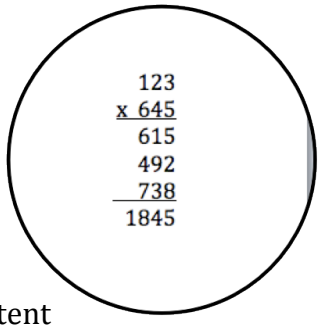
This lack of understanding of place value and the number line is a huge part of student's inability to make sense of mathematics. At the end of the survey I decided to add a question that was presented to U.S. teachers in Liping Ma's comparative study between the understanding of mathematics of American teachers and Chinese teachers. In her study Ma asks the teachers to look at the following mistake made by a student. They are to diagnose the problem and then explain how they would help the student reach the



correct answer. Overall the answers to these questions were very procedurally driven. When Ma asked the teachers to identify the students' mistake, sixteen of the U.S. teachers (70%) thought it was a problem of carrying out the lining-up procedure, whereas the other seven teachers (30%) suggested that the students did not understand the rationale of the algorithm. Sadly, fourteen (61%) of the sixteen the procedurally directed teachers had "limited knowledge of the topic" and although they explicitly described the "moving over" rule", none were able to give a mathematical reason for it (Ma, 1999). When asked to explain the rule, several U.S. teachers simply stated that you move the numbers over because it is a rule.

Even the teachers who understood that the zeros were placeholders did not see the mathematical meaning behind that concept. These teachers used the zero as a simple reminder to move the next multiplied number over. The zero was no different than putting in an arbitrary x or another meaningless placeholder (Ma, 1999). The U.S. teachers knew how to do the problem, and how to teach students how to carry out the algorithm. Most in fact could explain the rule quite easily, but very few understood why the "moving over/ adding zeros rule" was created or why it worked (Ma, 1999).

I wanted to add this question to the end of my survey to see if the current education majors could come up with better responses. The below chart shows their reaction to the same question posed above in the Ma study. The thing that stood out to me most while analyzing the responses was the inconsistent and incorrect use of math vocabulary.



What is the student doing wrong?	How would you instruct the student to fix his or her mistake?	Analysis of Response
They are forgetting to put the zero place holders in.	Put a zero in the tens place for the second row and two zeros in the third row.	Addresses procedure mistake only, does not address problem with understanding place value.
The student did not multiply each top number by five and then by four and six. He also did not add zeros after he multiplied by five and four.	I would remind the student that he must multiply each bottom number by each top number and add zeros after he starts multiplying by a new number. I would also show him an example problem as a reminder.	Procedurally driven, uses incorrect term "Add Zeros".
Not putting the numbers in the right place value.	Work straight down.	Procedure fix only
No idea.	Supportive and retracting myself first.	No understanding of the mathematical content
The student is not adding zeroes to the ones and then tens places.	I don't know.	Procedurally driven, uses term "Add Zeros".
They did not carry the number to the next place.	I would probably demonstrate a similar problem and show that you carry the number for 10s, 100s, etc.	Incorrect use of the term "carry"
They wrote 15 instead of carrying over the one.	I would write out the steps on the board and have them solve with me on individual white boards.	Incorrect use of the term "carry"
They are not adding a zero each time	Show them how to do it correctly.	Demonstration only, no explanation of reasoning
The student forgot to put zero placeholders on the second and third lines (0 and 00)	Add the missing zeros and re-add the three numbers to get your answer	Uses two different meanings of the world "add".
They are not placing the zeros for the tens and hundreds place. The numbers they are adding together should be 615, 4920, 73800.	I would remind them that they can't forget to save the ones place when they are multiplying the second number, and they can't forget the ones and tens place when they are multiplying by the last number.	Good, but still missing the reasoning of why they must shift.
The are not using 0 to hold the place of the next row of numbers, its should be 4920 and 73,800,	I would remind him to use place holder zeros when he multiplies.	Good, but still missing the reasoning of why they must shift.
Student is not multiplying over all the way placement of numbers is not right	Start of the right, with the bottom number. Work your way across to the farthest top left number. Then start with the middle bottom number and do the same. Then multiply the last bottom number on the left all the way across the top. Then carry on with the equation.	I am confused by this explanation.
They are not putting a zero for the first number in the second row.	No Answer	Term: "Putting a zero"

They are forgetting to drop down the zero place holder. 123 x645 615 4920 73800 79335	I would circle where they made a mistake, model the correct way on a separate piece of paper while verbally explaining what I'm doing, and let them try again.	Good procedure, still no explanation of why these steps are necessary.
Not using 0's as place holders when moving on to the next line	Add a zero at the right of the second line, and two zeros at the end of the third line.	Term: "Add a zero"
They need to be shifting one space to the left after each line. For example: 615 492 738	I would instruct of the error and display the correct method for the student to visualize. Then I would have them proceed to try again.	Good procedure, still no explanation of why these steps are necessary.
The student is not shifting the 492 or the 738 to represent the correct place value.	I would have them add one zero in the answer (because the 4 is really a 40) or in the 10s column. Ten has one zero. I would have them add two zero in the answer (because the 6 is really a 600) or in the 100s column. Hundred has two zeros.	Term "Add a zero" but FINALLY, someone understands that the 4 is actually 40 and the 6 is actually 600!!! This teacher understands and can the reasoning behind the student mistake. This was not just a procedurally driven answer. This teacher understands place value.

Overall, just like in Ma's study, the elementary education majors knew the procedure but did not understand the mathematical reasoning behind the traditional algorithm. The student teachers knew how to do it correctly but only one was able to explain to the student why they must keep place values. Many used the term "add zero" to explain how you should keep a placeholder. This concept of "add zero" is mathematically incorrect and inconsistent. Adding a zero to a number does not change the value of a number according to the very basic "identity property of addition". This is an example of the importance of understanding math vocabulary. Using terms incorrectly confuses students and provides frustration and prohibits understanding.

Teachers in the U.S. are smart capable individuals. They just lack training in mathematics. Teachers need to develop a profound understanding and feel at ease with the subject in order to be able to help their students, especially female students who lack confidence, feel comfortable with the mathematics content.

In Finland primary education teachers have more training in mathematics at the university level. They were also all in the top 10 percent of their graduating class and therefore must have done very well in mathematics at the high school level. Finnish Universities, who only accept 10% of those who apply to primary education major, will only accept candidates into the teaching program who were very skilled at mathematics as demonstrated by top scores on their matriculation exam and University entrance exams. In the United States however, elementary education is a very attractive degree to those who do not favor or understand mathematics because is a degree that requires very little mathematics training or prior background.

If we want U.S. students to have a better understanding of mathematics, they must be taught by professionals who have a profound understanding of the fundamentals of mathematics. U.S. teachers must have the confidence and ability to teach the basic concepts. To do this we must provide more training in mathematics for elementary math teachers, raise the math standards to attain an elementary education degree, and possibly raise the bar for the SAT score for those accepted into the elementary education program.

Finland understands that the most formative years of a child's education happens from grade 1 to 6. In fact the best educators in Finland are not the secondary teachers. The best educators are those teaching primary school. These are the teachers who are respected the most. Primary teachers in Finland have the most training and are the most effective. I think most of Finland's educational success stems from their early childhood education, not what happens at the secondary level.

The United States needs to make the educational profession more attractive to the top graduates. To do this the United States needs to get rid of the cancerous philosophy of "those who can't do, teach". That philosophy does not exist in Finland. Teachers are highly respected and the teaching profession is a highly coveted field of study. We have to select the best and the brightest to teach our youngest

children. We need to follow Finland's lead and set the bar high for those going into the education profession.

Beyond Formal Training: Time to Develop the Art of Education

Beyond formal training, Finnish teachers have the time and freedom to develop themselves as mathematical thinkers. Teachers in Finland have time to think about, create and develop their lessons. They have time to thoughtfully build lessons, projects and units. They teach fewer hours and have more freedom. US teachers are systematically loosing the opportunity to develop themselves as teachers and mathematical thinkers.

The standardization of education in the US has taken away a teacher's ability to connect to the material and gain true understanding and insight. Teachers have become drones that repeat the words from the pages of the textbook without ever gaining a true understanding of the content.

I believe that all students, but female student especially, would benefit from a more relaxed time schedule and with teachers who have the freedom and ability to develop their craft of education. When teachers feel more comfortable with the subject, less rushed and less anxious about the mathematics content, female students will start to feel more at ease with the content as well.

Also, when teachers have a greater understanding of the mathematical content they teach, they will then have the ability to teach it within the context of real world applications. This way mathematics will become less procedurally focused and more focused on application. This can only happen when teachers really understand the mathematics content they are teaching and have the time to develop lessons that are culturally relevant, mathematically sound and applicable.

Overall Thoughts and Observations on Finnish Education as it connects to Female achievement

While I believe that classroom environment, cultural biases, learned math anxiety and teacher training are all important factors when discussing female achievement in mathematics, I believe there is also an even larger explanation for Finnish success in female achievement. There were four questions that often presented themselves as I learned more about Finland's education and female achievement levels in mathematics.

1. Are students in Finland reaching their full potential?

Finland, a country that prides itself on equitable education, does a great job at getting and keeping everyone; boys, girls, rich, poor on the same playing field. Mirroring the philosophy of their society and governmental structures, education in Finland is more concerned with the collective good and making sure that every student does well instead of focusing on competition, tracking and ranking.

The result is that every student learns what they need to learn and does quite well at the basics, but not much more. There are very few high achievers in Finland. In fact on the recent PISA assessment Finland, while ranking far above the international average, Finland only had around 15% reach a top performing category, while the Asian Nations who beat Finland had between 30% to 50% of their students reach that top category. Yet, at the same time Finland had very few students on the low spectrum.

In Finland no one is pushed to become great, but no one gets left behind either. When everyone in society is doing at least "okay", this creates a collectively high average that beats the average of a country like the U.S. or China that have gigantic educational achievement gaps that mirrors their societal and economic structures.

This also produces a seemingly high level of female achievement in mathematics, which may more accurately depict a lack of male achievement. When discussing the gender gap in mathematics in the United States and around the world, it is important to note that there is only a huge gender gap in high achievers in mathematics. Boys tend to do much better on the high end than do girls, however there does not seem to be a gender gap in the low achieving category. This means that men make up the majority of those who perform at the top level in mathematical ability, while there is a same number of boys and girls who struggle with the mathematics content. What we might be seeing in Finland is not actually girls reaching the top level, but a lack of Finnish boys reaching a high level of mathematical achievement as compared to the rest of the world.

This isn't surprising when you take into account that while Finnish students have ruled and outscored most other countries on the international PISA test for the past decade, they have not faired well in the International Olympiads. Since 1959 China has had 132 medals, the United States had 205 and Finland had only 53 (and 47 of them were bronze) even though Finland had more student participants than the U.S. or China (Sahlberg, 2011).

Finland is not producing any extremely high achievers in mathematics. Its education system, while very equitable and fair, is not pushing its students to reach that top level. Finland does a very good job at getting a collectively high average, but does not do a good job at pushing talented students to reach their highest potential. And without that typical high level of male achievement the overall male average plummets and the female average surges.

Can a focus on problem solving not calculations improve female confidence?

Math classrooms in Finland do not focus on calculations, solving algebraic equations, factoring or what I would call formal mathematics that are usually confusing, cumbersome and intimidating to female students. Finnish math education isn't overly concerned with calculations or formulas. The kids in Finland

don't do rows and rows of algebraic problems. They don't sit around factoring complex equations for months on end. They are taught more practical skills and ways of thinking about and learning mathematics. The math itself is not complicated or difficult. The students must read the problem, assess the situation, and figure out the answer. And the Finnish students who have been treated more like adults than children have more real life experiences from which to pull to problem solve. This gives them more confidence in themselves as mathematical thinkers and problem solvers. This helps the female population gain confidence in the subject and allows them to see the purpose behind learning the math content.

Students in Finland have been given independence at a young age and have therefore figured out how to deal with real-life issues and problems on their own. They have also had an education system that has not spoon-fed them all of the answers. They have learned how to read through a problem, think it through logically and actually attempt to find an answer before they give up. The U.S. needs to focus less on actual drill and skill in mathematics and work more on problem solving and logic, especially if we want to inspire female students to achieve and have confidence in themselves as mathematical thinkers.

Is Physics the key?

Physics is a very important part of Finnish education. Students in Finland have a physics class every single year starting in primary school. Physics is just another component to basic education provided by Finnish public school. However The concept of Physics is terrifying to most Americans. We don't know it, we don't understand it and we assume it is a field for only the highly gifted and talented. While it is common for U.S. students to take ONE physics course in high school, it isn't a requirement. U.S. students are also not exposed to very much physics before the age of 16. However in Finland starting as early as 4th or 5th grade Finnish students learn the basics of physics. They have a physics class every year in middle

school and high school. Most of the math teachers are also qualified to teach physics. It is a common subject and one that does not breed disdain and fear.

The female students in Finland I interviewed actually tended to favor their physics class to their mathematics class. Why? They prefer physics because it is actually APPLIED mathematics. The girls stated that they like to know how math can be used, applied and how it is relevant to the actual physical world in which they live. When you look at the questions being asked on the PISA test, the questions are more geared toward an understanding of physics than formal calculated mathematics. This is the huge difference.

While American 15-year-old students can calculate circles around Finnish students, they are clueless when it comes to physics and mathematical application. Our students don't know how to properly apply the math they know so well. Where Finnish students, who have had years of physics classes, understand the questions being asked and know how to apply their knowledge of math in a real and logical way. They also do not fear it as a subject they way it is feared in the United States.

I believe the United States needs to introduce physics to students at a younger age. It also needs to become a mandatory course for all high school students. However, I think we should focus more on applied physics instead of calculus based theoretical physics.

Is Less More?

Overall my time here in Finland has taught me to believe that less is more when it comes to education. This is demonstrating itself to be true when discussing female achievement in mathematics. Finnish girls tend to do better in mathematics because subject does not overwhelm them. Instead of being pushed to do more and

more at a speed in which no actual learning or understanding happens, Finnish students are allowed to go at a more natural pace.

Instead of simply learning and regurgitating procedures, they learn how to apply what they are learning and not feel rushed. And while I believe that Finland could be pushing its gifted students a little more, I applaud their ability to get everyone to understand how to apply mathematics in a logical way. Finland does a great job at teaching students to know what they need to know to become successful members of society. They have mastered the concept of "less is more" and allowed all students regardless of gender, race, or economic status to succeed and thrive.

Conclusion

Overall I believe that there is much to be gained from observing Finnish education. I will adopt a "less is more" attitude in my own mathematics classroom. I plan on assigning less homework and focusing on fewer topics. I also hope to help teachers see the influence their attitudes towards mathematics has on their students, especially their female students, and to help them understand the power of their words and actions.

I want all teachers to have confidence in their abilities to think mathematically. I want students and teachers alike to see mathematics as an exciting thrilling subject, not one that is tedious or scary. As a society we must remove the idea that a mathematically geared brain is an inherited attribute instead of one gained through hard work and effort. We need all of our students to see math as something that anyone can understand. We need to help them see that it is logical and flexible and everyone is capable of learning it if they persevere and work hard. When that happens, all students will begin to gain confidence in themselves as mathematical thinkers.

Works Cited

Ashcraft, M. H. (2002). Math Anxiety: Personal, Educational and Cognitive Consequences. *Current Directions in Psychological Science* , 181-185.

Baker, D. P., & Jones, D. P. (1993). Creating gender equality; Cross-national gender stratification and mathematical performance. *Sociology of Education , 66*, 91-103.

Duckworth, A. L., & Seligman, M. E. (2006). Self-Discipline Gives Girls the Edge: Gender in Self-Discipline, Grades, and Achievement Test Scores. *Journal of Educational Psychology , 98* (1), 198-208.

Freyer, R. G., & Levitt, S. D. (2009). *An Empirical Analysis of the Gender Gap in Mathematics.* Harvard University, University of Chicago. NBER.

Geary, D. C., Bailey, D. H., & LIttlefield, A. (2012). The Co-development of skill at and preference for use of retrieval-based processes for solving addition problems: Individual and sex differences from first to sixth grades. *Journal of Experimental Child Psychology* .

Harris, C. R., Jenkins, M., & Glaser, D. (2006). Gender Differences in Risk Assessment: Why do Woen take fewer Risks than Men? . *Judgement and Decision Making , 1* (1), 48-63.

Ma, L. (1999). *Knowing and Teaching Elementary Mathematics: Teacher' Understanding of Fundamental mathematics in China and the United States. .* Mahwah, NJ: Lawrence Erlbaun Associates .

National Girls Collaborative Project. (2015). *State of Girls and Women in STEM.* http://www.ngcproject.org/statistics.

PISA. (2012). *What Students Know and Can Do.* OECD.

Roland G. Freyer Jr., S. D. (2009). *An Empirical Analysis of the Gender Gap in Mathematics.* Harvard University, University of Chicago . NBER.

Sahlberg, P. (2011). *Finnish Lessons: What Can the World Learn From Educational Change in Finland.* New York: Teachers College Press.

Study, N. E. National Center for Education Statistics. US Department of Education .