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Mathematical Connections

The Gender Gap in STEM

Abstract

The gender gap is a problem very prevalent in the modern world yet often under addressed. The root of this problem lies in education and can be addressed through changes in the structure and content of courses. The impact of this serious gap can be seen in various fields such as medicine, research and design, and can negatively impact the lives of women every day. Those interested in this topic and its intersection with historical figures can find additional sources and studies attached at the bottom. Also attached will be more papers connecting gender with race and class as this paper will focus more solely on the gendered aspect of this problem.

Introduction

For a long time, there has been a notion that girls are worse at math than boys and it is used to explain why there are less girls in the math field. This is not only just wrong, but this stereotype forgets the complexity of education and adopts a very male centric measurement for being "good" at something. This paper will attempt to (1) identify the problem, (2) identify the effects of this problem, (3) proposes some changes to address this problem before delving into some examples of important female mathematicians forgotten from school's curriculum, add personal experience to the story, and finally address some of them more interesting comments received after this talk.

Identifying the Problem

Firstly, and perhaps most importantly, what is the gender gap in STEM education and what does it mean? The history of education shows that it has been centered around teaching boys for the majority and even today we can still see those structures in place. This culture has forced not just girls, but many others to change their style of learning and thinking to better fit a male ideal style of learning. Our current education system is catered to a select few individuals and forces the rest to conform to fit this. Studies have shown that girls perform as well as if not better than boys throughout elementary school and middle school in math. However, around high school, there is a significant drop in attendance of girls in higher level math or science classes.

"This gap widens the longer girls are in school and is often compounded by issues of race and class."[1] This eventual divide in education continues to impact women further on down the road and creates a cycle that negatively impacts future generations. If fewer women advance into math, then there are fewer role models for younger girls to look up to and it continues the cycle.

Root Causes

So what appears to cause this sudden divide? There are many different factors that impact the field of education and it is nearly impossible to address each possible cause of the current problem, yet I will identify a few main ones here. These causes are not unique to gender issues alone and area also prevalent in the question of race and class in our educational system. Especially this first one, which ties directly into my opening statement on harmful stereotypes.

Known as the Stereotype Threat, this phenomenon is defined as the idea that a certain group is a part of is inherently not good at a certain field of study; i.e. the idea that girls are bad at math.[2] Both teachers and the curriculum can inadvertently lead to this as well as society around us as sexism remains heavily present in stereotypes regarding especially the STEM fields. It's also hard to believe you can do something when you rarely see anyone who looks like you doing it and this is why representation is also a key issue. As spoken on with the cycle before, girls don't often have role models that can relate to them personally and thus are less likely to believe that they can succeed in a similar position or job.

One final probable cause for this gap that I will mention lies in the very format of classes and the flaws that lie within our education system. The current push to learn as much content as possible in a short period of time is alienating at best and rewards only a select few who have mastered that particular skill. In a recent analysis of admission test scores for an elite high school in New York, it was found that girls often scored lower than boys on the math section of these tests, yet would receive similar if not better grades during actual class. A Stanford professor noticed something similar during one of his experiments and further stated that girls often struggled more on multiple choice questions as they tended to guess less. On the flip side, they tended to perform better on open-ended questions.[3] However, most standardized tests push a multiple choice format, thus impairing many girls ability to properly show their skills in math. So, by continuing to teach and test in this manner, it is alienating and discouraging girls from continuing in STEM. This compounded with harmful stereotypes and a lack of representation make up three main causes of this divide between girls and boys in mathematical education that seems to start around high school.

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[1] Carly, Berwick. "Keeping Girls in STEM: 3 Barriers, 3 Solutions." *Edutopia*. March 12, 2019. https://www.edutopia.org/article/keeping-girls-stem-3-barriers-3-solutions

[2] Berwick. "Keeping Girls in STEM"

[3] Ibid

Addressing the problem

But not everything is doom and gloom. There have been many suggestions on how to properly combat this concerning gap in education and I shall list a few of them below. These changes could not only help girls in math, but also can serve to help everyone in the classroom regardless of race, gender, or class as they push towards a more inclusive learning environment for everyone.

There are two main areas that improvements can fall under and these are in the teacher category and the curriculum category. Changes to teaching styles is more of an individual and singular type of changes where the curriculum can be more widespread yet both are equally important in promoting a fairer classroom environment. For teachers, striving to create an atmosphere that promotes a growth mindset and moving away from multiple choice tests could be beneficial. Creating an environment that emphasises practice and learning over inherent skill can benefit most children and can encourage those who are less confident in math regardless of gender. On the curriculum side of things, including more images of female mathematicians or scientists throughout classroom materials could directly combat the earlier idea of stereotype threat.

A comment I received after giving this talk directly questioned this idea and I would like to respond to it here. The commenter basically stated that male mathematicians are also not taught in class either and thus "it would be impossible [to] give more representation of women in the math field when there is barely representation of the math field to begin with" (Matthew Dreher, October 1, 202). This is an interesting point, yet I do not understand exactly why it was made. From my experience, male mathematicians are in fact taught in almost every level of math (Pythagorus, Euclid, Euler, Gauss, Newton just to name a few). And while it is true that the history of mathematicians is often left untaught, I don't see how adding more history to math classes would inherently be a bad thing. The changes to the curriculum can also include adding more historical context to math classes which would serve to help connect math more to other subjects and the world around us to help students grasp it better. So to counter this point, why not add more history in math classes anyways?

Similarly, the addition of afterschool programs to specifically address this gap as well as a general reconstructions of mathematical programs could improve the rates of girls in math overtime. When put together, the changes to these different spheres of learning could only help include more children in mathematical conversations and help push girls to continue succeeding in math throughout their careers.

The Work of Sophie Germain

In this paper I would also like to take a brief moment to highlight the work of one of the many brilliant female mathematicians. Her name was Sophie Germain and she was a French

mathematician from 1776 to 1831. She was unable to receive a formal education due to the times yet despite family pushback, continued to study math on her own through books. She was even able to receive notes from a university lecture under a male pseudonym until she was eventually found out and the professor of that course became her mentor. Over the years, she struck up correspondence with Gauss on his interest in number theory and even submitted a few attempted proofs of her own to him. Most notably perhaps was her attempt to prove Fermat's Last Theorem and her proposal of a key part of this theorem that now takes its name from her.

Fermat's Last Theorem (FLT) states that no three positive integers a,b, and c can satisfy the equation $an + bn = cn$ for any integer of n greater than 2.[4] Germain's attempted proof dealt with exponents $n = p - 1$ where p is a prime number in the form of $8k + 7$. In quick summary, she assumed p to be prime and greater than 3. From that, if x, y, and z are relatively prime integers satisfying the following: $x^{p-1} + y^{p-1} = z^{p-1}$ then p must divide the even one of x and y, while z must in fact be odd and not divisible by p.[5] From this, we can also see that then x must be a quadratic residue (mod p). However, further along in her proof she makes an assumption for some $m = k^{2p'}$ and uses this to say that when p is in the form $8n + 7$, then $p-1$ is not divisible by 4 and also not divisible by 3 thus assuming she had proved FLT for the exponent $p-1$.[6] Yet one cannot assert her claim that $m = k^{2p'}$ so her proof is thus incomplete.[7] However, this work would remain an important idea and attempt of FLT's proof for decades to come until it was eventually proven in 1994 after 358 years of effort by mathematicians.

In her second attempt at tackling this problem, she states a key theorem that intends to help prove the first case of FLT and this theorem would go on to be published by her mentor and given her name as Sophie Germain's Theorem. Her theorem states the following: Let p be an odd prime. If there is an auxiliary prime θ satisfying the two conditions:

1. $x^p + y^p + z^p = 0 \pmod{\theta}$ implies that $x = 0 \pmod{\theta}$ or $y = 0 \pmod{\theta}$, and
2. $x^p = p \pmod{\theta}$ is impossible for any value of x

then case I of Fermat's Last Theorem is true for any p.[8]

This would remain the most progress made towards proving FLT for decades to come and would split FLT into two cases. Her work is often confused or miscredited towards her mentor Legendre yet her ideas and proof remain central to FLT and number theory. She never received a formal education yet was still able to contribute greatly to the math field as a whole. In thinking of her story, I think it is important to appreciate how far we have managed to come in our education system. While this paper is intended to point out the flaws in our current state of education, I think it is also important to remember the progress that has been made and continue pushing forward with renewed vigor.

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[4] A. Del Cetina. "Unpublished manuscripts of Sophie Germain and a revaluation of her work on Fermat's Last Theorem." *Arch. Hist. Exact Sci.* **62**, 349–392 (2008). https://doi.org/10.1007/s00407-007-0016-4, 351

[5] Cetina, "Unpublished manuscripts of Sophie Germain", 354

[6] Ibid, 354-355

[7] Ibid, 355

[8] Larry Riddle."Sophie Germain and Fermat's Last Theorem." *Biographies of Women Mathematicians*, Last revised: July 21, 2009. https://www.agnesscott.edu/lriddle/women/germain-FLT/SGandFLT.htm

Conclusion

I received many comments addressing my lack of connection to hard mathematical concepts and ideas after my talk. And I concede, this paper does not focus on numbers, AI, linear algebra, or the likes. That was not my intention from the start. Instead, I focused on the second word in the title of this course - connections. And I believe that is exactly what I have done. The topic I discussed, the sexism, the divide, has been present in nearly every one of my math classes in some way or another. So to me, the connection is obvious. It's been my experience since high school and its constant pressure is not something to ignore. For men, it is simply not present. It is not something that impacts their daily lives and so no it doesn't appear in their classes and so no the connection is not obvious for them. So that's why I choose this topic. Because it is perhaps one of the most important connections to make in math and it's one that does not have a set audience anywhere. It's not technical enough for math classes, yet does not reach its intended audience in humanities courses. So I pose this question in response; if not here, then where?

Works Cited

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Further Readings

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