The Great Divide: The Lack of Female Mathematicians in Higher Education

Abstract

The gender imbalance in STEM (science, technology, engineering, and mathematics) has been perpetuated by the misconception that girls are not as strong in STEM as boys. This is especially true in academia, where women struggle to attain fellowships and tenure positions in higher education. Research has shown that without proper training and mentorship of young women, it is difficult for female students to continue down the path of mathematical research and professorships. In response, this paper aims to examine related themes such as girl's attitude towards math, the positive influence of role models, and women's access to STEM jobs. Journal articles were gathered from science and education journals. Several news articles were used for further insight. The findings revealed that efforts must be made on all fronts, from educational institutions to government agencies, group such as the Association of Women in Mathematics and the National Institute for Women in Trades, Technology, and Science (IWITTS) are working hard to nurture women in STEM fields and highlight their achievements.

Introduction

The lack of women in science, technology, engineering, and mathematics, popularly known as STEM, has become a pressing issue in recent decades. In particular, the field of mathematics has been male-dominated for centuries and struggles to recruit women even today. To gain a clear understanding of this gender imbalance, it is critical to comprehend how girls are affected beginning elementary school. Although many research studies report that boys and girls have similar levels of achievement throughout elementary, middle, and high school, some researchers have noted that girls experience higher anxiety levels in math classes than boys. In high school, enrollment in advanced math courses did not vary by gender and neither did the number of girls and boys taking the advanced placement exams. The statistics, however, drastically change at the college level. Many women graduate with a degree in biological sciences but are significantly underrepresented in the "hard sciences" such as computer science, engineering, physical sciences, and mathematics. It is telling when the cover of the American Mathematical Science magazine are scholars who are all white men. A mere 15 percent of women hold tenure-track positions in the math departments of a majority of colleges, a statistic that is consistent with the percentage of women on the editorial boards of academic journals (Hu 1). This is a problem that requires a closer examination of girls' attitude towards math, the significance of positive role models, and the opportunities available to girls in the field of mathematics.

Background

Until recent decades, girls were discouraged to learn arithmetic at school. They were taught simple arithmetic on very rare occasions. Boys, on the other hand, were expected to learn

mathematics because they were expected to earn jobs in commerce and bookkeeping. It was deemed extremely controversial to teach girls anything above addition, subtraction, multiplication, and division; moreover, advanced math was viewed as concepts only boys could master (Midzak 1). However, after the Revolutionary War, people began to realize how important it was to teach girls mathematics so that they are able to manage business matters in the home. As the times progressed, one key figure named Emma Willard, a well-known educator, was attributed for starting the movement to teach advanced mathematics to all women (Midzak 2). After teaching herself geometry, she opened an all girls school where she taught her students what she learned. She then decided to move to Waterford, New York where she taught geometry to the female students there. This shocked the local community who criticized her saying the students merely memorized the concepts and did not have the capability to truly understand the material (Midzak 2). She went onto teach herself algebra and then moved to Troy, New York where she opened a seminary to teach math to female educators. It was Willard's belief in women that enabled her to greatly contribute to the advancement of women in math education as Troy graduates went onto to teach at other institutions around the country.

Female mathematicians such as Emma Willard, Marie Curie, Elizabeth Blackwell, and so many are unknown to students today. Positive female role models are crucial in inspiring young girls to pursuing mathematics in college, among many other factors. Granted the job of a mathematician is not a sought after career, more often than not, boys secure higher positions in the field than the girls. A great majority of publications are dominated by men and they often take on board positions in many reputable publication journals. Historical challenges, female stereotyping, improper training, and the lack of female role models, all contribute to the gender

balance we see today. In order to gain a deeper understanding of the problem at hand, a closer look at girls' math performance in the classroom is telling of why girls fail to pursue math in college.

Girl's Attitude Towards Math

In the article titled, "Elementary Girls' Attitudes Toward Mathematics in Mixed-gender and Single-gender Classrooms", Tichenor et al. performed an experiment comparing the girls' attitudes between mixed-gender and single-gender classrooms in an elementary school. The experiment was conducted on 168 girls (1st through 5th grades) with an equal mix of high and low performing students and mixed races and ethnicities (Tichenor et al. 93). The experiment followed the guidelines from the *Classroom Mathematics Inventory* and the survey contained both negative and positive (10 for each) statements, such as "I am good at math" or "I like math" (Tichenor et al. 93). The results showed that girls in mixed-gender and in single-gender classes generally reported positive attitudes towards math. More than 75 percent of all students reported positive attitudes towards math in eight of the ten questions (Tichenor et al. 93).

However overall, girls in the single gender classroom answered the questions more positively than the girls in mixed-gender classrooms. The girls in the single-gender classroom noted that they could imagine themselves using math outside of school (Tichenor et al. 99). In addition, they found math to be less boring than the girls in the mixed-gender class. Speculations suggest that as girls grow older they feel less confident in math than their male counterparts which reinforces the idea that single-gender education helps to breakdown gender stereotypes (Tichenor et al. 99). The author concludes that the most important factor for increasing girls' interest in math is to create an environment where girls feel welcomed and comfortable. In order

to create this environment, it is critical for the teachers to teach the "growth mindset" to students because it builds confidence when they are doing challenging work. Therefore, a growth mindset pushes young girls to go beyond their limits that success is defined by effort rather than one's talent or ability.

Stereotypes and Math Performance

The class environment impacts girls more often than not. The most concerning are negative comparison to boys including stereotypes which may affect a girl's ability to focus, thus, affecting her performance. One study showed just how girls' are affected by negative stereotypes in the classroom. Central China Normal University designed an experiment which examined 267 students including 116 boys and 151 girls at high schools in central China with an average age of 15.55 years (Song et al. 946). The participants were asked to complete the Mathematics Competence Belief Scale and the Gender Stereotype Survey from the Modified Fennema-Sherman Attitude Scales (Song et al. 947). The relationships among mathematics, stereotype, and competence belief were calculated using Pearson's product-moment and correlation coefficient. Sample statements included lines such "I am certain I can succeed in mathematics" which the students had to rate from a scale of 1 (completely disagree) to 7 (completely agree) (Song et al. 947). In the Mathematics Gender Stereotype Survey, statements such as "when a woman has to solve a mathematics problem, she should ask a man for help" (Song et al. 946). In addition, the students were also asked to complete the Achievement Goal Questionnaire, originally developed by Elliot and church (1997) and the Effort Questionnaire which was originally developed by Chouinard et al. (2007) (Song et al. 947). For the first, statements such as "My goal is avoid doing poorly on the mathematics test" and for the second,

"I work hard in mathematics tests" were included (Song et al. 947). Finally, the students' had to answer 12 math questions from the Chinese National Public Servant Administrative Career Aptitude Test to determine their performance level.

This study was based on the stereotyped task engagement process model which is closely related to the achievement goal theory. The model suggests that female students adopt performance-avoidance goals which is the act of focusing their attention on covering up their incompetence to other students (Song et al. 944). On the other hand, performance-approach goals refers to students who demonstrate their competence level in comparison to other students. As expected, the results of the study revealed that the girls were negatively related to the performance and competence belief in mathematics, while for boys, the gender stereotypes positively affected them. The experiment results indicated that the gender stereotypes had a negative effect on Chinese female students' mathematics performance. Being a part of a devalued group made the female students anxious about the possibility of failing which in turn became a self-fulfilling prophecy (Song et al. 946). They demonstrated a lack of confidence and placed less effort into the work which made it difficult to learn abstract mathematical concepts among other tasks. Although this study was performed in another cultural context, it is still relevant to girls worldwide where stereotypical practices exist in the classroom. Therefore, no matter the context, it is critical for women to have a strong competence belief in mathematics to excel in the subject.

The Influence of Role Models

To combat negative stereotypes, it is critical for teachers and other adults to take an active role in a young girl's life, particularly in the classroom. In another study, the Department

of Psychology and Committee on Education in University of Chicago devised an experiment testing girls' ability in math instructed under a female teacher with math anxiety. This experiment is significant because the math requirements are quite mild for an individual seeking to become an elementary school teacher in America. In fact, many do not possess strong math skills which is telling in a field that is predominantly female. Therefore, it is not uncommon for teachers to experience math anxiety in the classroom; and more often than not, young girls are likely to emulate the behavior and attitudes of teachers who are of the same sex. To test this hypothesis, the experimenters targeted 12 first-grade female teachers and 5 second-grade female teachers from five public elementary schools (Beilock et al. 1861). It was expected that the lower the student's math achievement level, the higher levels of anxiety the female teacher had.

The students of these teachers were examined (52 boys and 65 girls) in the first 3 months and the last two months of the school year in regards to their math performance, beliefs about gender, and success in math (Beilock et al. 1861). A math achievement test was orally given to the children at the beginning and at the end of year by an experimenter. At the end of the year, the students were asked to draw a picture of the student in two gender-neutral stories, one about a student who is good at math and the other who is good at reading. If they drew a boy for the student who is good at math and a girl for the student who is good at reading, this would imply that they do not believe girls are "good" at math. For the teachers, math anxiety and math knowledge was tested using the Mathematics Anxiety Rating Scale which included questions that addressed how anxious they felt when applying their math skills in real life such as "studying for a math test" or "reading a receipt after a purchase" (Beilock et al. 1862). The

Elementary Number Concepts and Operations section of the Content Knowledge for Teaching Mathematics was used to test the teachers' math knowledge.

As predicted, the results at the end of the school year showed that the teachers' math anxiety greatly affected the girls' math final scores. However, interestingly enough, the math anxiety level of female teachers did not have any impact on the boys (Beilock et al. 1862). The author suggests that the girls were the only ones affected because the math-anxious female teacher subconsciously confirmed the stereotype that girls were not good at math compared to the boys. This idea was supported by the data which reflected a significant number of the students drawing a boy when referring to the student who is good at math and drawing a girl for the student who is good at reading (Beilock et al. 1862). The study also suggested that the girls with lower math achievement may have adhered to traditional gender beliefs compared to the girls with higher math scores who showed a higher level of confidence. The assumption here is that since many young girls emulate the behavior of teachers who are of the same sex, it is pertinent for girls to have a confident female teacher to boost the female students' own level of confidence.

So what does this mean for male teachers in the classroom? Another study suggests how important it is to consider the characteristics of a great role model in general, which includes men. In one journal article titled *Virtues of a Hardworking Role Model to Improve Girls' Mathematics Performance* by Bages et al. (2017) revealed that there may be key characteristics in role models that help significantly improve girls' performance in math. Given the lack of women in STEM, men serve as important role models as well. Therefore, it is the characteristics of the mentor that propel girls forward. Bages et al. (2017) performed an experiment to study

what these characteristics are and conducted a survey on 554 French students including 276 girls and 278 boys in seven public junior high schools (Bages et al. 56). The students were asked to take a French national standardized math test, which contained 16 problems, after reading a description about a successful ninth grade female role model. The students were divided into groups of 8 to 14 students; one group was read about a ninth grader who works hard, another group was read about a ninth grader who is gifted, and the last group had no role model explanation. They were also required to distinguish themselves ranging from 1 (strongly disagree) to 5 (strongly agree), indicating how strongly them identify with the successful role model (Bages et al. 59).

As expected, the results depicted that the girls scored as well as the boys with the hardworking role model, but underperformed compared to the boys with the gifted role model or with the the no explanation role model. Another result indicated that the math performance of the group of students who were exposed to the hardworking role model was higher than the students who were exposed to the role model whose success was either not explained or explained by the gifted role model. These results did not vary between gender; it was the same for the boys and the girls. The results proved that the girls felt threatened by the underlying stereotype that girls are not "gifted" in math, which was proven by the results which showed that the girls who were read the story of the gifted role model had a lower math score compared to the girls who were read the story about the role model achieved success by working hard. Overall, this study showed that regardless of gender, students felt more encouraged by the role model who worked hard because success is then attainable for them as well as long as they work hard. As for the role

model who is gifted, this person made them feel defeated because the students do not believe they have the talent to succeed, so why try at all.

Building Confidence and Enjoying Math

The current literature revealed that a student's success or failure in college STEM courses are particularly affected by a student's high school experiences. While more and more opportunities are offered to girls than ever before, continued efforts may help elevate female students' level of interest in mathematics. This effort must begin in the classroom, where teachers must consciously develop stronger beliefs in girls' about their abilities in math, encouraging them to work hard to overcome setbacks and accept new challenges (Meadows 35). The National Association of Gifted Children Math and Science Task Force suggests that students take the right classes and be allowed to take higher-level courses to learn at a pace, depth, and breadth corresponding with their talents and interests that spurs their intellectual curiosity and creative problem solving skills (NSF, 2010). Technology and engineering curriculum should be core classes through primary and secondary education in a rapidly developing society. After school programs, summer programs, competitions, and special school subjects regarding STEM topics may help further develop their interest in a more meaningful way because it is applied to the real world. This should include observations in laboratories and independent research.

Furthermore, the Southeast Comprehensive Center (2012) recommended that teachers develop their content knowledge in order to increase the number of high quality teachers in mathematics (Meadows 38). This means curriculum improvements must be made in the credential programs to include exercises that address building girls confidence in math through helpful exercises. Teachers must also know how to recognize STEM talent and provide growth

opportunities for that students. Observation of problem-solving and off-level testing may help track the girls level of progress to target solutions early on. At end, it is critical that girls in high school and college are targeted in order to increase the number of women in STEM. Since women are still a minority in the field of mathematics even though they have made impressive gains in math, creating environments that support women will encourage more girls in these fields.

In order for girls to genuinely enjoy mathematics, it is important for girls to "generate their own knowledge and connect with the knowledge of other students" (Cantley et al. 433). It is in the act of sharing what they learned with their peers that cements the knowledge gained. To promote girls' interest in and enjoyment of mathematics, collaborative cognitive-activation strategy is highly encouraged. This is a learning strategy that engages in-depth learning by focusing on how to formulate a solution rather than only focusing on the answers. The cognitive-activation strategy, which emphasizes problem solving, reflection, guided discovery, and collaborative efforts, is highly correlated with increasing a student's intrinsic motivation to learn math (Cantley et al. 40). Instead of mere memorization, through word problems, the students are required to think deeply and find solutions through guided discovery from the teacher. In constructing their own opinions and solutions, the students can build a sense of confidence without overly relying on the teacher. Rather group work allows the students to seek answers together, sharpening one another's skills by posing questions and coming to a solution as a team.

When the cognitive-activation strategy was put to the test by Cantley et al. (2017) among 253 mixed ability first year post-primary school students, including 151 girls and 102 boys, the

enjoyment factor among female students increased while the boy's scores decreased slightly. Students were asked to work in groups for six weeks, one task per week presented by Izak9, a learning tool which consists of computerized cubes used to solve mathematical tasks (Cantley et al. 42). The study revealed that by working with each group member, the students were able to cultivate their problem-solving and collaborative learning ability. It also challenged teachers to adapt to new strategies that engage students instead of relying on dry facts and memorization.

Closing the Gender Gap in Math Publications

As female education efforts in primary and secondary school systems are improved, more and more girls are expected to enter the STEM field and earn positions of leadership. However, this is especially difficult in the world of academia where female mathematicians struggle to secure tenure-tracks and faculty positions at the university level. This may be because many women are unable to become published in major scholarly journals, a key factor to gaining professorships at universities. One study revealed that there exists a higher dropout rate of women who decide not to complete their mathematics papers (Mihaljevic-Brandt et al. 3). The exact reason for this is unclear but it is suggested that due to family responsibilities and the lack of encouragement from colleagues, women are less likely to complete their projects. In addition, reputable journals such as the Annals of Mathematics, the Inventiones Mathematicae, and the Journal of the AMS have not experienced any upward trends of female representation despite the growing number of women in STEM fields in the last 40 years (Mihaljevic-Brandt et al. 3). Although a comprehensive data set of authors from every math publication between 1970 and 2013 revealed that female authors who have been active for 5 to 10 years have tripled, women tend to give up their careers within a 10-year span (Mihaljevic-Brandt et al. 3).

To address this problem, the first issue that must be brought to attention is who is setting the standard in scholarly publishing. Journal editors often drive the peer review process which is a critical component of advancing in modern science. In another study performed by Chad Topaz and Shilad Sen, Topaz a mathematics professor and Sen a computer scientist professor at Macalester College, analyzed 13,000 editorship positions in 435 journals to better understand the existing gender disparity (Hu 1). The study found that 1 in 10 journals do not have any female editors and a mere 9 percent of all editorial positions are held by women (Hu 1). Topaz and Sen believe that a part of the problem is that women are seen as less "brilliant" than their male counterparts. One example of this is that when mathematician Sarah Brodsky was granted the National Science Foundation's Graduate Research Fellowship, some of her colleagues told her it was because she was a woman (Hu 1). On many occasions, Brodsky was discriminated against because of her gender as the men in her graduate program often excluded the six women in the program (out of 40) during social outings, often commenting on their outer appearance. When women are excluded socially, this could also mean being excluded from collaborative research projects and less encouragement to apply for funding. To minimize the gender disparity, Topaz, Sen, and Brodsky suggest anonymizing names during paper submissions to reduce bias and create an environment on editorial boards where women are less likely to leave, such as parental leave policies. Overall, the recruitment of women to pursue a mathematics graduate programs is needed but ultimately, it must begin at the top where editorial boards must begin to consider how to increase their own female representation.

The Association of Women in Mathematics

One organization working to combat these issues is the Association of Women in Mathematics (AWM). An organization that began in the 1970s, AWM strives not only to become a "conscious raising" organization but also to become recognized as an academic society. In 1976, AWM became an affiliate of the Conference Board of Mathematical Sciences and Mary Gray became the second vice president of AMS, nearly 70 after Agnes Scott in 1906 (Greenwald et al. 16). AWM also fought hard to include women as speakers for the International Congress of Mathematics (ICM). More than 500 women protested against ICM in 1976 to address why there were no women invited to speak at ICM. Karen Uhlenbeck was invited to speak in 1990, as the second female lecturer in ICM's history, following Emmy Noether in 1932 (Greenwald et al. 17). In 1994, ICM incorporated the Emmy Noether Lecture series and in 1996, MathFest launched a lecture series to recognize women in the mathematics. More and more lectures series were created to include women such as the AWM-SIAM Sonia Kovalevsky Lecture series (2003), the Olga Taussky-Todd lecture at the International Congress of Applied Mathematics (2007), and more. Today, AWM also works to provide financial assistance to female students to attend these conferences, the goal being to engage young women in their specific research fields in mathematics. AWM added the phrase "and girls" to their mission statement realizing that an interest in mathematics and careers in math must be addressed at a younger age.

With the amount of accomplishments that AWM has been able to achieve, in an time where more attention is given to women, AWM efforts may be more critical than ever to truly achieve equality. The truth of the matter is women still experience discrimination, unequal pay, harassment, and an absence of child care in the workplace. In addition, the statistics show that less than 25 percent of STEM jobs are granted to women (Greenwald et al. 19). In the field of

mathematics, women still struggle to secure tenure tracks. Hee Oh became the first female math professor to earn a tenure track in the school's history. AWM exists to help women gain the recognition they deserve for their hard earn efforts. Also, the Association for Women in Science (AWIS) created the "Advancing Ways of Awarding Recognition in Disciplinary Societies" to assure equitable measures for granting awards which included best practices for selection committees (Greenwald et al. 19). Progress, however, does not happen overnight, thus AWM and other mathematical societies must continue to work hand in hand to push forward with their agenda.

Recruiting Women in STEM Fields

Donna Milgram, the Executive Director of the National Institute for Women in Trades, Technology, and Science (IWITTS) works to even the gender imbalance that exists in STEM fields. Recruitment is critical because without a clear strategy it is difficult to improve the number of women in a variety of STEM fields, including mathematics. IWITTS organizes WomenTech Educator Trainings, where an exercise called "Messages" to understand what kind of messages are being played out by teachers, counselors, peers, and parents in the classroom (Milgram 5). Milgram who has administered training sessions around the country confirms that the "messages" are often mixed or extremely negative towards girls. Public campaigns, therefore, can have a highly beneficial impact when passing on positive messages to the public. One such example is of "Rosie the Riveter" who was developed by the American government to recruit work women to work in local factories while the men were fighting World War II (Milgram 6). Based on a real woman, the campaign resulted in an increase of women in the workplace by 57 percent.

A current example similar to “Rosie the Riveter” is IWITTS CalWomenTech Project which sought to recruit more women to STEM fields at two-year colleges. There are many colleges who benefited from this effort. The City College of San Francisco’s Computer Networking and Information TEchnology (CNIT) saw an improvement of girls in the program from 18 percent to 30 percent, and then to 33 percent the following year (Milgram 6). At the colleges, some of the specific recruitment strategies included presentations to counselors about the project and to educate their students about such programs. Counselors are important because students seek out career advice from them, who can act as a pipeline for female students to STEM programs.

Conclusion

A girl’s experience at school will greatly impact the fields of study they will choose in the future. With so many outside factors working against women, organizations such as AWM are critical to push for change in a variety of STEM fields but most of in academia. Recently in 2014, Maryam Mirzakhani won the Fields Medal, the highest honor offered by IMU (Greenwald et al. 20). Her honor highlights a milestone for women in academia. In response, she states, ‘‘This is a great honor. I will be happy if it encourages young female scientists and mathematicians. I am sure there will be many more women winning this kind of award in coming years. (Greenwald et al. 21)’’ Through the hard work of women (and men) around the world who promote women in math, it is only a matter of time as more and more women actively pursue academic research and are acknowledged for their great contributions.

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