In the world that we live in today, math is being turned out from a long cycle of misinterpretation. We base our teachings of math on sets of rules and laws of order, with emphasis on memorization of patterns. Although patterns make up large parts of math they were not founded on memorization but on exploration of the unknown and stepping outside of the "rules." This false presentation of math in our standard education system has caused many students to struggle with math and develop a phobia of working with numbers. The format of mathematical teaching had also filtered out girls and women causing exclusion from the field. This further limits accessibility to math in the future and hinders people's ability to create math in an imaginative and inventive way.

If we look to history and historic mathematicians we see that math is not being worked with in this overly structured way. But rather historically math was a mystical practice that was exploratory.

Most consider the first ever formal "mathematician" to be Pythagoras. Pythagoras discovered many ways that math creates the world around us. He for instance created the concept of octaves by discovering that different lengths of string produce different sounds. These individual strings sounded best and harmonized with each other if they followed a numerical ratio of 1 to 2 or 2 to 3. He is also credited with providing the well known Pythagorean Theorem which is a substantial component of trigonometry and further connected geometry to algebra. Pythagoras gathered this information through travels around other ancient civilizations. Pythagoras brought this knowledge back with him from his travels and created a cult called the Pythagorean Brotherhood. He would give lectures about his mathematical philosophy and discovered material.

Pythagoras had an influence on the philosopher Plato which inspired platonism. Plato was a philosopher during the classical period in ancient Greece. Mathematical Platonism is the metaphysical view that mathematical concepts are abstract objects that exist within their own reality. These abstract mathematical objects exist according to their laws of nature regardless of human knowledge of their existence. Similar to how planets and electrons exist independently from us and our knowledge of them, so do the abstract objects that form mathematics. Such as, numbers, geometric forms, the laws of logic and others. Therefore, according to mathematical platonism these abstract objects are discovered and encountered rather than created or invented.

Mathematical platonism states that reality reaches much farther than our perception. Within this farther reality are mathematical objects not belonging to our physical realm of space and time. Professor Dan Rockmore of Dartmouth College explains, "Sometimes we mathematicians call the things we think about and work with "objects," which doesn't mean triangles, spheres, or other shapes. Mathematical objects are big ideas about algebra, geometry, and logic, about the properties and definitions of numbers." Although Rockmore was not directly referring to mathematical platonism, this philosophy of working with mathematical objects as if they were real is the foundational belief of mathematical platonism. This concept is also considered mathematical realism.

Many other mathematicians believe that this theory is naive, and that numbers and ideas only exist within our minds and in the physical world. This physicalist ontology disregards the idea of any existence outside of our physical world.

However, many mathematicians feel a connection to this reality of abstract mathematical objects. Yet the discovery of these objects is always just out of reach. Mathematicians often struggle to discover new concepts and can feel out of touch with what they are trying to find. A solution for many is finding a way to take their brain out of its normal state of consciousness. This being a way to step out of the endless loop of frustrating thought that we face when overthinking an idea. To avoid this cycle that results in dead ends, mathematicians find ways to remove themselves from their standard experience of reality.

How one experiences reality is subjective to their personal experience and is easily affected by factors such as drugs and alcohol, mental health, or something as simple as the time of day. Being able to alter your perception of the world can sometimes help you to see new things. In regards to the idea that there is a sort of alternate reality of abstract mathematical objects, it could be suggested that altering the way you experience reality might help you "tap into" this other mathematical reality. There is a long and substantial history of mathematicians using different methods to change their perception of reality in order to spark mathematical ideas.

Hungarian mathematician, Alfréd Rényi who made significant contributions in number theory and probability theory was known for having a high caffeine intake. As evident by his well known quote, "a mathematician is a machine for turning coffee into theorems." For him this was a way of putting his brain into an alternate state to best discover new mathematical concepts.

Rényi's close friend Paul Erdős, who was also a mathematician, preferred the use of Benzedrine or Ritalin, which he would take almost everyday. These types of Amphetamine drugs speed up your brain to body transmission and are usually prescribed to treat hyperactivity disorders like ADHD. Erdős found that they helped him to produce mathematical discoveries and improved his work.

French mathematician Henri Poincaré was enthusiastic about mathematical creativity and found that when he was drowsy in the morning and laying in bed his brian was the most creative. He would lay in bed and watch his room while thinking about mathematical ideas and possibilities. Professor Dan Rockmore has said that he used to sleep with paper and pen next to his bed in hopes that he could capture the equations he continuously dreamt about.

The idea that all these different mathematicians were able to do some of their best thinking when in an altered state of reality boosters the ideology of mathematical platonism. Henri Poincaré and Dan Rockmore specifically found this to be true when they were closest to being asleep. They both felt most connected to the mathematically creative part of their minds when in a dreamlike state of mind. This is a mysterious connection that could support the concept that these abstract mathematical objects exist in another reality.

This mysteriousness of math and where it best exists in our minds is part of what makes it so beautiful. It's not just sitting right in front of us waiting to be found. The way it works is strange and all the bits and pieces of it's way of being are sort of scattered throughout reality like easter eggs. This makes finding parts of it that make sense and discovering new ideas is an overwhelming enjoyable feeling.

Henri Poincaré said that to ignore the aesthetically joyful way of experiencing math, "would be to forget the feeling of mathematical beauty, of the harmony of numbers and forms of geometric elegance. This is a true esthetic feeling that all real mathematicians know, and surely it belongs to emotional sensibility."

This concept of math consisting of abstract objects presents the idea that these objects are just as much a part of our world as anything else. Just as many admire the natural beauty of nature and landscapes, music, and visual art, math can be viewed as beautiful. In fact many mathematicians love math for the concept of mathematical beauty. This beauty refers to the aesthetic response to the purity, abstractness, complexity, and yet simplicity and depth of mathematical order.

Neurobiologist, Mathmatician, and Physicist, researchers who were interested in this concept of mathematical beauty did a series of brain scans in relation to this aesthetic experience. They showed sixteen mathematicians different math equations, some considered “ugly” and others considered “beautiful.” When the mathematicians were shown the “beautiful” equations brain scans showed that the same part of the brain that is activated when viewing art or listening to music was active.

One of the researchers Professor Semir Zeki says, “A large number of areas of the brain are involved when viewing equations, but when one looks at a formula rated as beautiful it activates the emotional brain - the medial orbito-frontal cortex - like looking at a great painting or listening to a piece of music…. Neuroscience can't tell you what beauty is, but if you find it beautiful the medial orbito-frontal cortex is likely to be involved, you can find beauty in anything,"

This type of mathematical beauty is what inspires so many mathematicians to work. However not everyone views math so positively. In early history many feared math because they couldn’t always physically see what mathematicians were working with. This sometimes was perceived as a way of working with spirits or considered a form of witchcraft. At the time math was mystical and tried to explain the unknown, which frightened many. Those who worked with mathematical concepts were sometimes considered to be witches and wizards. John Dee is an example of someone in history who was misunderstood for their work.

John Dee was considered to be a crazy wizard and his collections of work looked more like mumbo jumbo than anything anyone felt they could trust during the 1500s. Many viewed math as disreputable and allied with witchcraft. Math books were often burned as conjuring books. Consequently, John Dee had an extensive personal library that was burned to the ground leaving little behind.

Another example in history would be Hypatia. Hypatia was a brilliant scholar who taught philosophy and astronomy at the neoplatonic school in Alexandria. Hypatia was one of the first females we have recorded in history known to study math. She was a highly respected academic who wrote about her mathematical discoveries. However, while she was teaching in Alexandria christianity was starting to expand. Many pagans were converting to christianity in fear of prosecution. However, Hypatia continued to practice paganism and as a female scholar who studied math she was seen as a threat by the christian church. She was called a witch, dragged through the street, and murdered by a group of christian monks.

Hypatia is one of the only female examples we have of historic mathematicians being murdered for “witchcraft.” This is because women who were murdered and burned were rarely documented, as this was not deemed important. Forgoing the historic witch hunts women were healers and helped with the medical needs of their communities. However, this threatened the future of a male dominated medical field. Barbara Ehrenreich and Deirdre English write in “Witches, midwives, and nurses,” “Under intense pressure from the medical profession, state after state passed laws outlawing midwifery and restricting the practice of obstetrics to doctors...For the new, male medical profession, the ban on midwives meant one less source of competition." This being the case despite many women healers having superior skills and knowledge about medicine, especially in regards to maternity. Now if one wanted to become a doctor they had to study medicine at university, and since women were banned from nearly every university they were excluded from the field.

They were excluded from many other forms of professional fields. Today we might think of the most "professional" areas of work as being business, medicine, law, sciences, academia, politics etc. These areas of work, that might commonly be considered to be the most professional, are also well known for having very high salaries. Yet they are also notorious for having low percentages of female representation. Although women make up about 90% of nurses only 20% of surgeons are women (18). When looking at the #1 paying job on LinkedIn, Orthopedic Surgeon, that percentage of women drops to 7%. This trend can be found in almost every other one of the top paying jobs in the US and is evident when taking a moment to think about how many women you personally might know in one of these fields.

As a result in our current academic society there is a significant lack of female representation in STEM fields, especially in mathematics. Only 15% of tenure-track positions in academia are held by women in mathematics, one of the lowest percentages within the sciences (15). Part of this is due to mathematics being a historically male dominated field. Many women often feel that math can be a "boys club." Women who are working in mathematics are not taken seriously, and are usually the only woman in the room. Often times if they are acknowledged for their work they are seen as a token, playing the "woman card."

This could be due to something researchers call the "brilliance effect." This is the idea that someone is just naturally brilliant rather than learning through hard work. A recent study looked into this concept by sorting through a popular website for rating professors, RateMyProfessors.com. They found that fields that used "brilliant" and "genius" most often to describe professors also had the lowest percentage of women in higher academia and that these words were rarely used to describe female professors. This suggests that people are less likely to think of women as being "genius" or "brilliant." This mentality is made clear to girls at a young age and causes a lack of confidence.

One of the main causes for this gender gap is rooted in education. The Organisation for Economic Co-operation and Development did a worldwide study showing that there was a common performance difference between boys and girls in math. Even high performing female students had lower performances in math. The study also found that, "Girls were more likely than boys to report that they 'just weren't good at maths' and less likely to agree that maths was one of their best subjects." However, this difference in performance was not due to difference in ability. The OECD pointed to low expectations among parents and teachers, as well as lack of self-confidence as the cause for the disadvantage girls face in maths and science. Girls often lack the confidence to do what the OECD called the ability to "think like a scientist" in answering problems. The OECD wrote, "This gender difference in the ability to think like a scientist may be related to students' self-confidence. When students are more self-confident, they give themselves the freedom to fail, to engage in the trial-and-error processes that are fundamental to acquiring knowledge in mathematics and science."

This fixed intelligence mindset is what holds many students back from learning math. The belief that intelligence is fixed and will not improve with effort is called Entity orientation. In contrast Incremental orientation is the belief that intelligence is malleable and quality will improve with effort. It's been shown that students with incremental orientation tend to get better grades and will work through issues when struggling in school. However those with entity orientation give up more easily. Since they assume they are just naturally not intelligent based on the feedback they are given from our education system they see little point in trying to improve and have low confidence. Young girls when in regards to math and science tend to have an entity orientation and low confidence in their abilities which prevents them from putting in effort.

Computer scientist Shilad Sen says he often sees in his own class, "Women come into my introduction to computer science class and when they don't quite get something, they think, *I don't get this, it looks like everyone else is getting this, I'm just not good at this,"* However, he says men just assume everyone else is equally stuck, "They think 'I don't get this, everyone else in the class doesn't get it either.'"

Girls are less likely to be encouraged to take an interest in math and science and since there is little to no representation in the field it can be assumed by young girls that being a mathematician or scientist is not meant for them.

I can recall from my own math classes struggling with problems and when working with my female classmates feeling that we were working together and helping one another. Whereas when working with male classmates I would have to prove my points and convince them of what I was doing. Even if what they were doing was wrong they would do everything with such confidence and lack of overthinking that most times when I was younger I would just accept everything they did as correct.

In middle school I remember feeling like I wanted to prove myself and was afriad of being viewed as "stupid." In my mind, owning the common "bad at math" label gave me control. So that if I didn't understand something or got a bad grade, no one would think less of me because I had already declared that this was not my strength. This to me seemed better than trying hard, appearing confident, and then failing. I've noticed that this seems to be a common pattern in students who don't excel in math.

A lot of this fear I think comes from a fear of failing, which unfortunately is the only alternative to being a naturally "brilliant math person" in our standard math education system. I remember thinking that I liked math because it was simple either you got it right or you got it wrong. However, now that I'm older and have learned a little bit more about math and the parts of it that interest me, I've found that I like it for the opposite reasons. I like that there are so many different ways to approach math in terms of the type of math your doing, what questions you're asking, how you want them answered, or simply the way you might approach solving an equation. There's always a way to make what your learning make sense by thinking about things differently.

This is something that I didn't realize until coming to Oxbow since I had been taught math one way my whole life. If I had never left my school I would have not known about different notations; I would not have seen the list of 5 different ways to write out the same answer that are all mathematically accurate written on our whiteboard. Which goes to show that our current math education system is limiting students and hindering their potential for mathematical ability, or the ability to "think like a scientist," by teaching math in such a constrictive way.

When we look into the history of math and those who, not only studied it, but made significant contributions to mathematics we see it as this newly discovered language that makes up the world around us. We can look to the universe and see signs of mathematical order in parts of our world that have no influence by humans. One example that illustrates the physical side of mathematical beauty is the flower of Venus. When Venus orbits the sun for 8 earth years we can see that the planet follows a pattern that draws out a five pointed flower. One that consists of overlapping cardiods, a mathematical shape named after it's heart-like appearance.

Alfréd Rényi, Paul Erdős, Henri Poincaré, John Dee, Hypatia and other historic mathematicians were all working creatively when making their contributions to mathematics. By teaching math as a creative subject we would be encouraging students to explore within their abilities and without the fear of failure. This could hopefully lead to less people having an almost universal phobia of mathematics.

In an english class we are taught that critical feedback is a positive message to improve your work. Whereas in math students are penalized for mistakes and wrong answers. In english we read work from different authors and talk about what that specific author was thinking and writing about. We learn about history through reading and talking about what we read in class. In Math we are shown theorems and equations as facts that seem to appear out of nowhere. If we were taught math in a way that also included the history and reasoning behind different math concepts, math would most likely seem less foreign to students.

This better understanding of math as a whole could inspire students to see mathematical beauty and spark a passion to work through different math problems. This could also inspire more young girls to study math and bring more women into the STEM fields. I know that through my research and now somewhat better understanding of the vast world of math I want to pursue it in the future. Especially being a girl, I want to be able to break up the "boys club" of mathematics. The lack of women in the field only encourages me more to disrupt mathematics male dominated trend and interject myself into the field.

In conclusion by shifting our interpretation of math as a creative and exploratory subject rather than a set of rules followed by graded punishments we can put a wrench in the cycle of false presentation of math in school. This change in perspective would likely reduce the amount of tears shed over math homework and help people to enjoy math and see it as a beautiful part of our world.

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