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Reflections:
Explorations on Popular Representations of Mathematics

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26 April 2019
Media Studies Senior Project
Advisor: Tom Ellman

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Finally, I wish to thank my family and friends for their support and encouragement throughout my study.

Introduction

“Theorem 1. *Take two mirrors in \mathcal{R}^2 that pass through 0 and have root vectors α and β . Let $\theta (\leq \pi/2)$ be the dihedral angle between the mirrors, and let C be the closed wedge between the mirrors. Assume that the interior of C does not contain any virtual mirror generated by multiple reflections in the two mirrors...*”¹

Be honest. Did you even attempt to read that? Or did your eyes glaze over as the very idea of mathematics fatigued you? Don’t worry. You are not the only one. Indeed, I expect this to be the most common reaction. Math is hard; it takes years of continual practice and growth to reach a point of confidence. However, it is not as inaccessible as our culture would lead us to believe.

As the title of my thesis, “Reflections,” implies, I will reflect upon the ways in which beliefs around math anxiety and cultural representations of math achievement further the negative manner in which math is regarded in modern American culture. Furthermore, I will create an installation with the goal to encourage a different perception of mathematics.

Through a three-pronged approach, I will investigate the ways in which society views mathematics. I will begin with an exploration of math anxiety. It causes people to react negatively to math. Furthermore, the widespread acceptance of math anxiety augments these negative sentiments. Then I will analyze various cultural stereotypes to understand the representations of mathematics. Cultural stereotypes further the reach of math anxiety. Negative representations of mathematics and, moreover, of people who have high math

¹ Roe Goodman, “Alice through Looking Glass after Looking Glass: The Mathematics of Mirrors and Kaleidoscopes,” *The Mathematical Association of America* 111, (April 2004): 281.

achievement deepen these feelings. Finally, I will create an installation. The goal of the installation will be to encourage a different perception of mathematics.

Math Anxiety

(i) “The group G of matrices

$$I_2, R_\alpha, R_\beta, R_\alpha R_\beta, R_\beta R_\alpha, R_\alpha R_\beta R_\alpha, \dots$$

generated by R_α and R_β is finite if and only if $\theta = \pi/m$ for some integer $m > 2$. In this case G is the dihedral group $I_2(m)$ of symmetries of the regular polygon with $2m$ sides...”²

What is math anxiety?

Often, it is said that mathematics remains unimportant outside the classroom and within normal, everyday life.³ However, this misconception leads to greater math anxiety throughout society as a whole. Math is ingrained into everyday life. From simply adding a tip to evenly dividing a cake, mathematics is at the basis of many human interactions. Simply put, math is important. To believe differently is absurd. It would be extremely detrimental to one’s future success if they are stricken by anxiety every time they have to complete the most basic of calculations. Math anxiety and, moreover, its widespread acceptance throughout American culture cause people to view math as an inaccessible subject.

Math anxiety is when anxiety affects one’s achievement within mathematical subjects.⁴ It is a detrimental emotional response to either the math or the anticipation of doing

² Roe Goodman, “Alice through Looking Glass after Looking Glass: The Mathematics of Mirrors and Kaleidoscopes,” *The Mathematical Association of America* 111, (April 2004): 281.

³ Erin A. Maloney, and Sian L. Beilock, “Math Anxiety: Who Has It, Why It Develops, and How to Guard against It, in *The Best Writing on Mathematics 2013*, edited by Pitici Mircea, by Penrose Roger. Princeton University Press, 2014, 144.

⁴ Mark H. Ashcraft and Jeremy A. Krause, “Working Memory, Math Performance and Math Anxiety,” *Psychonomic Bulletin and Review*, 14 (2007): 245.

the math.⁵ This fear often follows the sufferer outside of the classroom. Everyday activities, such as calculating a tip or comprehending sporting statistics, elicit strong adverse emotions.⁶ Despite otherwise ordinary reasoning abilities, people with math anxiety perform inadequately when numerical information is involved.

While math anxiety is an immense detriment to math achievement, it is not demonstrative of a lower intellect level.⁷ The high levels of anxiety cause the brain to function at a lower ability, which in turn results in low math achievement. Low achievement is then regarded as an example of the sufferer's low math ability, which increases their math anxiety, resulting in even lower mathematical success.⁸ Truly, the danger of math anxiety resides in the cyclical nature of its behavior and growth.

Furthermore, because math anxiety afflicts the sufferer outside the math classroom and follows them into the "real world," it is of great importance that math anxiety becomes more greatly recognized. Moreover, the lack of methods for the opposition of math anxiety furthers the deep and lasting influences of math anxiety throughout the sufferer's life.⁹

⁵ Erin A. Maloney, and Sian L. Beilock, "Math Anxiety: Who Has It, Why It Develops, and How to Guard against It, in *The Best Writing on Mathematics 2013*, edited by Pitici Mircea, by Penrose Roger. Princeton University Press, 2014, 144.

⁶ Maloney, 143.

⁷ Mark H. Ashcraft and Jeremy A. Krause, "Working Memory, Math Performance and Math Anxiety," *Psychonomic Bulletin and Review*, 14 (2007): 245.

⁸ Ashcraft, 245.

⁹ Ashcraft, 245.

Because math anxiety can affect people throughout their entire lives, it is vitally important that it can be combatted against.¹⁰

How it begins

Recent studies on math anxiety have proven that it begins at a much earlier age than previously thought. Originally, it was thought to begin during junior high, accompanying the increase in difficulty in the subject.¹¹ However, math anxiety takes hold during early childhood, the first years of elementary school.¹² Therefore, because math anxiety begins at a stage of childhood, the reasons behind its conception must be rethought.

The conception of math anxiety is believed to be provoked by elementary school teachers and the dissemination of their personal negative sentiments towards math.¹³ Throughout all college majors, the students who report the highest amounts of math anxiety are elementary education majors.¹⁴ These teachers then go on to proliferate their anxieties to the young students they teach. As elementary school teachers are responsible for a

¹⁰ Ashcraft, 245.

¹¹ Erin A. Maloney, and Sian L. Beilock, "Math Anxiety: Who Has It, Why It Develops, and How to Guard against It, in *The Best Writing on Mathematics 2013*, edited by Pitici Mircea, by Penrose Roger. Princeton University Press, 2014, 144.

¹² Maloney, 144.

¹³ Sian L. Beilock, Elizabeth A. Gunderson, Gerardo Ramirez, Susan C. Levine, and Edward E. Smith, "Female Teachers' Math Anxiety Affects Girls' Math Achievement," *Proceedings of the National Academy of Sciences of the United States of America* 107, no. 5 (2010): 1860.

¹⁴ Beilock, 1861.

generation's first introduction to mathematics, the manner in which they approach the subject will greatly influence their students' interactions with the material. Studies have found that students placed in classes with teachers with math anxiety are negatively influenced by their teacher's anxiety.¹⁵ When comparing students' rates of math anxiety from the begin of the school year with their rates from the end of the year, the reported levels of math anxiety always rise in accordance with the math anxiety reported by the teacher.¹⁶

Furthermore, it would be highly imprudent to discuss math anxiety without also detailing the gender disparity of the sufferers. Math anxiety is more commonly found within girls.¹⁷ At least partially, this discrepancy can be attributed to the high prevalence of female elementary school teachers.¹⁸ As most elementary school teachers are female, they are most often the ones disseminating their negative mathematical sentiments to their students. When their students are tested for math anxiety, the female students are always more highly affected

¹⁵ Beilock, 1861.

¹⁶ Beilock, 1862.

¹⁷ Erin A. Maloney, and Sian L. Beilock, "Math Anxiety: Who Has It, Why It Develops, and How to Guard against It, in *The Best Writing on Mathematics 2013*, edited by Pitici Mircea, by Penrose Roger. Princeton University Press, 2014, 143.

¹⁸ Sian L. Beilock, Elizabeth A. Gunderson, Gerardo Ramirez, Susan C. Levine, and Edward E. Smith, "Female Teachers' Math Anxiety Affects Girls' Math Achievement," *Proceedings of the National Academy of Sciences of the United States of America* 107, no. 5 (2010): 1862.

by the anxious teachers.¹⁹ Young children desire to emulate the same sex adults around them.²⁰ Therefore, the young girls emulate their female teachers; the math anxiety exemplifies the adults around them. Male elementary school teachers do not have the same effect on their students. As more than 90% of elementary school teachers in the United States are female, any effects of male elementary school teachers are deemed negligible.²¹ Moreover, students tend to emulate their same-sex teachers. Therefore, the female students would not mirror their male elementary school teachers to the same degrees as they would female. However, male students do not emulate their elementary school teachers to the same degree as female students. Due to the gender differences in cognitive and emotional development, young boys are often unable to make the necessary emotional connection needed to emulate their teachers to the same degree as girls.²²

¹⁹ Erin A. Maloney, and Sian L. Beilock, "Math Anxiety: Who Has It, Why It Develops, and How to Guard against It, in *The Best Writing on Mathematics 2013*, edited by Pitici Mircea, by Penrose Roger. Princeton University Press, 2014, 145.

²⁰ Sian L. Beilock, Elizabeth A. Gunderson, Gerardo Ramirez, Susan C. Levine, and Edward E. Smith, "Female Teachers' Math Anxiety Affects Girls' Math Achievement," *Proceedings of the National Academy of Sciences of the United States of America* 107, no. 5 (2010): 1863.

²¹ Erin A. Maloney, and Sian L. Beilock, "Math Anxiety: Who Has It, Why It Develops, and How to Guard against It, in *The Best Writing on Mathematics 2013*, edited by Pitici Mircea, by Penrose Roger. Princeton University Press, 2014, 145.

²² Sian L. Beilock, Elizabeth A. Gunderson, Gerardo Ramirez, Susan C. Levine, and Edward E. Smith, "Female Teachers' Math Anxiety Affects Girls' Math

The gender disparity is furthered by the gender stereotypes of math achievement. Throughout Western culture, there exists the stereotype that boys are good at math and, therefore, girls are not.²³ Researchers find that when girls present with high levels of math anxiety, they utilize this stereotype to justify their anxiety and the resulting low achievement.²⁴ Concordantly, math anxiety affects the college majors and future careers these girls choose.²⁵ Therefore, the high rates of math anxiety found within girls must be at least partially responsible for the gender disparities found within STEM fields.²⁶

How it affects math achievement

In order to understand the myriad ways in which math anxiety affects math achievement, an exploration between cognitive function, effects of memory, and math achievement is vital. For high success within mathematics, the student requires the capacity

Achievement," *Proceedings of the National Academy of Sciences of the United States of America* 107, no. 5 (2010): 1863.

²³ Erin A. Maloney, and Sian L. Beilock, "Math Anxiety: Who Has It, Why It Develops, and How to Guard against It, in *The Best Writing on Mathematics 2013*, edited by Pitici Mircea, by Penrose Roger. Princeton University Press, 2014, 145.

²⁴ Maloney, 145.

²⁵ Sian L. Beilock, Elizabeth A. Gunderson, Gerardo Ramirez, Susan C. Levine, and Edward E. Smith, "Female Teachers' Math Anxiety Affects Girls' Math Achievement," *Proceedings of the National Academy of Sciences of the United States of America* 107, no. 5 (2010): 1863.

²⁶ Beilock, 1864.

for abstract thought. This is typically a late developmental milestone.²⁷ Therefore, because students often lack this ability when they are first exposed to intricate mathematical equations and systems, their ability is actually hindered by their cognitive development. High levels of mathematical achievement are nearly impossible without this ability.²⁸ Accordingly, the students' first interactions with mathematical subjects forever taint the subject as inaccessible. It is nearly impossible to alter these perceptions, even after the ability for abstract thought develops. These negative feelings only augment throughout the student's further interactions with mathematics.

Additionally, there exists a further and deeper connection between anxiety and its effects on memory. Math anxiety leads to a lower amount of achievement. Anxiety consumes most of the brain's energy.²⁹ Because the math anxiety requires so much of the brain's focus, there is then less energy available for the act of remembrance and the execution of mathematical equations and systems. Due to the anxiety, the student then has low mathematical performance. This is taken by the student as an example of their ineptitude, which then leads to an increase in their math anxiety. In other words, as math anxiety increases, math achievement decreases concordantly. Therefore, if a student never confronts their math anxiety, it will keep affecting them to higher and higher degrees.

Anxiety acts an intense deterrent to one's mathematical achievement, however it is not representative of a student's intelligence.

²⁷ Mark H. Ashcraft and Jeremy A. Krause, "Working Memory, Math Performance and Math Anxiety," *Psychonomic Bulletin and Review*, 14 (2007): 245.

²⁸ Ashcraft, 246.

²⁹ Ashcraft, 247.

How to combat math anxiety

Due to the fact that the effects of math anxiety follow the sufferer throughout their entire life, it is of vital importance that math anxiety is faced head on and successfully combatted against. In many schools, educators have attempted to combat math anxiety by providing more rigorous training and education.³⁰ However, this course of action has proven to be completely ineffective.³¹ If highly anxious students are faced with more rigorous material without first obtaining effective coping mechanisms, their anxiety will steadily increase in accordance with the difficulty of the material.

In order to successfully manage math anxiety, the educator must not approach it from the belief that the student's math ability is the issue. Instead, the problem lies with the anxiety and providing the student with capabilities to manage it. In order to alleviate the effects of math anxiety, the students must be taught how to cope with their anxiety, which needs to be confronted head on in order for the student to overcome it. The students must realize the extent to which the anxiety affects their math achievement. Moreover, the students must recognize their anxiety has no bearing on their intelligence. The only obstacle to high mathematical achievement is their anxiety.

³⁰ Erin A. Maloney, and Sian L. Beilock, "Math Anxiety: Who Has It, Why It Develops, and How to Guard against It, in *The Best Writing on Mathematics 2013*, edited by Pitici Mircea, by Penrose Roger. Princeton University Press, 2014, 145.

³¹ Mark H. Ashcraft and Jeremy A. Krause, "Working Memory, Math Performance and Math Anxiety," *Psychonomic Bulletin and Review*, 14 (2007): 247.

Furthermore, in order to lead to an increase in girls' math achievement it is necessary to breakdown the gender stereotypes.³² As long as the stereotype of girls being bad at math exists, the lack of gender diversity in STEM will remain the norm and, concordantly, their presence will remain transgressive.

³² Sian L. Beilock, Elizabeth A. Gunderson, Gerardo Ramirez, Susan C. Levine, and Edward E. Smith, "Female Teachers' Math Anxiety Affects Girls' Math Achievement," *Proceedings of the National Academy of Sciences of the United States of America* 107, no. 5 (2010): 1864.

Cultural Stereotypes

- (ii) “Assume that $\theta = \pi / m$. The images $g \bullet C$ for g in G (the “fundamental chamber” for $g = 1$ and the “virtual chambers” for $g \neq 1$) have disjoint interiors and fill up \mathfrak{R}^2 . Furthermore, if $gC = C$ then g is the identity matrix. Hence the chambers (fundamental and virtual) correspond uniquely to the elements of G . In particular, $|G| = 2m \dots$ ”³³

Within Western culture, there exists a dichotomy between the humanities and the sciences.³⁴ It is a commonly held belief that these two cultures exist on completely opposite ends of the spectrum of society.³⁵ Each of these cultures maintains their own stereotype. The humanities are overly concerned with past events, while the sciences are too focused on the future.³⁶ The intersections of the stereotypes are elided in favor of maintaining the divisions.³⁷ While one could say that both the humanities and the sciences have issues with relating to the present, any and all intersections are omitted. Moreover, society decrees that a person cannot exist in both cultures at the same time.³⁸ These divisions contribute to the negative stereotypes surrounding mathematics.

Representations in popular cultures possess a vital role in the ubiquity and pervasiveness of the negative coding and reception of the nerd. They influence the way we

³³ Roe Goodman, “Alice through Looking Glass after Looking Glass: The Mathematics of Mirrors and Kaleidoscopes,” *The Mathematical Association of America* 111, (April 2004): 281.

³⁴ C. P. Snow and Stefan Collini, *The Two Cultures*, Canto Classics, Cambridge: Cambridge University Press, 2012.

³⁵ Snow, 2012.

³⁶ Snow, 2012.

³⁷ Snow, 2012.

³⁸ Snow, 2012.

think about the realities of myriad social groups.³⁹ The way social groups are treated in widespread representation affects the way they are treated in real life.⁴⁰ These representations delimit and enable what people can be in society.⁴¹ It is from stereotypes that society receives its ideas about various social groups.⁴² Moreover, these stereotypes demonstrate who is able to belong to a certain social group.⁴³ Due to the wide distribution of the stereotypes, their codes are vulnerable to being regarded as natural.⁴⁴ In other words, because representations in popular culture present nerds as awkward and weird, these ideas become connotative links to the whole conception of being a nerd.

Stereotypes vary across cultures; they are the results of the history and knowledge of their society.⁴⁵ Therefore, the audience must be part of the same society as the encoder.⁴⁶

³⁹ Richard Dyer, *The Matter of Images: Essays on Representation*. New York: Routledge, 2002.

⁴⁰ Dyer, 1.

⁴¹ Dyer, 3.

⁴² Dyer, 14.

⁴³ Dyer, 15.

⁴⁴ Stuart Hall, "Encoding, decoding," in *The Cultural Studies Reader*, ed. by Simon During, (New York: Routledge, 1993), 96.

⁴⁵ Roland Barthes, "The Death of the Author," *The Book History Reader*, 2002. 224.

⁴⁶ Richard Dyer, *The Matter of Images: Essays on Representation*. New York: Routledge, 2002, 12.

In order for the audience to correctly decode these meanings, the filmmakers require an audience that works within the same set of cultural codes.⁴⁷ In other words, the creators and audience must work within the same culture, knowledge and history in order to understand each other clearly.⁴⁸ Furthermore, the meaning of these codes rely on the ones that came before them.⁴⁹ These meanings coalesce into a unified set of knowledge.⁵⁰ In order to fully decode a sign, it is important to situate it within the culture and dimensions in which it originated.⁵¹ The audience, therefore, must be aware of the previous codes and their meanings. For the following analysis of representations in popular culture, I will evaluate the dominant positions of coding. In other words, I will examine the encoded meanings that the filmmakers wanted the audience to receive.⁵² Within the following examination of nerd characters, I will be analyzing American films and television shows. I am part of American society, a member of the intended audience. Therefore, I will be able to fully decode the intended meanings behind these characters, as I share a history, culture, and knowledge with the encoders.

⁴⁷ Stuart Hall, "Encoding, decoding," in *The Cultural Studies Reader*, ed. by Simon During, (New York: Routledge, 1993), 101.

⁴⁸ Roland Barthes, "The Death of the Author," *The Book History Reader*, 2002. 224.

⁴⁹ Eco, Umberto. *A Theory of Semiotics*. Indiana: Indiana University Press, 1976.

⁵⁰ Eco, 1976.

⁵¹ Hall, 97.

⁵² Stuart Hall, "Encoding, decoding," in *The Cultural Studies Reader*, ed. by Simon During, (New York: Routledge, 1993), 101.

Traditional cultural stereotype

The stereotypical representation of the nerd character is a heterosexual, white male, whose high intelligence impedes his ability to foster genuine personal relationships.⁵³ He possesses little to no social skills and awareness, resulting in both his ostracization from the social order and his failure at romantic relationships.

There are two main methods of representation of a nerd character.⁵⁴ The first is the under-sexed teenage boy.⁵⁵ Stereotypically, he is lanky, thin, and clumsy. He has a face full of acne and oversized glasses. He wears a button-down shirt, a pocket protector, and a tie. A social failure, he is ostracized from the societal structures around him. His intellect causes an inability to connect socially with his peers, making him a target for taunting and bullying. The other representation is the mad scientist.⁵⁶ With his wild, unruly hair and oversized lab coat, the mad scientist spends his time ranting and raving about. Like the teenage nerd, he is unable to connect socially with those around him. However, whereas the teenage boy is completely preoccupied with achieving the respect of his peers, the mad scientist lives in his own world. He is content to be left alone.

⁵³ Lori Kendall, ““White and Nerdy”: Computers, Race, and the Nerd Stereotype,” *Journal of Popular Culture* 44, no. 3 (2001): 507.

⁵⁴ Lori Kendall, “Nerd Nation: Images of Nerds in US Popular Culture,” *International Journal of Cultural Studies* 2, no. 2 (August 1999): 261.

⁵⁵ Lori Kendall, “Nerd Nation: Images of Nerds in US Popular Culture,” 262.

⁵⁶ Lori Kendall, “Nerd Nation: Images of Nerds in US Popular Culture,” 264.



Figure 1 Bill Haverchuck, a geek, from *Freaks and Geeks*

The television show *Freaks and Geeks* presents the lives of a myriad of teenage nerds.⁵⁷ The show follows an academically gifted teenage girl and her younger brother as they migrate through the various social cliques in their high school.⁵⁸ The geeks are often portrayed according to the traditional stereotype.

They are mostly white men from middle class

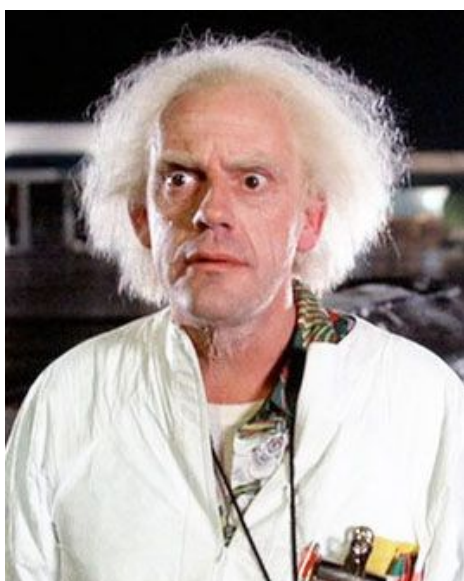


Figure 2 Doc Brown from *Back to the Future*

backgrounds, who are unattractive and socially awkward.

Seemingly as a result of their intelligence, they are separated from the mainstream culture of their school.

They are derided by the rest of the school. One of the most classic depictions of the mad scientist can be found in the character of Doc Brown in *Back to the Future*.⁵⁹

The characterization of Doc Brown relies on the stereotypical depiction of the mad scientist. With his crazy hair and jargon filled speech pattern, Doc Brown

exemplifies traditional caricature of the scientist. He is a white, aging man clad in a white lab coat and gloves. While expressive in his communication, he often struggles to communicate clearly with the people around him.

⁵⁷ *Freaks and Geeks*, season 1, episode 1, “Pilot,” directed by Jake Kasdan, aired September 25, 1999, on Fox. Television show.

⁵⁸ *Freaks and Geeks*. Television show.

⁵⁹ *Back to the Future*, directed by Robert Zemeckis, performed by Michael J. Fox and Christopher Lloyd, Universal Pictures, 1985, film.

Many depictions of nerd characters are problematic in the ways in which they present mental illness and their effects on intelligence. Therefore, it is important to include a discussion of the representations of mental illness in this paper. However, this is will not be an depth examination, as only a cursory analysis is required for this essay. For these characters, their mental illnesses are responsible for the unique methods of thinking. However, the prevalence of these depictions circulates the problematic idea that all people with mental illnesses are intelligent.⁶⁰ Moreover, there is an implicit understanding that it is their intelligence that makes them acceptable within mainstream society. Creating a link between mental illness and intelligence diminishes the abilities and skills of mentally ill people.

In *A Beautiful Mind*, the protagonist, John Nash, is an extremely talented mathematician, who happens to have schizophrenia.⁶¹ While his antisocial behavior is a direct result of his mental illness, the film creates a connection be his genius and his lack of social awareness. Like a stereotypical nerd, he is a white man, who is unable to properly connect with society. His genius is portrayed as an effect of his schizophrenia when this is most definitely not the case. Not everyone with schizophrenia is a mathematical genius. This link between mental illness and genius is furthered by the film *Rain Man* and its portrayal of an autistic savant.⁶² The character has forever created a link between mental illness and

⁶⁰ Ron Eglash, "Race, Sex, and Nerds: From Black Geeks to Asian American Hipsters," *Social Text* 20, no. 2 (June 2002): 51.

⁶¹ *A Beautiful Mind*, directed by Ron Howard, performed by Russell Crowe and Ed Harris, Universal Pictures, 2001, film.

⁶² *Rain Man*, directed by Barry Levinson, performed by Dustin Hoffman and Tom Cruise, MGM/UA Communications Company, 1988, film.

intelligence. The term Rain Man now creates a shorthand for autism and savantism. Again, this underscores the idea that an intelligent person is unable to connect to and communicate with the others around him. Furthermore, the idea that mentally ill people will only be tolerated due to their intellect is furthered by the television show *Sherlock*.⁶³ The main character of Sherlock Holmes is a stereotypical nerd. He is a tall, thin, white man with wild hair. He has very poor social skills and is often inconsiderate. He also has rude manners when interacting with other people. However, these negative character traits are quickly forgiven in exchange for his intellect and deduction skills.

The representations of the awkward teenage boy and the socially isolated mad scientist share many characteristics. They are always heterosexual, white men. With middle-class to upper-class backgrounds, they have seemingly unlimited resources for their inventions and experiments. Yet, they never seem to have a job. Furthermore, nerds are coded as queer. The film *Rebel Without a Cause* presents a nerd character who is overtly coded as queer.⁶⁴ Sal Mineo's character of John "Plato" Crawford is a stereotypical nerd. He is socially awkward and made fun of by his peers. Plato is also homosexual. While not overt, his feelings towards James Dean's character of Jim Stark are shown throughout the film. The stereotype of nerd already struggles with how to codify one's masculinity. By having Plato be both a nerd and gay, the film signifies that if someone is a nerd then they are at risk at losing any semblance of socially acceptable masculinity.

⁶³ *Sherlock*, Season 1, episode 1, "A Study in Pink," directed by Paul McGuigan, aired 25 July 2010, on BBC. Television show.

⁶⁴ *Rebel Without a Cause*. Directed by Nicholas Ray. Performed by James Dean and Sal Mineo. Warner Bros., 1955, film.

Nerdy characters and qualities are often emphasized by placing characters in contrast with a relationship with a hypermasculine, jock character.⁶⁵ In many depictions, the nerds spend the entire film or television show concerned with their masculinity.⁶⁶ They spend their time devising ways in which to prove their masculinity to their peers and romantic interests. The film *Revenge of the Nerds* is a prime example of a nerd's quest to prove their masculinity.⁶⁷ In this film, the nerds adhere greatly to the traditional stereotype. They are white, socially awkward, and unattractive. While searching for acceptance within their college society, the nerds decide to create their own fraternity. They are continually harassed by the jocks' fraternity and its sister sorority. This fosters the idea that nerds exist outside of society and require their own spaces. Furthermore, this creates the idea that nerds are continually attempting to fall in line with the norms of hegemonic masculinity; they want to be accepted by the very society that condemns them. Only when nerds behave in stereotypically masculine ways do they become accepted. For example, when the character Lewis tricks Betty into sleeping with him, she does not feel angry and violated. She, instead, falls in love with him. Only by acting in a horrid and manipulative fashion does Lewis become accepted by Betty. The nerds spend the entirety of the film attempting to prove their masculinity to both the people around them and to themselves.

⁶⁵ Christine Quail, "Nerds, Geeks, and the Hip/Square Dialectic in Contemporary Television," *Television & New Media* 12, no. 5 (September 2011): 467.

⁶⁶ Lori Kendall, "'White and Nerdy': Computers, Race, and the Nerd Stereotype," *Journal of Popular Culture* 44, no. 3 (2001): 510.

⁶⁷ *Revenge of the Nerds*, directed by Jeff Kanew, performed by Robert Carradine and Anthony Edwards, 20th Century Fox, 1984, film.

Within the dichotomy of the dumb jock and the science nerd, an inverse relationship between mental and physical strength emerges.⁶⁸ The physical strength of the jocks must be contrasted with their mental ineptitude, while the high intelligence of the nerds must be contrasted with their physical weakness. American culture states that a person must exist as one or the other. Disrupting the status quo is a highly transgressive act and ultimately leads to ostracization. If a person breaks this dichotomy (i.e. an intelligent athlete), they are implicitly forced to choose one social sphere and behave in according to this single stereotype.⁶⁹

An example of this forced adherence to a stereotype can be found in the film *Never Been Kissed*.⁷⁰ The film follows Drew Barrymore's character, a reporter, who gets sent back to her old high school to cover the high school social scene by going undercover.⁷¹ When Drew Barrymore's character was originally in high school, she was constantly made fun of due to her studious personality and involvement in the math club. When she goes back for her assignment, she first joins the math club again and as a result she is again unpopular. After she quits the club, she automatically becomes more popular and accepted throughout the school. However, in order to obtain this popularity, she pretends to be completely unintelligent. This highlights the idea that an intelligent person cannot be socially accepted.

⁶⁸ Todd Jones, "The Dumb Jock and the Science Nerd," *The Humanist*, September-October 1996, 44. *Expanded Academic ASAP* (accessed February 1, 2019).

⁶⁹ Jones, "The Dumb Jock and the Science Nerd."

⁷⁰ *Never Been Kissed*, directed by Raja Gosnell, performed by Drew Barrymore and David Arquette, 20th Century Fox, 1990, film.

⁷¹ *Never Been Kissed*, film.

Another example of this can be found in the film *Mean Girls*.⁷² When Cady moves from Africa to Illinois, she discovers the power of high school stereotypes. Though she loves math and wants to join the mathletes, she is very soon discouraged because she is told that it will ruin her social standing. In order to be popular, Cady pretends that she has no interest in mathematics. This emphasizes the idea that a person can only exist as part of a single culture.

Within films and television shows, the nerd is commonly placed within a relationship with a contrasting socially skilled, athletic figure.⁷³ This dichotomy emphasizes each character's personality. Often the nerd is portrayed as a sympathetic figure, the sidekick to their popular friend. While their friend is meant to be the epitome of masculinity, the nerd serves as an example of how a loss of masculinity leads to bullying and unpopularity. The jock, on the other hand, is meant to be the masculine example for the audience to strive for.

In the film *Grease*, an example of this dichotomy plays a role in the characterization of the protagonists.⁷⁴ The main characters of the film, the T-Birds and the Pink Ladies, are cool. Their coolness is underscored by the fact that they do not take school seriously and do not receive good grades. This highlights the idea that smart, serious people are socially awkward and uncool. This is further by the characters of Eugene Felsnick and Patty Simcox. Eugene is bullied by the T-birds for his intelligence and has no romantic interests. Patty is bullied by the Pink Ladies for her devotion to school activities. Both characters are meant to

⁷² *Mean Girls*, directed by Mark Waters, performed by Lindsay Lohan and Rachel McAdams, Paramount Pictures, 2004, film.

⁷³ Christine Quail, "Nerds, Geeks, and the Hip/Square Dialectic in Contemporary Television," *Television & New Media* 12, no. 5 (September 2011): 475.

⁷⁴ *Grease*, directed by Randal Kleiser, performed by John Travolta and Olive Newton-John, Paramount Pictures, 1978, film.

be annoying and weird. The awkward nerds only serve to highlight the perceived coolness of the other characters. Another example of this contrast can be found in the television show *Numb3rs*.⁷⁵ Charlie Epps adheres greatly to the traditional stereotype. He has unruly, curly hair and is wary of people. He often relies on his brother to further communication and foster connections with other people. A math prodigy, Epps views the world differently than the others around him. Literally. His insights and ideas about the world around him are shown in fast cuts and a yellow tinge to the screen. This underscores his differences from other people. This difference is then emphasized by the character of Don Epps, Charlie's older brother. Whereas Charlie is a socially awkward academic, Don is an accomplished FBI agent who is renowned for his ability to connect with people. Their dynamic has an implicit message that while Charlie is an intriguing and sympathetic character, Don will always be the hero at the end of the day.

In film and television shows, nerd characters are represented as an awkward, math savvy individuals, who are romantic and sexual failures. The audience is meant to disregard them and not to emulate them. Because the nerd is cast in an unfavorable light by the dominant depictions, they are then regarded in the same manner in their real lives. Furthermore, because the term nerd carries a connotative link of math and science achievement, these ideas are also tainted by the negative sentiments.

⁷⁵ *Numb3rs*, season 1, episode 1, "Pilot," directed by Mick Jackson, aired January 23, 2005, on CBS. Television show.

Complications to the traditional stereotype

As a direct result of the tech boom of the late 1990s and early 2000s, the very concept of the nerd began to evolve.⁷⁶ While the term “nerd” is still used in the pejorative sense, nerds now have the ability to become accepted within mainstream society for the very qualities they were once derided for.⁷⁷ Expertise and knowledge within STEM fields is now regarded as enviable. However, this acceptance is only partial. It only extends to the successful (i.e. wealthy) nerd.⁷⁸ Truly, the nerds will only be accepted as long as they are successful in their endeavors. Furthermore, gender, race, and sexuality disparities still exist within this acceptance. Moreover, many modern nerd characterizations have overcompensated for their long history of derision in popular films and television shows. Instead of now being portrayed in sensitive and positive lights, the nerd is now portrayed as rude and remote. The nerd now attempts to reclaim their masculinity by refusing to partake in society.⁷⁹

Myriad television shows and films attempt to provide a deeper insight into nerds. The television show *The Big Bang Theory* attempts to evolve the depictions of nerds.⁸⁰ By showcasing the main scientists in a sympathetic light, the show attempts to allow the

⁷⁶ Margaret A. Weitekamp, “‘We’re Physicists’: Gender, Genre and the Image of Scientists in *The Big Bang Theory*,” *Journal of Popular Television* 3, no. 1 (April 2015): 76.

⁷⁷ Ron Eglash, “Race, Sex, and Nerds: From Black Geeks to Asian American Hipsters,” *Social Text* 20, no. 2 (June 2002): 50.

⁷⁸ Eglash, 51.

⁷⁹ Jennifer Wright, “Jocks Rule, Nerds Drool,” *New York Times*, New York: New York Times Company, 18 August 2018.

⁸⁰ *The Big Bang Theory*, season 1, episode 1, “Pilot,” directed James Burrows, aired September 24, 2007, on CBS. Television show.

protagonists to become fully round, instead of complete caricatures. On the television *Gilligan's Island*, the Professor plays against the traditional stereotype of the mad scientist.⁸¹ Instead of an old and asocial man, he is shown as relatively young and attractive. Furthermore, he is presented as a viable romantic interest to the women of the island.

Both films *Good Will Hunting* and *Quiz Show* present nerds who come from lower-class society and blue-collar families. In *Good Will Hunting*, the genius protagonist of Will Hunting is a janitor at Harvard College.⁸² This difference is vitally important to the characterization of Will Hunting. He is self-taught. The other characters are astounded that a lowly janitor could possibly be so intelligent. This underscores the idea that intelligent people do not do manual labor. In *Quiz Show*, this film demonstrates the classism of intelligence.⁸³ John Turturro's character, Herb Stempel, is a poor veteran who is attending a community college on the G.I. Bill. He is contrasted by Ralph Fiennes character, Charles van Doren, is a highly intelligent professor at Columbia University from a prominent New York family. While each character is remarkably intelligent, classism influences the way in which each is viewed by the public. With this ill-fitting clothes and accent, Stempel was seen as nerd and was reviled by the audience of the show. On the other hand, van Doren wore nice clothes and spoke in a refined fashion. He was regarded as an erudite intellectual.

⁸¹ *Gilligan's Island*, season 1, episode 1, "Two on a Raft," directed by John Rich, aired September 26, 1964, on CBS. Television show.

⁸² *Good Will Hunting*, directed by Gus Van Sant, performed by Matt Damon and Ben Affleck, Miramax Films, 1997, film.

⁸³ *Quiz Show*, directed by Robert Redford, performed by John Turturro and Ralph Fiennes, Buena Vista Pictures, 1994, film.

The traditional stereotype demonstrates the pervasiveness of the negative stereotypes surrounding math achievement. A mathematically gifted character is automatically ostracized and regarded as aberrant by those around him. Due to the pervasiveness of these negative stereotypes within film and television shows, they take hold in real life. Nerds are negatively regarded by society at large. Therefore, there needs to be a positive change in their representations.

Race and cultural stereotypes

Racially diverse depictions of nerds result in the emphasis of the non-white race. The term “nerd” carries a connotative meaning of whiteness.⁸⁴ This connotation is furthered by the ubiquity of white nerds in popular culture.⁸⁵ The whiteness of nerds because an invisible feature; the whiteness is an assumed characteristic of the nerd.⁸⁶ Only when a representation breaks with this mold does the race of character then become visible.⁸⁷ Therefore, it is vitally important that representations of nerds of color begin to be as prominent as white nerds. Only when whiteness becomes noticeable, not assumed, will there be a racial equality of the representations.

⁸⁴ Richard Dyer, *White*. New York: Routledge, 1997.

⁸⁵ Stuart Hall, “Encoding, decoding,” in *The Cultural Studies Reader*, ed. by Simon During, (New York: Routledge, 1993), 93.

⁸⁶ Richard Dyer, *White*. New York: Routledge, 1997.

⁸⁷ Richard Dyer, *White*. New York: Routledge, 1997.

At the core of the traditional depiction of a nerd lies the question of race. The term “nerd” contains signifiers which imply the existence of a white man.⁸⁸ Therefore, whenever the character is of a different race, it becomes a somewhat transgressive representation. Different races then contribute their own stereotypes on top of the stereotype of the nerd. These additional stereotypes have the ability to either strengthen or contrast with the nerd characterization.⁸⁹ Asian American characters further the nerd stereotype. Due to their race, they are already stereotyped as timid, asexual beings; this stereotype corresponds perfectly with the stereotype of the nerd.⁹⁰ On the other hand, African Americans are stereotyped as over-sexualized beings, who radiate a sense of calm and cool.⁹¹ This is directly at odds with the nerd stereotype, which is a sexual and social failure. While depictions of Asian American nerds are prevalent, African American nerds seem counter-intuitive.

The film *The Goonies* provides an example of an Asian American nerd.⁹² The character of Data adheres to the traditional



Figure 3 Data from *The Goonies*

⁸⁸ Ron Eglash, “Race, Sex, and Nerds: From Black Geeks to Asian American Hipsters,” *Social Text* 20, no. 2 (June 2002): 52.

⁸⁹ Lori Kendall, ““White and Nerdy”: Computers, Race, and the Nerd Stereotype,” *Journal of Popular Culture* 44, no. 3 (2001): 510.

⁹⁰ Lori Kendall, “Nerd Nation: Images of Nerds in US Popular Culture,” *International Journal of Cultural Studies* 2, no. 2 (August 1999): 265.

⁹¹ Ron Eglash, “Race, Sex, and Nerds: From Black Geeks to Asian American Hipsters,” *Social Text* 20, no. 2 (June 2002): 57.

⁹² *The Goonies*, directed by Richard Donner performed by Sean Astin and Josh Brolin, Amblin Entertainment, 1985, film.

stereotype in that he is a socially awkward male. He spends his time creating various inventions. They do not often have the intended result, which causes Data to often be the comedic relief within the film. Unlike other depictions, he is Asian American. With both his characterization and race, he is perceived as a nerd.

Often when Asian Americans and African Americans are depicted as nerds, the representations resemble tokenization rather than true racial representation. The stereotype of African Americans relies on the idea of an inherent sense of “coolness.” Because this trope contracts greatly with the nerd stereotype, African Americans are often not taken seriously within nerdy situations. According to a review of Best Buy’s Geek Squad, customers treat African Americans in STEM fields less seriously than their white or Asian colleagues.⁹³ While African Americans nerds are regarded as intelligent, their intelligence does not become a core part of their identity.⁹⁴ This is in contrast to their nerd peers, whose intelligence plays a key role in their personalities. Due to the diametric positionality of their stereotypes, African American nerds struggle to be taken seriously in many academic pursuits.

⁹³ Lori Kendall, ““White and Nerdy”: Computers, Race, and the Nerd Stereotype,” *Journal of Popular Culture* 44, no. 3 (2001): 513.

⁹⁴ Ron Eglash, “Race, Sex, and Nerds: From Black Geeks to Asian American Hipsters,” *Social Text* 20, no. 2 (June 2002): 58.



Figure 4 Steve Urkel from Family Matters

The television show *Family Matters* presented the first mainstream depiction of an African American nerd.⁹⁵ The character of Steve Urkel is now a staple of popular American culture. His depiction is the epitome of a nerd of the era. He has large, thick glasses, wears suspenders, and has a high-pitched voice. His clumsiness is often the cause of accidents throughout the show. While he is a genius and inventor, he is constantly made fun of by his peers. Furthermore, his inventions often have unintended consequences. Urkel is very socially unaware. While he has been in love with the same girl since the first grade, he does not recognize that his love is very unrequited. He also does not realize the Winslow family's disdain and annoyance at his behavior. He was often played for humor, which in part relied upon the audience's implicit bias that an African American nerd seems counter-intuitive at first.

The film *Jurassic Park* also plays upon these biases.⁹⁶ This film portrays a variety of nerds. There are women and people of color. However, the most interesting aspect of this film is the differing depictions of white nerds and people of color. Both Samuel L. Jackson and Wayne Knight portray intelligent scientists, who are integral to the park operations. Whereas Knight's character adheres greatly to the stereotypical nerd (ie white, socially awkward, not conventionally attractive), Jackson's character is portrayed as cool and

⁹⁵ *Family Matters*, season 1, episode 12, "Laura's First Date," directed by Richard Correll., aired December 15, 1989.

⁹⁶ *Jurassic Park*, directed by Steven Spielberg, performed by Sam Neill and Laura Dern, Amblin Entertainment, 1993, film.

interesting. This highlights the stereotype of cool African Americans. Even though both characters would be similar on paper, their depictions vary greatly due to their race.

Gender disparities

While nerds face ridicule in society, female nerds face further discrimination due to their gender. They struggle to be taken seriously by society-at-large, as well as within the nerd subculture. Because the term nerd carries a connotation of masculinity, females are not automatically coded as nerdy. However, because they do not conform to the stereotypes of femininity, nerdy females are not accepted by society.⁹⁷ If they behave in stereotypically nerdy ways, they will be ostracized from society; however, their acceptance by the nerd subculture is not guaranteed.⁹⁸ Therefore, many girls would rather hide their true nerdy interests in order to remain part of the status-quo.

Moreover, typically feminine characteristics are diametrically opposed to nerd characteristics. Many women find themselves sacrificing their femininity in order to be taken seriously within the nerd subculture.⁹⁹ It is difficult to present as feminine and also be assured that you will be taken seriously within academic pursuits. Women are often judged more

⁹⁷ Wilhelmina J. Vialle, "Pink or Paris? Giftedness in popular culture," *Australasian Journal of Gifted Education* 16, no. 1 (2007): 9.

⁹⁸ S. M. Pruitt, (2018), *Pwning it: Voices of nerd women in a male-dominated subculture* (Order No. 10636588), Available from ProQuest Dissertations & Theses Global. (2061861265).

⁹⁹ Christine R. Starr, "'I'm Not a Science Nerd!': STEM Stereotypes, Identity, and Motivation Among Undergraduate Women," *Psychology of Women Quarterly* 42, no. 4 (December 2018): 493.

harshly than men who are at their same intelligence level.¹⁰⁰ Because intelligence is an attribute that is coded as masculine, any sign of femininity is regarded as violating the social norms of intelligence, specifically within STEM fields. In accordance, any sign of intelligence is regarded as a contradiction of femininity. Overtly intelligent women are seen as less feminine.¹⁰¹ Therefore, society implicitly tells women that they must choose to be either feminine or intelligent; they are not permitted to exist as both.

The film *It's My Turn* emphasizes the struggle of women to be taken seriously in academia.¹⁰² This film goes against the traditional stereotype in that the main character is a beautiful and intelligent woman. She is the antithesis for the stereotype. Indeed, this is highlighted when her student refuses to recognize her authority because she does not conform to his ideas of

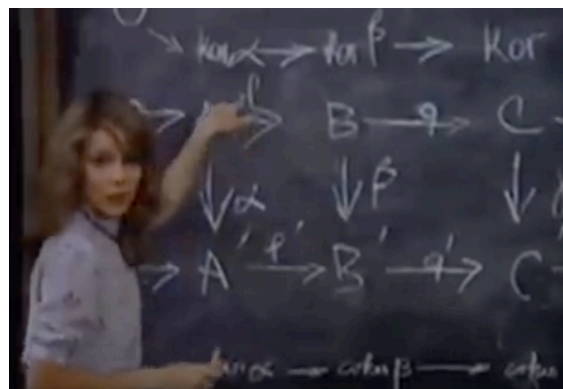


Figure 6 Kate Gunzinger from *It's My Turn*

what a math professor should look like. Even though she has all of the pertinent qualifications, she struggles to be taken seriously because of her gender. Part of this struggle lies within the main character's overt femininity. The television show *Good Trouble* also demonstrates the struggle of a feminine woman to be taken seriously in a STEM



Figure 5 Elle Woods from *Legally Blonde*

¹⁰⁰ Wilhelmina J. Vialle, "Pink or Paris? Giftedness in popular culture," *Australasian Journal of Gifted Education* 16, no. 1 (2007): 9.

¹⁰¹ Vialle, 10.

¹⁰² *It's My Turn*, directed by Claudia Weill, performed by Jill Clayburgh and Michael Douglas, Columbia Pictures, 1980, film.

field.¹⁰³ On her first day as a programmer at a top social media platform, the protagonist, Mariana, is told that she should be careful how she dresses while at work. Wearing dresses, frilly shirts, and heels become signifiers that she does not belong to the boys' club. These examples of her femininity will cause her coworkers to question her ability. This idea is also explored in the film *Legally Blonde*.¹⁰⁴ The main protagonist, Elle Woods, struggles to be taken seriously at Harvard Law. Due to her overtly feminine style, she is singled out amongst her peers. She is not taken seriously just because she chooses to wear pink.

Furthermore, even when women do adhere to all of the stereotypical nerd conventions, their acceptance to the nerd subculture is not guaranteed. Because of their gender female nerds are often accused of being fake fans or, worse, of faking their intellectual prowess.¹⁰⁵ Many times, women attempt to distance themselves from the nerd stereotype. As the term is still used in the pejorative sense, women do not want to risk further alienation within society.¹⁰⁶ Women are often forced to choose between overt intelligence or social acceptance.

¹⁰³ *Good Trouble*, season 1, episode 1, "DTLA," directed by John Cho, aired January 8, 2019, on Freeform. Television show.

¹⁰⁴ *Legally Blonde*, directed by Robert Luketic, performed by Reese Witherspoon and Luke Wilson, MGM Distribution Co., 2001, film.

¹⁰⁵ S. M. Pruitt, (2018), *Pwning it: Voices of nerd women in a male-dominated subculture* (Order No. 10636588), Available from ProQuest Dissertations & Theses Global. (2061861265).

¹⁰⁶ Christine R. Starr, "'I'm Not a Science Nerd!': STEM Stereotypes, Identity, and Motivation Among Undergraduate Women," *Psychology of Women Quarterly* 42, no. 4 (December 2018): 491.

Installation

(iii) “Assume that $\theta = \pi / m$. As an abstract group G is generated by $a = R_\alpha$ and $b = R_\beta$ with all relations generated by the three relations

$$a^2 = 1, \quad b^2 = 1, \quad (ab)^m = 1 \dots$$
¹⁰⁷

Math can be fun, exciting, engaging and life-changing.

When I was a child, my favorite museum was the Discovery Center of Idaho. An interactive math and science museum, I spent hours wandering around the building. Every time I went, I would run to the second room, the Blue Room, and turn to the left. After I ducked under the red echo-chamber, my favorite installation would be in front of me. It was a triangle of mirrors. Crouching below the frame, I climbed onto the stool in the center of the piece. Multiple infinities of my own reflection surrounded at me. For my installation, my goal is to recapture this sense of wonder and excitement.

This experience has been replicated in various instances throughout my life. When I was in the second grade, I became entranced by my teacher’s screensaver. Myriad ribbons of color swirled across the screen, inventing and forming new patterns as they moved. My teacher told me it was just pure math that I was watching. In the eighth grade, my practical science teacher demonstrated the principle of the Conservation of Energy with a bowling ball pendulum. When the bowling ball is dropped from the tip of your nose, it will swing back to exactly where it started. Then in my Algebra II class, our teacher had the class work out the proof for the quadratic equation, without alerting us to the outcome of the exercise. When the students reached the end, the class exploded with enthusiasm.

¹⁰⁷ Roe Goodman, “Alice through Looking Glass after Looking Glass: The Mathematics of Mirrors and Kaleidoscopes,” *The Mathematical Association of America* 111, (April 2004): 281.

For me, these experiences were like magic. Mathematics has the ability to explain these marvelous, almost mystical, events. Moreover, while these experiences were wonderful in and of themselves, they encouraged a deeper understanding of the principles governing them. In other words, I would have a more meaningful interaction when I learned the exact mathematics and principles behind them.

This installation encapsulates the origination of my thesis. Math does not have to be horrifyingly difficult – an unending array of numbers, symbols and equations. It is not a subject relegated to only the most intelligent people. When I stepped into that triangle of mirrors, I never knew any of the equations, formulas, or terms. Yet, I implicitly understood the mathematics. It was not a daunting experience; instead, it was invigorating.

For my installation, I want to create a human sized, interactive kaleidoscope. Three equally sized mirrors will be situated in a triangle. The participant will be able to enter into the middle of the triangle. When they do so, twelve infinities of their reflection will surround them. My installation will invite the spectator to reflect upon their past experiences with math. Indeed, my goal for this installation is for it to act as a prop for discussion about the ways in which math is truly more than its stereotype. It is fun and exciting. It does not have to be scary and difficult.

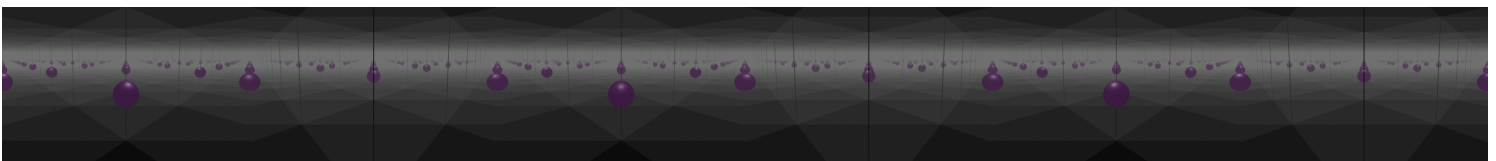


Figure 7 Ellman, Tom. *Triangle-360*. 19 April 2019. Computer generated image. Maya.

In a kaleidoscope, mirrors are used to produce images of remarkable beauty.¹⁰⁸ However, these beautiful images are only realized when the mirrors are properly aligned.¹⁰⁹ Light usually travels in a straight line. However, when it encounters an object its direction can change. Since the inside of a kaleidoscope is mirrored, the light then bounces off each of the mirrors, which causes the image to repeat.¹¹⁰ The eye sees these bouncing reflections and then creates the patterns.¹¹¹ The object shifts as the kaleidoscope shifts, resulting in new patterns.¹¹² Math is like the reflections. It is wonder and imagination.

The traditional kaleidoscope utilizes two mirrors joined along an edge at an angle $180^\circ/m$ (for some small integer $m \geq 2$).¹¹³ Then, some real object (typically pieces of colored crystals) is placed in the area between the two mirrors.¹¹⁴ The kaleidoscope presents an image

¹⁰⁸ Roe Goodman, "Alice through Looking Glass after Looking Glass: The Mathematics of Mirrors and Kaleidoscopes," *The Mathematical Association of America* 111, (April 2004): 281.

¹⁰⁹ Goodman, 282.

¹¹⁰ "Kaleidoscope," Questacon: The Australian National Science and Technology Centre, April 2019, <https://www.questacon.edu.au/visiting/galleries/fundamental/exhibits/kaleidoscope>.

¹¹¹ "Kaleidoscope," <https://www.questacon.edu.au/visiting/galleries/fundamental/exhibits/kaleidoscope>.

¹¹² "Kaleidoscope," <https://www.questacon.edu.au/visiting/galleries/fundamental/exhibits/kaleidoscope>.

¹¹³ Roe Goodman, "Alice through Looking Glass after Looking Glass: The Mathematics of Mirrors and Kaleidoscopes," *The Mathematical Association of America* 111, (April 2004): 281.

¹¹⁴ Goodman, 282.

consisting not only of the real object, but virtual objects in virtual chambers.¹¹⁵ These are the multiple reflections of the real chamber and object.¹¹⁶

The above mathematics holds for my installation. When somebody stands inside the giant three-way kaleidoscope, they will be able to see their reflection repeat to infinity.¹¹⁷ The three mirrors form an equilateral triangle. Each mirror is of an equal length and stand at 60° to one another.¹¹⁸ Light reflects off the object or person onto each mirror's surface. The light then reflects off the mirror's surface onto the surfaces of the other mirrors, which creates the multiple reflections.¹¹⁹ The reflected image becomes darker as it gets farther away. Whenever the light reflects off another mirror, some of the energy is absorbed.¹²⁰ As the angle between the mirrors decreases, the number of images increases. This is due to the fact that the decreased angle allows the light to bounce between the mirrors more times before the energy becomes too low to be visible.¹²¹ For example, if two mirrors were at 0° to one another, the number of reflections is theoretically infinite.¹²² However, because the

¹¹⁵ Goodman, 282.

¹¹⁶ Goodman, 282.

¹¹⁷ "Kaleidoscope," Questacon: The Australian National Science and Technology Centre, April 2019, <https://www.questacon.edu.au/visiting/galleries/fundamental/exhibits/kaleidoscope>.

¹¹⁸ "Kaleidoscope," <https://www.questacon.edu.au/visiting/galleries/fundamental/exhibits/kaleidoscope>.

¹¹⁹ "Kaleidoscope," <https://www.questacon.edu.au/visiting/galleries/fundamental/exhibits/kaleidoscope>.

¹²⁰ "Kaleidoscope," <https://www.questacon.edu.au/visiting/galleries/fundamental/exhibits/kaleidoscope>.

¹²¹ "Kaleidoscope," <https://www.questacon.edu.au/visiting/galleries/fundamental/exhibits/kaleidoscope>.

¹²² Roe Goodman, "Alice through Looking Glass after Looking Glass: The Mathematics of Mirrors and Kaleidoscopes," *The Mathematical Association of America* 111, (April 2004): 284.

mirrors are absorbing small amounts of energy each time the light bounces, the images will keep getting darker. Therefore, the reflections are not truly infinite in a physical sense; they are in a mathematical sense though.¹²³

¹²³ Goodman, 284.

Conclusion

“Proof. Set $g = R_\alpha R_\beta$. Then g is rotation by the angle 2θ , hence it is of finite order if and only if θ is a rational multiple of π . Assume that $\theta = n\pi/m$, with m and n relatively prime positive integers. We claim that $n = 1$. To prove this, note that the action of g on the given mirrors produces two virtual mirrors that make angles of 2θ and 3θ with the first mirror. Hence for every integer k there is a virtual mirror that makes an angle of $k\theta$ with the first mirror. Since m and n are relatively prime, there is an integer k such that $kn \equiv 1 \pmod{m}$ by the Euclidean algorithm. Hence if $n > 1$ there is virtual mirror that makes an angle of π/m with the first mirror, contradicting the assumption that there are no virtual mirrors between the two given mirrors...¹²⁴

Math is important, fun, and exciting. It allows for a deeper understanding of the world and phenomena around us.

At the beginning of each section, I have included sections of the theorem which classifies all the possible two-mirrored kaleidoscopes. While the theorem is important to the mathematical understanding of the functionality of kaleidoscopes, I hope the inclusion of the theorem also caused you to reflect upon your own reactions to mathematics. While it may have been jarring in the begin, hopefully by the end it became natural, ordinary.

The effects of math anxiety are widespread and have influenced the ways in which modern society regards the subject of mathematics and the idea of high math achievement. Math anxiety has a profound influence at both the individual and societal level. The individual struggles to face the importance of math within their life and their future is negatively impacted by their anxiety. At a societal level, the widespread effects of math anxiety combine to create a culture that is predisposed to math apprehension. These societal sentiments justify the existence math anxiety.

¹²⁴ Roe Goodman, “Alice through Looking Glass after Looking Glass: The Mathematics of Mirrors and Kaleidoscopes,” *The Mathematical Association of America* 111, (April 2004): 282.

Representations of mathematics in popular culture present it as an inaccessible and difficult subject. It is cast in a completely negative light. Moreover, the people who achieve high math success, nerds, are negatively coded as well. Furthermore, people of color and women struggle to be accepted in nerd circles. Because they do not adhere to the dominant representations of nerds, their intelligence is not taken as seriously.

The goal of this project is to generate a different perception of mathematics. Through an examination of the effects of math anxiety and cultural representations, I analyzed the ways society at large views mathematics. My kaleidoscope installation will act as a prop for discussion. I hope people will reflect upon their own views and experiences with mathematics. I hope they will ask themselves what specific views they have on the subject of mathematics and why do they hold these specific views. While I may not change their minds, I will hopefully encourage a new perception of mathematics.

Math is magical. I hope they experience the same magic of mathematics that I do.

“Now assume that $\theta = \pi/m$. From the relations

$$R_\alpha^2 = R_\beta^2 = (R_\alpha R_\beta)^m = I$$

one checks that there are at most $2m$ distinct matrices in the set (1) (the cases m even and m odd need separate consideration). This proves (i). Part (ii) follows from elementary geometry. To present $I_2(m)$ as an abstract group in terms of generators and relations, use the relations, as in (i), to see that at most $2m$ distinct words

$$1, a, b, ab, ba, aba, bab, abab, \dots$$

can be formed. Since $I_2(m)$ has $2m$ elements, this proves (iii).”¹²⁵

¹²⁵ Roe Goodman, “Alice through Looking Glass after Looking Glass: The Mathematics of Mirrors and Kaleidoscopes,” *The Mathematical Association of America* 111, (April 2004): 282.

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