Unleashing Students' Mathematical Potential by Embracing a Growth Mindset

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Abstract

The extent to which a student embraces a growth mindset has a significant impact on their belief that they can problem solve. According to Jo Boaler and others, recent neuroscience research indicates that an individual's mathematical ability to learn and grow is not predetermined at birth. That is, everyone has the ability to engage in and understand mathematics. If this is the case, then why do so many students have such an unfavorable perspective towards mathematics? In this study, we will analyze responses collected from students which reveal their perspectives towards math and what it means to embody a growth mindset. Ultimately, our goal is to understand how educators can foster a belief in their students that they have unlimited potential.

Keywords: growth mindset, perspective

Unleashing Students' Mathematical Potential by Embracing a Growth Mindset

For many people, mathematics is perceived as a subject that requires talent. In other words, many students believe that only certain people are capable of learning math. Many people do not realize that "with the right mindset and right teaching, people are capable of a lot more than we think" (Dweck, 2016). In our research, we wanted to study students' experiences and perspectives towards mathematics in order to determine possible issues that may exist in mathematics education and what students would like to see change in the way mathematics is being taught. We designed our procedure around the ideas of researchers, Carol Dweck and Jo Boaler. Carol Dweck has conducted psychology research providing evidence that when people change their mindset towards a certain area in life, they create opportunities for learning how to reach their full potential. Jo Boaler has taken Dweck's research and has studied the impact of growth mindsets and how educators can implement a growth mindset in mathematics classrooms.

The goal of the study is to analyze students' responses in order to gain a better understanding of how students feel about mathematics and how educators can improve and make changes in math education. Our research questions are:

- How does having a growth mindset impact student's mathematical learning?
- What can educators do in order to increase interest in learning math, help boost confidence, and increase self-belief in mathematical ability?
- How many Georgia College students demonstrate a growth mindset for learning mathematics?

What we found is that many students' negative experiences in math have hindered them from either reaching their full potential or have even led them to adopt an unfavorable

perspective towards math. We also found that the majority of students would like to see more of Jo Boaler's ideas and theories implemented in math classrooms. Many students understand how having a growth mindset can affect and change their mathematical learning, but it is evident that many students have never been given the right messages, support, or encouragement to do so. Our ultimate goal is to take this research and learn how to create more opportunities for students to understand that math does not have to be the dreadful subject many people think it is and that they are capable of being successful in their mathematical learning.

Literature Review

The idea of Fixed and Growth mindsets was discovered by a psychologist named Carol Dweck. She explains how success in school, work, sports, and almost every area of our lives can be dramatically influenced by how we think about talents and abilities. People with a fixed mindset believe that their basic abilities, their intelligences, and their talents are set in stone. In other words, they believe they are born with a certain amount and that is all. People with a growth mindset believe that their talents and abilities can be developed through effort, good teaching, and persistence. They do not necessarily think everyone is the same or anyone can be Einstein, but they believe everyone can grow and learn if they work hard at it (Dweck, 2016).

Unfortunately, there exist the idea that math is only for some people. When students think that only certain people can learn math, they easily accept that they will fail which will ultimately lead them to having an unfavorable perspective towards math. One of the major problems in math education, is that there are teachers who place students in categories of being good or bad at math. Too often students receive messages like, "If it's not easy for you, you don't belong here." It is no surprise students are afraid of math or claim they are not "a math person."

The question of what educators can do in order to make math learning happen for all students is crucial. How can educators get students to believe that their math ability can be developed?

Jo Boaler, a math professor at Stanford University, has conducted research dealing with the effect of mindsets in math education. According to Boaler and others, there exists neuroscience research showing that "no one is born with a math brain and no one is born without one. When people change their mindsets, and start to believe that they can learn at high levels, they change their learning pathways and can succeed at those levels" (Boaler, 2016).

It follows that mathematics should be taught in a way that gives every student the opportunity to succeed. In this study, we will focus on three teaching methods Jo Boaler has discovered can help educators create and maintain a growth mindset in math classrooms which are:

1. Believing in All Students
2. Valuing Struggle and Failure
3. Opening Up Mathematics

It is our human nature to want to be accepted and cared about. What students really need is adults who believe in them, especially teachers. "A lot of scientific evidence suggests that the difference between those who succeed and those who don't is not the brains they were born with, but their approach to life, the messages they receive about their potential, and the opportunities they have to learn" (Dweck, 2016). Students are more likely to succeed when they have people who believe they can achieve. "The best opportunities to learn come about when students believe in themselves" (Dweck, 2016). When teachers are intentional about encouraging students, sending the right messages, and giving praise in the right way, students may start to believe that

they are capable of learning mathematics. This is why it is important as educators to express to students we believe in them and their potential.

It is our human nature to not want to make mistakes, especially in math classrooms, because many believe that making mistakes in math means you are not smart. Students do not realize that there is value in struggle and failure. When teachers encourage students to make mistakes and create classroom environments where students are not afraid to make mistakes, it can change the way students perceive math. When students struggle, their brain is challenged, and it is in the time of struggle when the brain learns the most (Dweck, 2016). So, if you're learning, then are you technically failing? The answer to this question is self-evident, and this is why it is vital for teachers to respond positively about mistakes so that students feel comfortable working on harder problems.

Unfortunately, the testing and performance culture in mathematics education is one of the greatest problems. Many students believe the objective in math classes is to calculate answers and to memorize facts and formulas. "Students rarely think that they are in math classrooms to appreciate the beauty of mathematics, to ask deep questions, to explore the rich set of connections that make up the subject, or even to learn about the applicability of the subject" (Boaler, 2016). Jo Boaler has discovered effective teaching methods designed to help create and maintain a growth mindset, some of which are:

- Encouraging students that they can problem solve
- Explain how math is a subject of patterns and connections
- Use visual representations and math modeling
- Encourage deep thinking
- Value depth over speed

- Encourage students to pose question, reason, and justify
- Teach with technology and manipulatives
- Allow students to work in groups and facilitate class discussions

"When teachers are designers, creating and adapting tasks, they are the most powerful teachers they can be. Any teacher can do this; it does not require special training. It involves knowing about the qualities of positive math tasks and approaching tasks with the mindset to improve them" (Boaler, 2016). When teachers take responsibility in finding ways to open up mathematics, students' can change their perspective towards math, and potentially even build interest in learning math.

Method

Participants

In this study, we analyzed responses from 72 college students attending Georgia College & State University. We conducted our experiment by surveying students in two separate statistics courses, one mathematics education course, and by finding other volunteers across campus.

The study consisted of responses comprised of 64% females and 36% males. The sample also consisted of 89% of participants Caucasians, 7% African Americans, and 4% participants of other ethnicities. We also took into account each student's class rank and major as shown in Figure 1 and Figure 2. This is an approximate representation of the Georgia College student population.

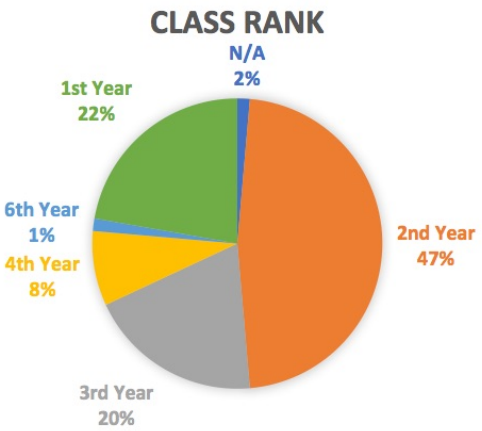


Figure 1

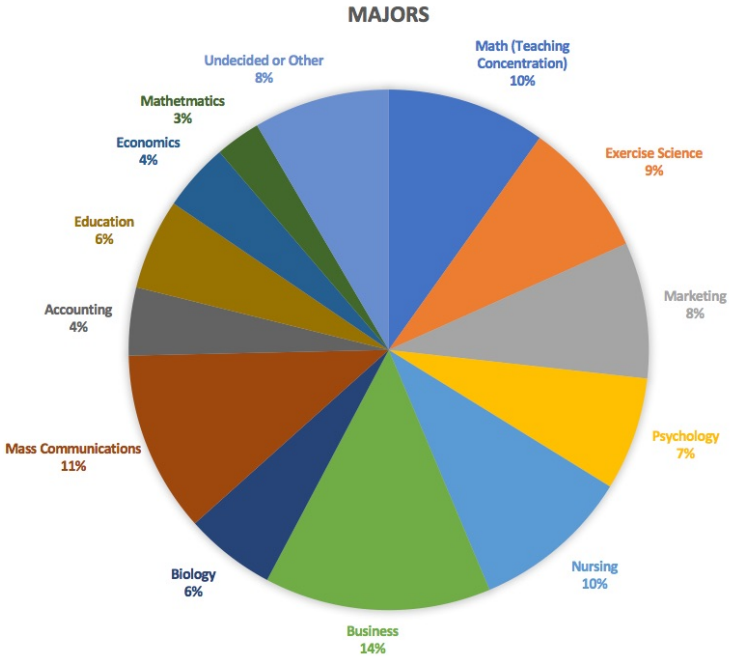


Figure 2

Procedure

The purpose of this study is to analyze the perspectives students have towards math, to determine the causes of math anxiety, and to develop possible solutions for teachers. Each participant was given a series of tasks to complete, which took about 35 to 40 minutes to complete.

After each student received a copy of a letter from the investigator describing the purpose of the study and a consent form to sign, the participants were given a pre-test Survey composed of 21 statements to rate from 1 to 5, with 1 being “Strongly Disagree” and 5 being “Strongly Agree”. Ten of these statements were pulled from an online test to help individuals determine whether or not they have math anxiety (Freedman, 1997-2017). When analyzing the data, we added up each students’ total according to their rating of all 10 statements and then compared it to their response to Question 4 on the post-test. In order to align the scales, we adjusted the numbers so that a high number corresponded to a positive response. For example, if a student

rated “I am afraid to ask questions in a math class,” as a 1, we adjusted this to be 5, with five being a positive response to this statement. The remaining 11 statements consisted of characteristics of a growth mindset we created in order to see if we could assess the student’s pre-mindset. We also added up each students’ total according to their rating of all 11 statements and compared it to their response to Question 4 on the post-test. The purpose of the pre-test survey was to analyze each student’s math anxiety as well as their pre-mindset and compare both to their self-assessment of the level of their growth mindset.

After the participants completed the survey, they were asked to watch a video of Jo Boaler, speaking at an Oxford TEDx talk. In the video, she explains why mathematics is traumatic for many people and describes different ways people can relate and learn mathematics. She also shares information about the latest brain science to show the ways our brains process mathematics, the importance of visual learning, and the importance of self-belief in our mathematics learning and experiences (Jo’s Oxford TEDx 2017 Talk). This purpose of the video is to not only inform participants of what it means to embody a growth mindset, but to see whether or not students agree with the theories of a growth mindset.

Following the video, the participants were given time to respond to a post-test questionnaire composed of 5 free response questions. The questions were:

1. What each participant liked, disliked, agreed, or disagreed with the video
2. The kinds of messages each participant has received about mathematics throughout their mathematical experiences
3. The advice each participant would give to teachers in order to increase their interest, build their confidence, or meet their full potential in mathematics classes

4. Each participant's mathematical perspective by asking them to rate themselves on a scale from 0 to 10 with 0 being a strong fixed mindset and 10 being a strong growth mindset
5. Whether or not participants were encouraged to make mistakes by their teachers throughout their mathematical education and if they believe or do not believe that making mistakes is an essential part to learning

The purpose of the post-test questionnaire was to analyze each students' experiences and perspectives towards mathematics.

The last component of the procedure consisted of participants' voluntarily signing up to partake in a 30-minute one-on-one interview process with the principal investigator. However, only 10 interviews were conducted and volunteers were selected randomly by an online number generator. The purpose of the interview process was to further discuss their responses to the post-test questionnaire and to better understand each student's mathematical experiences.

Findings

Theme 1: Believing in All Students

Often students are given the wrong messages in math classes. Every student deserves adults in their lives, especially teachers, who believe they can achieve. It is vital as educators to communicate this belief to all of our students with positive messages and high expectations.

Post-Test Question Two Results. Participants were asked what kinds of messages they have been given that influenced their perspective of math. The messages students receive about mathematics play a vital role in the positive or negative perspective they could have towards mathematics. In other words, certain messages can either help foster a fixed or growth mindset

towards mathematics. In analyzing our data, we took in account various responses and recorded those that were most occurring among the participants. The most prevalent responses were:

1. I am not good at math/I have struggled with math.
2. I had good math teachers.
3. I was always good at math.
4. I like math.
5. We are supposed to memorize math/You are either good or bad at math.

We observe that the most prevalent messages students have received in their experience with mathematics are ultimately negative messages, with exception of "I had good math teachers," and "I like math," which are not necessarily messages about math. However, the response "I like math," can stem from the assumption that these students may associate themselves as being good at mathematics. We speculate that students who believe they are not good at mathematics would not agree with liking the subject.

It is important to point out that the response "I was always good at math" is actually a negative message. It is possible that students who consider themselves good at math have the potential of having a fixed mindset. There becomes an urgency to prove yourself over and over. These students might get praise for being able to solve a problem quickly or easily instead of their hard work. Note that this is not always the case, but it is possible that the message "I am good at math" can foster a fixed mindset.

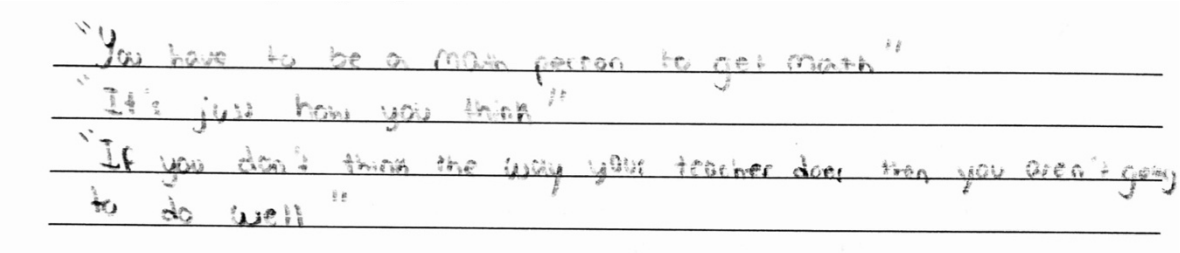

"You have to be a math person to get math"
"It's just how you think"
"If you don't think the way your teacher does then you aren't going to do well"

Figure 3

From Figure 3 above, we see that this student gave quotes. It is hard to determine whether these are actual quotes a student received from a teacher or the student's own personal thoughts about what they believe about their mathematical ability based on how they may have performed or been taught in mathematics classes. "The labeling of students as gifted or not gifted sets students on a fixed mindset pathway, making them vulnerable and less likely to take risks" (Boaler, 2016). Having a fixed mindset does not necessarily mean that a student cannot be successful in a mathematics course, but it can hinder students from reaching their full potential and overcoming adversity and challenges. We speculate that this students' math perspective has been affected by these negative messages.

Another reoccurring problem in math classrooms we observed from students' responses is that students believe being successful in mathematics classes means being successful at memorization as shown in Figure 4.

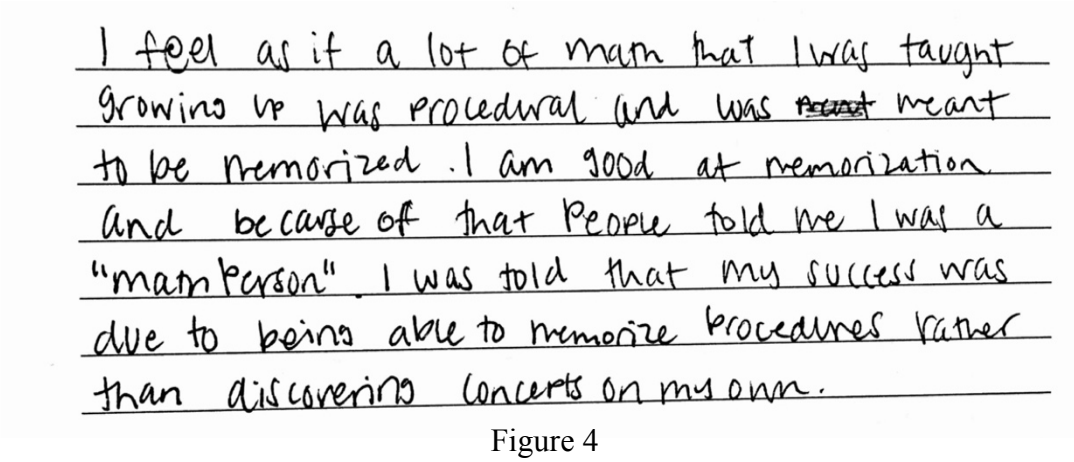

I feel as if a lot of math that I was taught growing up was procedural and was meant to be memorized. I am good at memorization and because of that people told me I was a "math person". I was told that my success was due to being able to memorize procedures rather than discovering concepts on my own.

Figure 4

"There are some math facts that are good to memorize, but students can learn math facts and commit them to memory through conceptual engagement with math" (Boaler, 2016). Using the word "procedural" or "procedures" in mathematics classes gives students the wrong perception towards mathematics. Students begin to believe that mathematics can only be learned by recalling math facts at a certain speed. "It will always be the case that some students are faster or slower when memorizing facts, but this has nothing to do with their mathematical potential" (Dweck, 2016). We can see that this misconception pushes students further away from developing a mathematical mindset. When students associate mathematics with memorization, they miss the opportunity of seeing the creativity, openness, and beauty of mathematics. We speculate that this student recognizes the issue with memorization in math and that "discovering concepts on their own," should be more important.

Apart from the negative messages students have received, we observed that a select group of students gave responses dealing with the positive messages all students should be receiving in mathematics classrooms such as:

- Math depends on social interaction.
- Math is a process.

- It is okay to not understand as long as you are willing to figure out what you did wrong.
- Math spans a great deal of topics.
- Math can be compared to real world things.
- Math takes practice.
- Never give up on math.
- Problems can be broken down.
- Effort goes a long way.
- There are several ways to solve a problem.
- Giving math a purpose would ultimately make it easier to grasp

In order to help students develop a growth mathematical mindset, these are the types of messages teachers should be giving to students. It is easy to encourage students, who appear motivated, to learn, but it is even more important to communicate positive belief and expectations to students who appear to be unmotivated or struggling. It is also important for teachers to not be quick to determine who will do well on certain mathematical tasks and who will not. Lastly, it is vital for teachers to get to know their students, to understand that each student has had different experiences and backgrounds in order to practice good mathematics teaching, express positive messages, and high expectations to all of their students.

Theme 2: Valuing Struggle and Failure

It is our human nature to not want to be wrong of fail. Unfortunately, being wrong in mathematics often results in students thinking they are not good at math. What students do not realize is that there is value in struggle and failure. The most productive classrooms are those in which students work on complex problems, are encouraged to take risks, and can struggle and fail and still feel good about working on hard problems. When students struggle and fail it does

not mean anything about their math potential, it means that they are learning and their brains are growing. This is why it is important for teachers to encourage mistakes in math classrooms.

Math Anxiety vs. Post-Mindset Graph. We took the 11 statements dealing with math anxiety in the pre-survey and added up each students' total to see what level of math anxiety they might have and then compared it to their post-mindset rating from the post-test. In Figure 5 we will observe six regions.

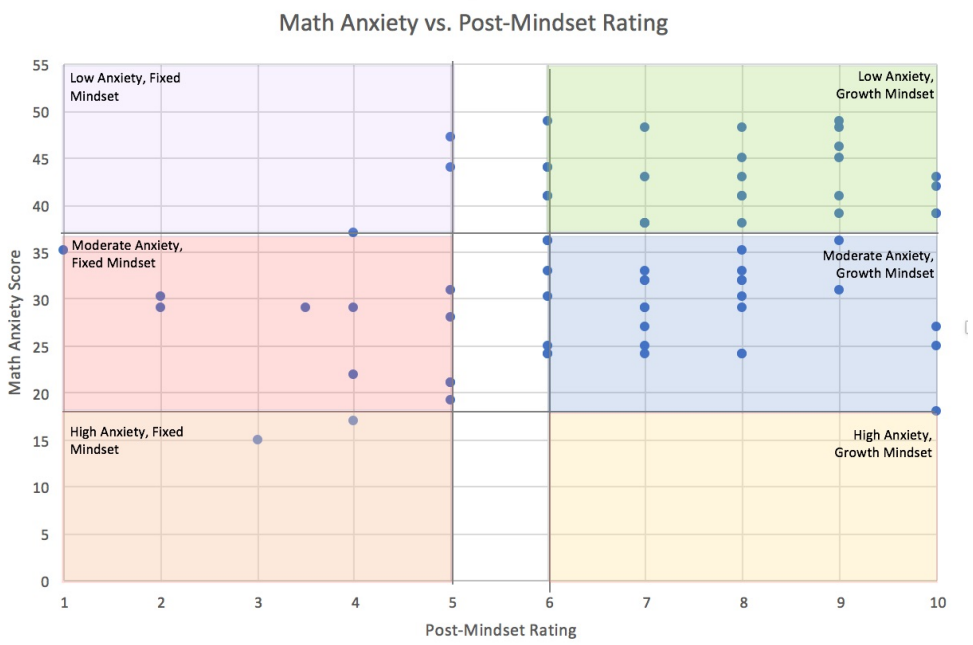


Figure 5

The green region consists of 37 percent of participants who have low anxiety and a growth mindset. These students have had positive math experiences and seem to truly embrace a growth mindset by their responses. These students need to be continuously encouraged and challenged. These students seem have a strong self-belief in their math abilities, but teachers should also challenge these students so that they can be pushed to reach their full potential by encouraging students to make connections and think deeper about concepts.

The blue region consists of 37 percent of participants who have moderate anxiety and a growth mindset. This region consists of two different types of students. The first half being students who are confident in their math abilities which we speculate stems from positive experiences and encouragement from their teachers. The other half of this group we are not as confident which we speculate stems from some negative experiences. However, these students seem to have more a growth mindset which may have helped them in overcoming any adversity in their mathematics classes. These students want their math classes to be challenging and student-centered.

The yellow region consists of one student who has high anxiety and a growth mindset. This student seems to have had bad experiences in mathematics classes in the past. We speculate that this student wants to be successful in math, but was never given enough support in order to overcome the challenges and mistakes that come with learning mathematics.

The purple region consists of 4 percent of students who have low anxiety and a fixed mindset. These students seem to have had good experiences meaning they consider themselves good at math or have never really struggled. However, this group of students need to be better informed of what having a growth mindset really means. Two out of the three students in this group rated themselves as a 5 which is technically half fixed and half growth, but in reality, these students do not have a clear understanding of what it means to embody a growth mindset. These students need encouragement and given messages that can help them foster a growth mindset.

The red region consists of 17 percent of participants who have moderate anxiety and a fixed mindset. We speculate that this group of students have had experiences where they have been placed in the category of not being capable of succeeding in math, whether that is due to teachers neither encouraging nor challenging them, or based off of their performance in their

math classes. Jo Boaler emphasizes how some teachers think they are the guardians of math and decide to dictate who can and cannot learn math. These students agree with the concepts and characteristics of growth mindset mathematics, but we speculate that these students were never given the chance to be challenged while being encouraged by their teachers that they can solve challenging math problems. These students need teachers who encourage them that it is okay to mistakes. These students need to be given opportunities and the belief they have the ability to be successful in math classes.

The orange region consists of 3 percent of students who have high anxiety and a fixed mindset. These two students believe they are not a math person. We speculate that these students want to believe what Boaler says is true and they are capable of being a math person, but were never given the right messages or encouragement. These students need to be encouraged the most. Educators should be sending these students words of encouragement constantly and opening up mathematics so they can potentially see the beauty of creativity of math. These students need a better understanding of what it means to embody a growth mindset.

Pre-Mindset vs. Post-Mindset Graph. We took the 10 statements dealing with characteristics of a growth mindset in the pre-survey and added up each students' totals to see if we could potentially assess their mindset before showing the video. We then compared these results to their post-test mindset rating from the post-test. In Figure 6 we observe two regions.

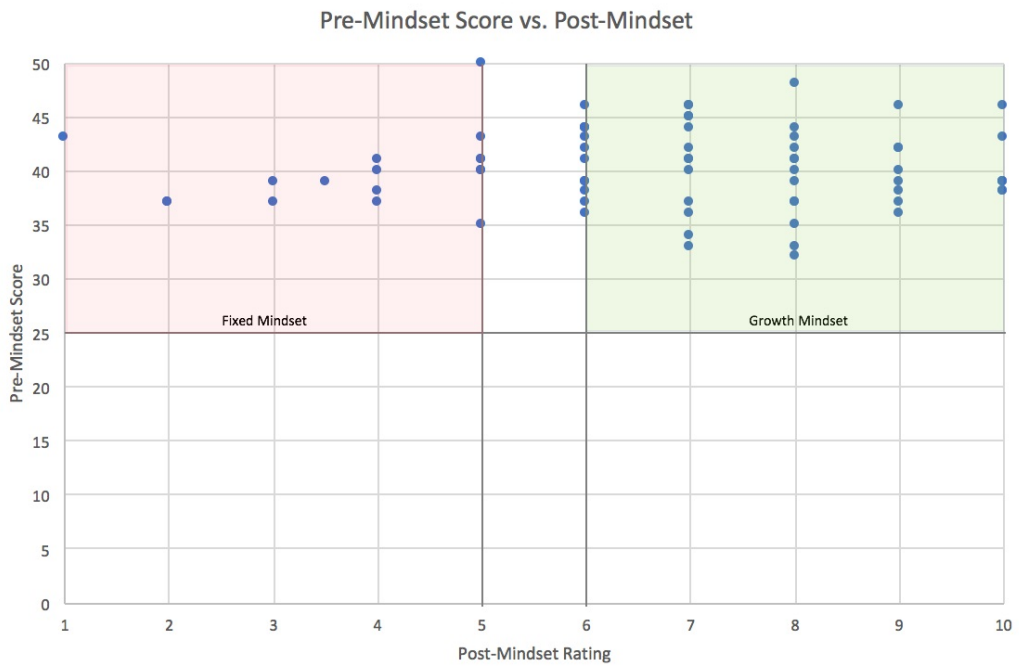


Figure 6

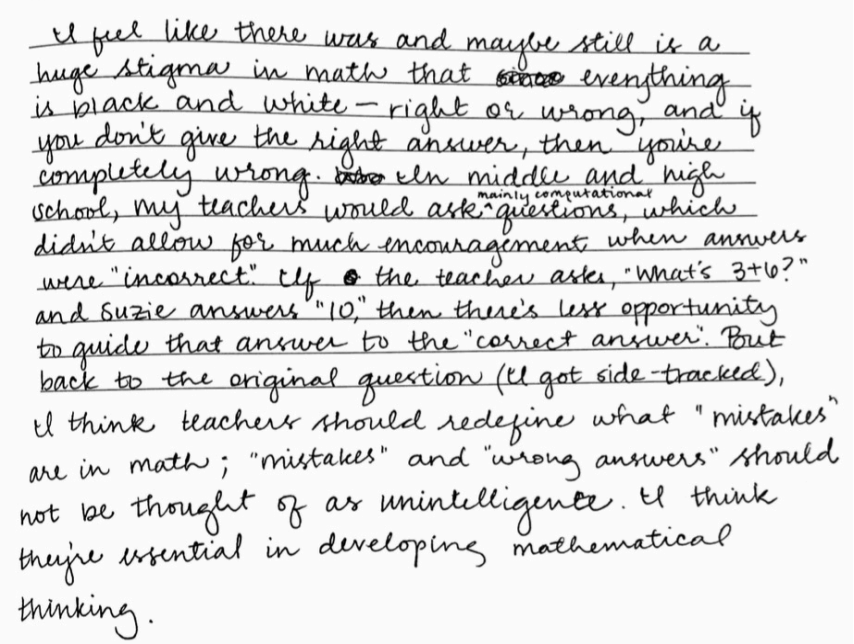
The green region tells us that these students value the growth mindset and also embody a growth mindset. The red region tells us that these students moderately to highly value the things associated with a growth mindset, but their personal assessment show that they are more of a fixed mindset. We speculate these students recognize and potentially value some of the characteristics of a growth mindset, but still do not fully understand the concept of a growth mindset. These results reveal that if we are going to make a change in math education, we have to better educate ourselves and others about what it means to embody a growth mindset.

Post-Test Question Five Results. When analyzing the student's responses to the last question in the post-test, we observed three different categories of students. The first category consists of students who believe making mistakes is an essential part to learning. In Figure 7, we see how often these students were encouraged to make mistakes by their teachers.

How often did your math teachers encourage you to make mistakes?	# of students
Very Rarely was I encouraged	5
All of my teachers encouraged me	4
Some of my teachers encouraged me and some did not	1
I was never encouraged	18
Only my college professors encouraged me	2
One of my teachers encouraged me	3
I cannot remember ever hearing my teachers encourage me	8
A few of my teachers encouraged me	3
I was only encouraged in the "learning period"	1
All of my high school teachers encouraged me	2
Unspecified	10

Figure 7

Even though these students believe making mistakes is an essential part to learning we see the majority of students were never or rarely encouraged to make mistakes by their teachers. These results reveal that many students and teachers see math as a performance culture and making mistakes is not accepted in math classes. In Figure 8, we observed a student's response from this category.



I feel like there was and maybe still is a huge stigma in math that everything is black and white – right or wrong, and if you don't give the right answer, then you're completely wrong. In middle and high school, my teachers would ask mainly computational questions, which didn't allow for much encouragement when answers were "incorrect." If the teacher asks, "What's 3+6?" and Suzie answers "10," then there's less opportunity to guide that answer to the "correct answer". But back to the original question (I got side-tracked), I think teachers should redefine what "mistakes" are in math; "mistakes" and "wrong answers" should not be thought of as unintelligent. I think they're essential in developing mathematical thinking.

Figure 8

In Figure 8, this student addresses the misconception of mistakes in the sense that many students believe if they make a mistake, they will be considered unintelligent. This misconception exists because teachers are not sending the right messages to students when they make mistakes. “There is a lot of intelligence out there being wasted by underestimating student’s potential to develop (Dweck, 2016). Teachers’ responses to students’ mistakes play a vital role in students’ mindsets towards math.

The second category consists of students who do not believe that making mistakes is an essential part to learning. Figure 9, is the response to the only student who fell into this category.

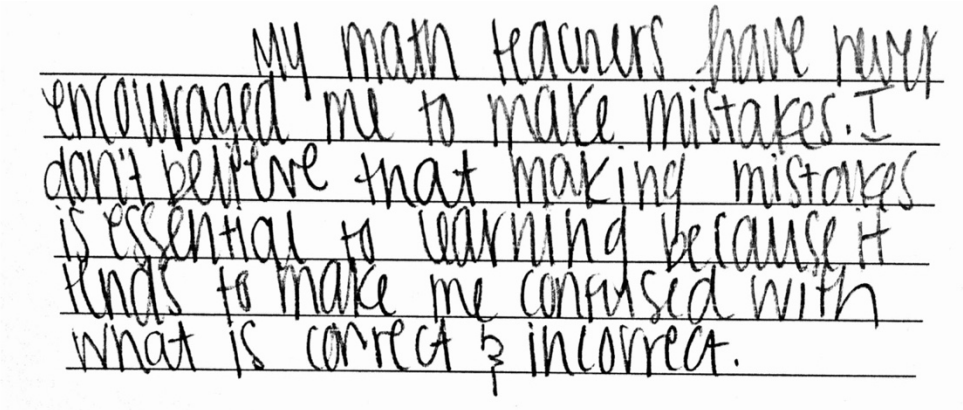

My math teachers have never encouraged me to make mistakes. I don't believe that making mistakes is essential to learning because it tends to make me confused with what is correct & incorrect.

Figure 9

This response brings us back to the stigma of mathematics being a subject consisting of black and white, right and wrong, correct or incorrect. Because this student was never encouraged to make mistakes, we speculate that their math perspective has been based of the "performance culture" of math. This takes away students' opportunities to ask deep questions, explore connections, and learn about the applicability of the subject. This is why it is important to send students messages that it is okay to make mistakes.

Lastly, the third category we observed is students who are conflicted on whether making mistakes is an essential part to learning.

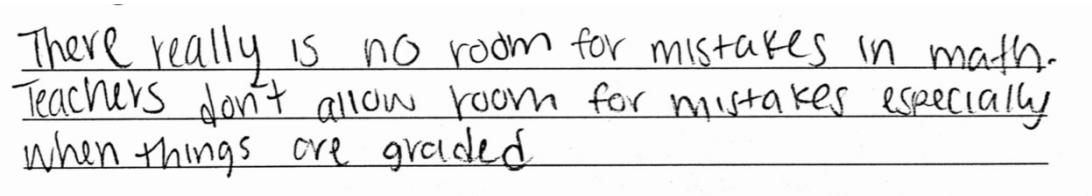

There really is no room for mistakes in math. Teachers don't allow room for mistakes especially when things are graded

Figure 10

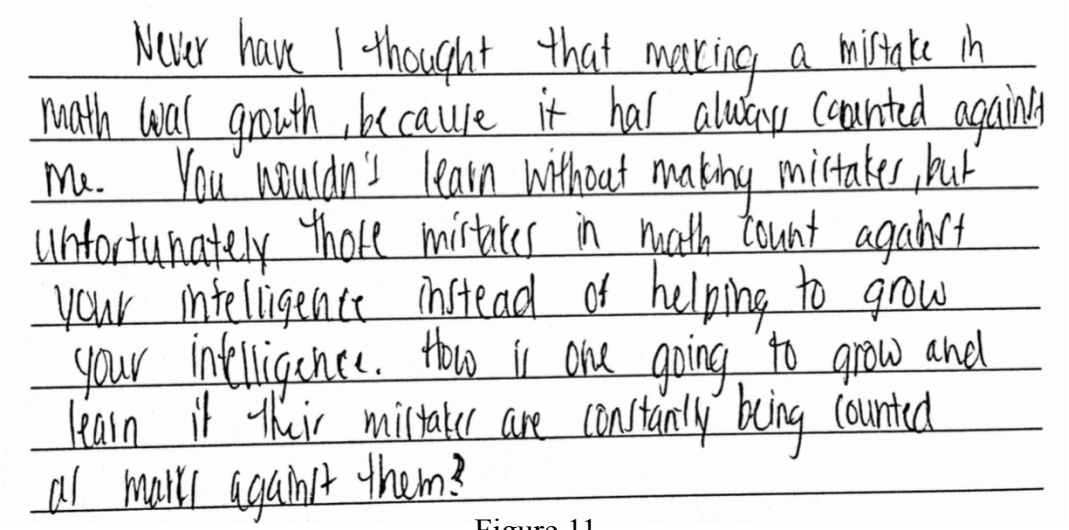

Never have I thought that making a mistake in math was growth, because it has always counted against me. You wouldn't learn without making mistakes, but unfortunately those mistakes in math count against your intelligence instead of helping to grow your intelligence. How is one going to grow and learn if their mistakes are constantly being counted as marks against them?

Figure 11

In Figures 10 and 11, we observe similar ideas on how the way mathematics is taught gives students the idea that the only way to succeed in math is to never makes mistakes. Another reason why students have this perspective towards mistakes in math is because of the grading. When students are constantly evaluated and given scores based on the correctness of their work, students become discouraged and students' see math as having "no room for mistakes." Jo Boaler gives educators advice on grading such as

- Always allow students to resubmit any work or test for a higher grade
- Share grades with school administrators but not with the students
- Use multidimensional grading
- Do not use a 100-point scale
- Do not include early assignments from math class in the end-of-class grade
- Do not include homework, if given, as any part of grading (Reference167-168)

Now whether or not educators will view these strategies as helpful, it can help make math seem less of a "performance subject." From students, responses we observe that the grading

in mathematics can sometimes take away a students' focus on actually learning the material. We understand that there is a need for grading, but we can change the way grading affects our students' learning. Educators should be providing students with assessments that provide students information about their learning rather than their achievement. When a students' learning becomes more important than their grades, it can change a students' mindset towards mathematics.

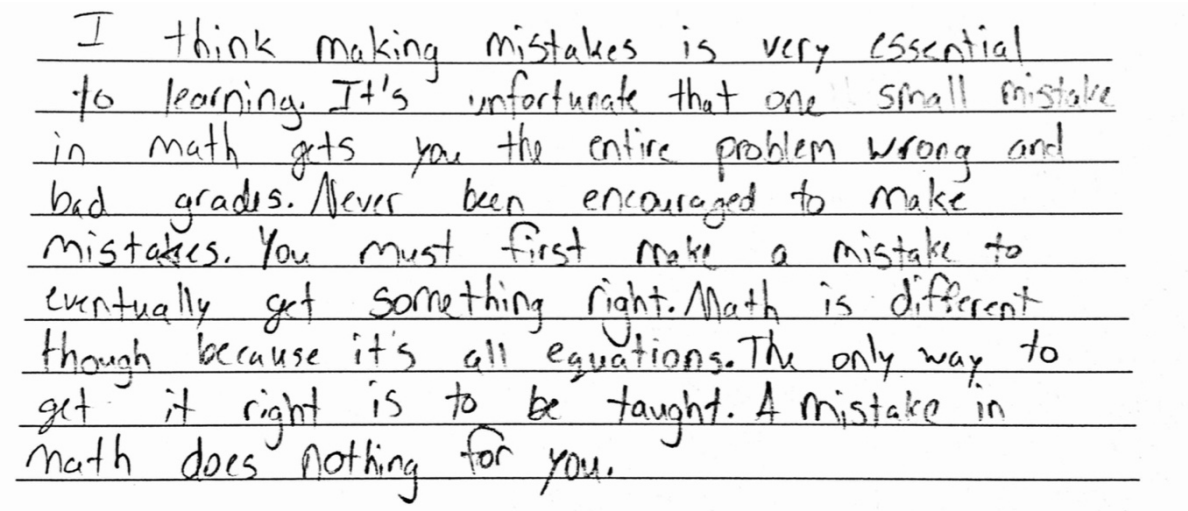

I think making mistakes is very essential to learning. It's unfortunate that one small mistake in math gets you the entire problem wrong and bad grades. Never been encouraged to make mistakes. You must first make a mistake to eventually get something right. Math is different though because it's all equations. The only way to get it right is to be taught. A mistake in math does nothing for you.

Figure 12

In Figure 12 we see the reoccurring perspective that math is a "different subject because it's all equations." This brings us back to the idea of math consisting of calculations and memorizing of facts and formulas. We can also connect this response to the importance of opening up mathematics. Students need to understand that making mistakes are okay and math can be seen as a subject where students are allowed to be creative in problem solving.

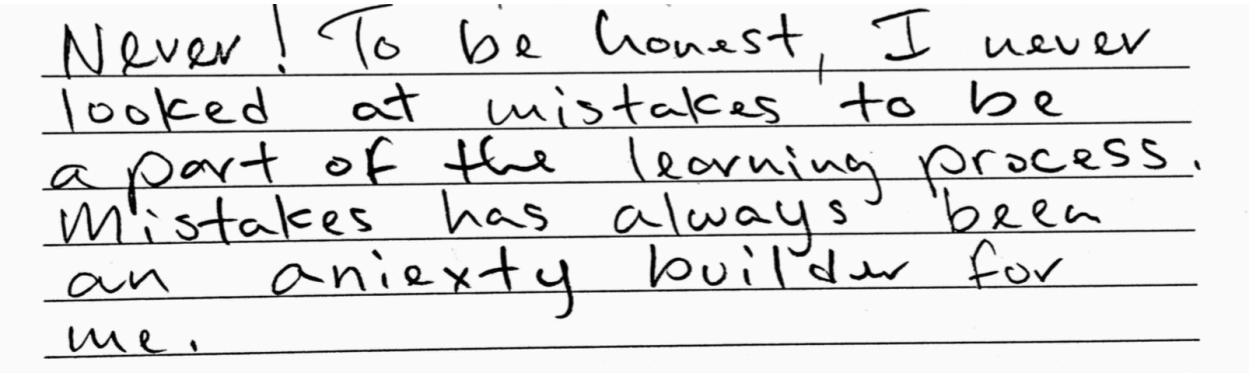

Never! To be honest, I never looked at mistakes to be a part of the learning process. Mistakes has always been an anierxty builder for me.

Figure 13

In Figure 13, we see the connection between anxiety and making mistakes. It is interesting to point out that this student fell in the low anxiety with a growth mindset category on the Math Anxiety vs. Post-Mindset graph and the green region on the Pre-Mindset vs. Post-Mindset graph. We went back and analyzed how they responded to the two of the survey questions. This student disagreed with “I am okay if the math class is challenging if I am not penalized for being wrong,” and agreed with “I am okay if the math class is challenging if I am given the right support.” We speculate that this student does not fully understand what it means to embody a growth mindset, because making mistakes is a characteristic of embodying a growth mindset in mathematics. We have already observed other responses about how mistakes are not accepted in today’s math classes. We speculate that anxiety can be caused by being penalized for making them, but it is interesting and hard to determine how this student really understands what a growth mindset is. It would have been interesting to conduct a one-on-one interview with this student so we could get more information about their experiences and perspectives.

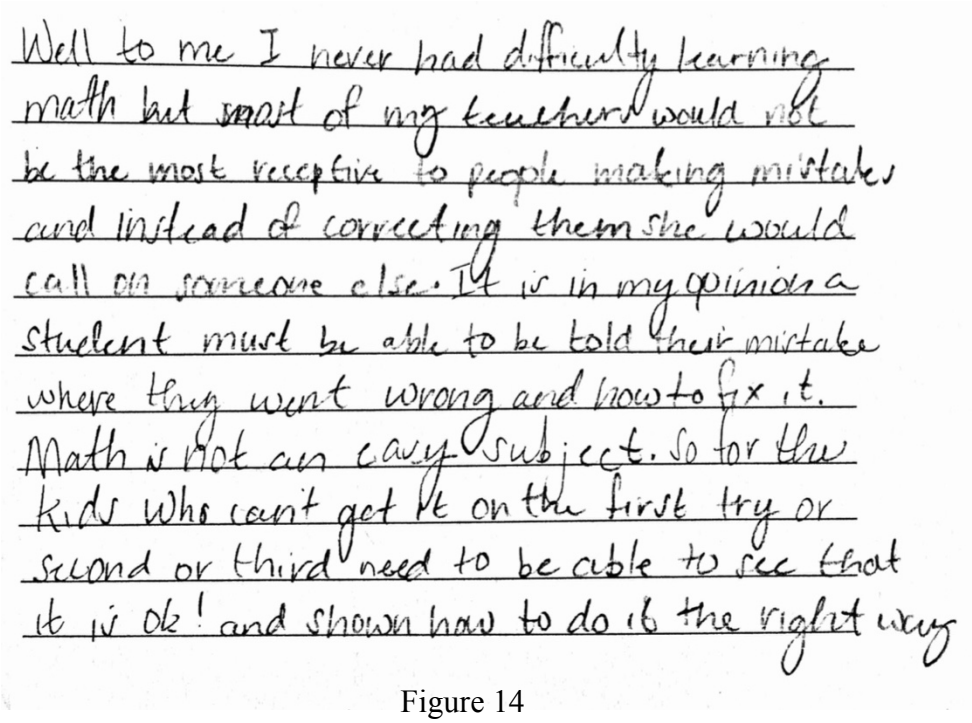

Well to me I never had difficulty learning math but most of my teachers would not be the most receptive to people making mistakes and instead of correcting them she would call on someone else. It is in my opinion a student must be able to be told their mistake where they went wrong and how to fix it. Math is not an easy subject. So for the kids who can't get it on the first try or second or third need to be able to see that it is ok! and shown how to do it the right way

Figure 14

In Figure 14 as well as a few other responses, we speculate some students believe "if a student is wrong the teacher should show them the correct answer or how to do it the right way…" but, do students really learn when they are given the answers? If a student were to answer this question they would more than likely say yes, but this goes against the idea of the value of struggle and failure. Of course, we do not want students to continuously not understand something, but at the same time we need to show them that they can solve problems on their own. This is why it is important for educators to encourage students to pose questions, reason, and justify, so that they can create an opportunity for the students to discover concepts on their own. If teachers can help guide students in the right direction without giving them for the answer, students ability to learn and grow will increase.

Theme 3: Opening Up Mathematics

Most students see math as a series of questions and answers, but many students have never been given the opportunity to see the creativity and beauty in math. “Math is a subject that allows for precise thinking, but when that precise thinking is combined with creativity, flexibility, and multiplicity of idea, math can come alive for people” (Reference). When teachers open up mathematics as a fun and exciting subject, they are the most powerful teachers they can be as discussed earlier. Jo Boaler gives educators teaching methods in order to help foster a growth mindset in classrooms. In the post-test, we wanted to observe if Jo Boaler’s teaching methods are indeed what students actually want and need in math classes.

Post-Test Question Three Results. We asked students if they could give teachers three recommendations of what could be done to help increase their interest, build their confidence, or meet their full potential in math, what would they be? When analyzing the responses, we recorded the top recommendations. The top reoccurring responses are as follows:

- Use different activities such as competition, visuals, prizes, etc.
- Allow students to discuss problems with their classmates (Group work)
- Show students you care by encouraging intentionally and often
- Make math interactive/interact and talk with students
- Extra study sessions/more review
- Relate math to real world problems
- Put less emphasis on grades and more emphasis on learning the content
- Contact students more frequently and encourage one-on-one conversations
- Break down problem, show all steps, and take more time when teaching a new subject
- Encourage students to make mistake and learn from them

These results reveal that students are on board with Jo Boaler's ideas, now it is the teacher's responsibility to implement these teaching methods in their math classes.

Other Big Ideas

Post-Test Question One Results. The purpose of showing students the video was to see whether or not they supported Jo Boaler's theories of a growth mindset. We asked the students what they thought about the video. We recorded the top positive reoccurring responses as follows

- Numerous ways to solve problems
- Everyone can learn math
- Visual mathematics is important
- Not everyone learns the same way
- Self-belief is important in math
- "I believe in you" from a teacher can have a major impact on students' learning
- Students can learn and grow by changing their mindset
- Positive criticism and encouragement impact the growth of students
- Working together creates opportunities for learning

Although a majority of students agreed and like the video, we had a select group of students who disagreed with some of Jo Boaler's ideas. Those responses consisted of:

- Group work is not a good idea
- I disagree because I am not a math person
- I disagree with visual math because visual representations always confused me

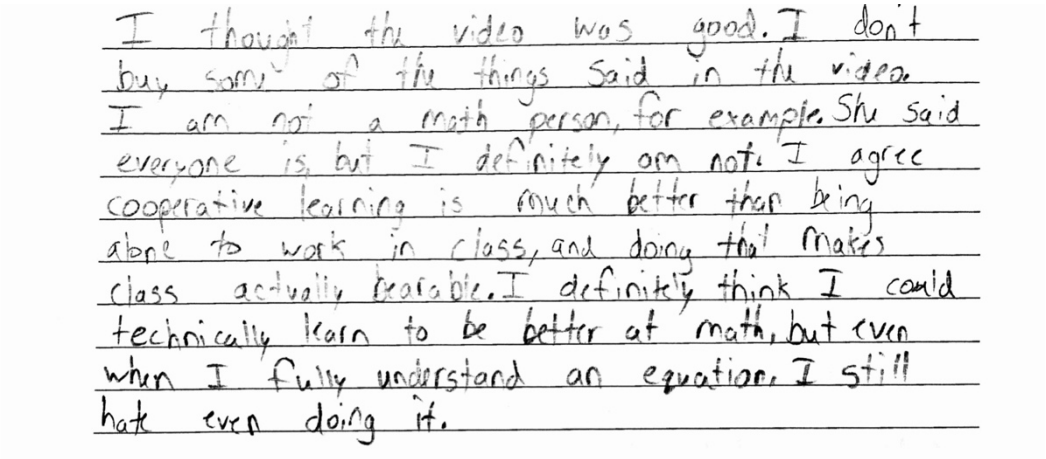

I thought the video was good. I don't buy some of the things said in the video. I am not a math person, for example. She said everyone is, but I definitely am not. I agree cooperative learning is much better than being alone to work in class, and doing that makes class actually bearable. I definitely think I could technically learn to be better at math, but even when I fully understand an equation, I still hate even doing it.

Figure 15

In Figure 15, we see how the growth mindset is something we have to work hard at to instill. It is responses like these that show us how important it is to have a growth mindset and how it can impact our learning. Students need to be better educated on what a growth mindset is, how it can help us be successful, and also how to foster a growth mindset.

Interview Process Results. Of the 10 students who were randomly selected to take part in the interview process, eight students had a growth mindset and the remaining two students had fixed mindset. It is interesting three students who embody a growth mindset mentioned that they had a parent who is a teacher and two other students said that their parents were supportive and able to help them with their math homework growing up. One student said, “The more support I have the better I am going to do,” which is true for any student. It is not always the case that every student will have parents at home who will be able to help them with their math homework or even support their math learning, but this is why it is so vital for teachers to encourage and support all of their students. Another student said, “As a teacher, if you don’t believe that the students can do something, then why should they believe in their selves?” Many students

consistently stated that having math teachers who create an environment where they feel capable of succeeding can make a difference in math education.

Another student said, “Sometimes teachers don’t realize that students are scared to approach them and so when the teachers approach them it makes them more comfortable and the student understands that the teacher really wants to help them.” This connects to one of the frequent recommendations participants had for teachers: contact students more frequently and encourage one-on-one conversations. It is evident that students want feedback, they want to ask questions, the want to feel okay about making mistakes, and most importantly they want their teachers to care about them and believe in them. The interviews were beneficial in this research because they reinforce this idea of these one-on-one conversations and getting to know your students by talking to them. For teachers with five classes consisting of about 30 students, it would be challenging to conduct these types of conversations with every student, but educators should always be making an effort to get to know their students and check on each student as much as possible, especially those students who seem to be struggling.

Another concept that was reoccurring among the interviews conducted was the idea that the students have to take responsibility and pride in their own learning. In other words, students agreed that a student’s learning it not solely the teacher’s responsibility. One students explained that in high school, their math classes were always lecture and homework. They never worked in groups, which made them feel like they were the only one who did not understand. This student also mentioned that they did not enjoy asking questions because their teachers did not want them to make mistakes. In situations like this, many students would have easily given up on math and created a fixed mindset, but this particular student took initiative in their own learning, which meant turning to Khan Academy or any other videos that would help them learn. This student

also said, “Your negative experiences can outweigh the positives sometimes. So that’s probably why people don’t like math because they’ve had one bad teacher and that’s all they remember.” It is evident that not all students who do not understand math will take initiative like this particular student. Even though students have just as much as a responsibility for their learning their teachers, it is even evident from student’s responses that the structure of a class and how a teacher approaches math plays a major role on whether or not students enjoy math.

“Over the years, school mathematics has become more and more disconnected from the mathematics that mathematicians use and the mathematics of life”. Conrad Wolfram proposed that working on math has four stages, but about eighty percent of school mathematics is spent on stage 3- performing a calculation by hand. (Reference). This is why many student’s see math as black and white and consisting of right or wrong answers. In the interviews conducted, students explained the importance of using different methods and learning styles, thinking outside of the box, relating math to real life things, and showing the multiple ways to solve problems. What we have observed from student’s responses and interviews is that many classrooms consist of lectures, work sheets, and not enough class discussion. We conclude that the inaccessible way mathematics is taught in classrooms, is the reason why so many students do not enjoy math. One student said, “Teaching kids how to think is so much better than killing an algorithm for adding or subtracting.” Too often, students are told how to think, as in they are given a formula and then shown where to plug in the numbers and they memorize this process, but what if math educators taught students how to think? What would happen if math educators started explaining to students the “why math works” and encouraging them to figure out these concepts on their own by testing a theory and seeing if it works? It would be interesting to see how opening up mathematics could change student’s perspectives towards math.

From student's responses, we observed that students who believe they have always been good at math can have a fixed mindset. One student interviewed with a fixed mindset said, "I put myself at a two because I feel like I have always been good at math. It was never something I worked hard at. I always felt like it came naturally and I never felt like it was a struggle for me to know formulas or to figure things out. I feel like I am a very visual person like mentally I can see things so it just kind of always happened." This student also said, "Any other teacher I have had, you don't have a formula sheet so you have to know your formulas and how to apply them. Instead of knowing oh this is what I'm solving for and this is what that means, it's like okay I know that these numbers go here." We speculate that this student is focused on their ability to memorize formulas and how to use them. This student also described that they were always in advanced math classes and that their teachers always challenged them, but the math was always simple. This is conflicting because we question if this student was really challenged. When students have this perspective, i.e., when students are understanding concepts, are teachers taking the time to ask deep questions, encourage the students to see other connections, and to think deeper about concepts? It is evident that this particular student is really good at math and likes the ideas of a growth mindset, but is still stuck in a fixed mindset. It is possible for students with a fixed mindset to succeed in math classes, but the major problem is when student start believing that they should not have to work hard at something. This perspective can lead to students giving up when they face challenges or adversity. By implementing a growth mindset in math classrooms, we can change the culture of mathematics.

Implications and Conclusions

Through this research, we have observed many different perspectives of students which has revealed some of the issues in math education. Most importantly, it has revealed that in order

to make a change in mathematics education, we have to better educate ourselves and our students about what a growth mindset is and how we can embody a growth mindset. It is evident that not all students have a bad experience with math, but we as educators can always improve the way we teach mathematics and how we speak to our students. It is encouraging that students' responses reveal that there are ways educators can increase students' interest, build students' confidence, and even help students' reach their full potential.

We have also learned that students want their teachers to care about them and make the effort to talk and interact with them. We speculate that if educators can try to implement some of the ideas discussed in this research, we can make a change in math education. To make a change, we as educators cannot assume that students already know how to learn. If we continue to show math as a subject full of calculations, answers, facts, and formulas, we will not give students opportunities to grow in their mathematics learning.

It is also important to remember that not all students come from families who support them and their learning. To some students, a teacher may be the only person influencing their mathematical thinking. If math educators can help students foster a growth mindset and show that we care about them and their potential, it is possible that students' can take this information with them and apply it to any area in their life. "The view you adopt for yourself profoundly affects the way you lead your life. It can determine whether you become the person you want to be and whether you accomplish the things you value" (Dweck, 2016). The growth mindset is something we all have to work hard at, but it can change the way we perceive ourselves and the things in our life. Every student deserves the opportunity to learn and grow, and we the educators can be the greatest facilitators.

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Appendix A

Pre-Test Survey

A Self-Test

Name: _____

Gender: _____

Race/Ethnicity: _____

Major: _____

Class Rank (e.g. 1st year, 2nd year, etc.): _____

Directions: Please rate each of the following statements on a scale from 1 to 5, with 5 being "strongly agree" and 1 being "strongly disagree."

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1. I am interested in learning math.	1	2	3	4	5
2. I feel better in math class when my teacher allows me to work with my classmates.	1	2	3	4	5
3. I am afraid to ask questions in a math class.	1	2	3	4	5
4. I feel confident in doing my homework after a lesson in class.	1	2	3	4	5
5. I am uneasy about going to the board in a math class.	1	2	3	4	5
6. I am more worried about my final grade in the math course than actually learning the material.	1	2	3	4	5
7. I tend to zone out in math class.	1	2	3	4	5
8. I cringe when I have to go to math class.	1	2	3	4	5
9. I am always worried about being called on in a math class.	1	2	3	4	5
10. I am okay if the math class is challenging if my tests do not account for such a high percentage of my overall grade.	1	2	3	4	5

11. It is clear to me in math class, but when I go home it is like I was never there.	1	2	3	4	5
12. I am okay if the math class is challenging if I am not penalized for being wrong.	1	2	3	4	5
13. I am afraid I will not be able to keep up with the rest of the class in a math class.	1	2	3	4	5
14. Completing my math homework is important to me.	1	2	3	4	5
15. I fear math tests more than any other kind.	1	2	3	4	5
16. I am okay if the math class is challenging if the teacher is more focused on my learning of the material.	1	2	3	4	5
17. I understand math now, but I worry that it is going to get really difficult soon.	1	2	3	4	5
18. I feel better about a math test if I am given a study guide or the teacher allows the class to review the day before a test.	1	2	3	4	5
19. I do not know how to study for math tests.	1	2	3	4	5
20. I am okay if the math class is challenging if I am given the right support.	1	2	3	4	5
21. I want to be mathematically successful.	1	2	3	4	5

Appendix B

Video Information

After the participants finish filling out the Self-Test, they will then be asked to watch a 12 minute and 36 second video of Jo Boaler speaking at an Oxford TEDx talk titled "Believe in Your Maths Potential – Set Yourself Free." In the video, she explains why mathematics is traumatic for many people and shows a different way people can relate to mathematics. She also shares the latest brain science to show the ways our brains process mathematics, the importance of visual learning, and the importance of self-belief to our learning and our experiences. The video can be found at youcubed.org or youtube.com.

Note: The above information describing the video was also found at youcubed.org.

Below are the links to the video:

https://www.youcubed.org/resources/jos-oxford-tedx-2017-talk/

https://www.youtube.com/watch?time_continue=385&v=al6gO9SLqBY

Appendix C

Post-Test Questionnaire

Post-Test Questionnaire

Name: _____

1. **What do you think about the video?**

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2. **In your experience with math, what kinds of messages have been given to you that have influenced your perspective of math?**

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3. **If you could give math teachers three recommendations of what could be done to help increase your interest, build your confidence, or meet your full potential in math, what would they be?**

_____

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4. **In the video Jo Boaler says,**

> "No one is born with a math brain and no one is born without one."

She then goes on to describe the idea of "mindset mathematics" which combines the important work of Carol Dweck on mindsets. Dweck's definition of fixed and growth mindsets is,

> "In a fixed mindset, students believe their basic abilities, their intelligence, their talents, are just fixed traits. They have a certain amount and that's that, and then their goal becomes to look smart all the time and never look down. In a growth mindset, students understand that their talents and abilities can be developed through effort, good teaching and persistence. They don't necessarily think everyone's the same or anyone can be Einstein, but they believe everyone can get smarter if they work at it."

With this in mind, please circle where you think you would fall on a number line with 0 having a strong fixed math mindset and 10 having a strong growth math mind set.

0 1 2 3 4 5 6 7 8 9 10

5. In the video, Jo Boaler says,

> "…with the idea that everybody has the knowledge… that everybody's brain can grow and change… and mistakes and challenges are the best way to do that..."

How often did your math teachers encourage you to make mistakes? In what ways do you believe or do you not believe that making mistakes is an essential part to learning?

_____

_____

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