Promoting a Math-Positive Classroom:
A Guide for TK–12 California Educators

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Introduction

Children are born with a natural curiosity about the world they inhabit. Their curiosity includes fundamental mathematical notions such as quantity, shape, and patterns. Despite this natural human interest in mathematical ideas, math teachers have historically felt as if they are fighting a losing battle for the hearts and minds of students.

In a 2015 Ogilvy PR survey, 60% of Americans admitted to having difficulty dealing with numbers in simple, everyday situations. Nearly a third of those surveyed said they would rather clean the bathroom than try to solve a math problem (Change the Equation, 2014).

This paper considers why this attitude toward math is so prevalent and what educators can do to address math anxiety or disinterest in TK–12 classrooms.

ABOUT THE AUTHOR

Dr. Raj Shah has always had an affinity for math. Powered by his love of math, he earned a Ph.D. in physics in 1999, which led to a career in R&D at Intel. In 2008, he quit his job and founded Math Plus Academy, an after-school STEM enrichment program for kids from ages 5–14. His mission is to introduce kids and adults to the wonders of mathematics. Dr. Shah also contributes his time to Math Teacher Circles, the Julia Robinson Math Festival, and is a founding member of The Global Math Project. He believes that everyone can enjoy math, develop strong number sense, and become a perseverant problem solver.

Why Students Give Up on Math

Despite the best efforts of TK–12 math educators, too many students lose interest in math, or—worse—they just give up. The underlying issues can provide clues as to how to help students overcome negative emotions around math.

There are three main reasons why students give up on math:

1. A belief that mathematical talent is innate

The most pervasive and insidious myth about mathematics in our culture is that some people are born with an ability to do math and everyone else is not. The idea that a "math gene" might exist traps people into thinking they lack an innate ability to be successful in math. When a learner suffers from this false belief, any setback in their mathematical progress simply confirms to the learner that they do not possess the math gene. This thinking can lead to a vicious, negative feedback loop.

Sadly, a very large number of students (and adults) fall into this trap. In a poll of 1,000 American adults, over a third (36%) admit that they've found themselves saying, "I can't do math." For people ages 18–24, that number jumps to 53% (Change the Equation, 2014)!

A study conducted at the Norwegian University of Science and Technology disproves the idea that math skills are innate by looking at how each individual math skill is attained. Researchers tested how well participants performed nine types of math tasks and found little to no correlation between being good at one skill versus another. For example, someone who can add fluently may not be good at word problems or geometry. Each math skill requires a different type of thinking, so one must practice each skill to be good at all of them. This understanding runs counter to the idea that math skills are innate, for if they were, those who are “good at math” would be naturally good at all math skills. The reality is that learners only master the math skills that they practice (Sigmundsson, 2014).

2. Failure in math is inevitable (eventually)

Unlike most school subjects, mathematical concepts get progressively more difficult from Transitional Kindergarten through Grade 12 and beyond. To make matters worse, math requires very diverse skills including number sense, algebraic thinking, spatial representations, and much more. No one will excel in all these areas without experience and practice, and eventually, every math student will face what might feel like an insurmountable hurdle in mathematics. At these moments, learners must decide if they have “run out” of the natural ability to perform math or if they can overcome the challenge with more effort and practice.

3. School makes math boring

As mathematician Paul Lockhart eloquently explains in his treatise, “A Mathematicianmat 0 0J/4Tex1Ō 1 Tfn(ane

Three Key Steps for Supporting Math Enthusiasm and Achievement

The changes required to help students become more enthusiastic about math and to increase their achievement are more focused on mindset than skillset. When TK–12 students believe that they can do math, and they are excited about accepting math challenges, their academic growth is assured.

Here are three ways TK–12 math educators can encourage a more positive approach to math:

- **1:** (desire to learn)
- **2:** (ability to persist even when the path forward is unclear)
- **3:** (how one copes with setbacks)

(about the same as conscientiousness). The study show
and curiosity can have as big an effect on performance

The good news is that teachers can make manageable changes in teaching methods and classroom culture to achieve all three goals.

STEP 1: Spark Curiosity

The first step to better achievement is to begin every lesson with something that sparks student curiosity.

A meta-analysis of research, which included over 200 studies and a total of about 50,000 students, found that curiosity does influence academic performance. In fact, it can have quite a large effect (about the same as conscientiousness). The study showed that, when put together, conscientiousness and curiosity can have as big an effect on performance as intelligence.

Lowenstein enumerates several stimuli that can induce curiosity, including presenting a riddle or puzzle, exposure to a sequence of events with unknown resolution, and violation of expectations. These stimuli are enhanced when an individual generates a prediction of the outcome. The desire to know if the prediction is correct compounds the level of curiosity.

It is important to note that if the individual has too much background knowledge, they may perceive the gap to be too small and not be as curious. Conversely, if the individual has too little knowledge, they may perceive the gap to be too large to overcome and not be curious. This makes the teacher's understanding of each child's background knowledge crucial in the generation of maximal curiosity.

Common Frameworks for Creating Information Gaps in the Mathematics Classroom

[illegible] 1: [illegible]

This framework pits two similar scenarios against each other and asks students to make a prediction.

- *E ample: In a store, ou get 20% o but must pa 10% sales ta . Would ou rather ha e the discount or the ta calculated rst?*
- *E ample: Would ou rather get a pound of nickels or a pound of dimes?*
- *E ample: Would ou rather share three donuts ith four friends or se en donuts ith eight friends?*

Resource: http://www.wouldyourathermath.com

[illegible] 2: [illegible]

This approach exposes students to a partial pattern to create an information gap that they will be compelled to try and close.

1=1

1+3=4

1+3+5=9

1+3+5+7=16

1+3+5+7+9=25

Example: Do you always get a square number when you add consecutive odd numbers? If so, why? If not, can you find a counter-example?

Y [illegible] 5: [illegible]

Teachers are accustomed to posing all the questions in a mathematics classroom. One powerful way to spark curiosity is to present students with a scenario and simply ask them two questions: “What do you notice?” and “What do you wonder?”

STEP 2: Develop Grit

> "This quality of being able to sustain your passions and also work really hard at them over really disappointingly long periods of time—that's grit."
>
> —Angela Duckworth, Psychology Professor at the University of Pennsylvania

Curiosity is the desire to learn, but it is transient. Curiosity fades when the challenge is very large or the time required is long. As the initial curiosity fades, some grit is required to sustain the effort. Curiosity sets the stage for hard work, but at some point, the learner must regulate their ability to persist in the face of an uncertain outcome.

Angela Duckworth calls the ability to persist over long-term goals "grit." Duckworth's research has shown that grit is a better predictor of GPA and graduation rates than IQ (Duckworth, 2007).

There is an active area of research around techniques that help develop grit, but there are few significant results at this point. That said, there are ways to challenge TK–12 students and help them develop grit.

[illegible]

There is a sense of discomfort when one tries to learn something new. Math teachers must recognize and acknowledge this feeling in their students, remind them that it is a natural feeling, and encourage them to push through.

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As discussed, students need opportunities to develop grit. When a student struggles to answer a question, teachers must resist the urge to swoop in and offer hints or solutions. Instead, they must allow students to try different solutions in the hope of finding a path forward. The idea is for kids to become comfortable with struggle so they understand it is a normal part of learning.

Counterintuitively, the role of the teacher is not to provide answers; rather, it is to construct an environment in which students have the time and space to ask their own questions and develop a thirst for knowledge.

Students easily lose sight of their progress in mathematics. Imagine a student who begins the year with a B grade in mathematics. At the end of the year, they remain a B student. The student may falsely believe they have made no learning gains because the grade has remained constant. What students often fail to recognize is that the learning goals increase throughout the year. In actuality, a student whose grade didn't change has still made a great deal of progress!

One powerful way to emphasize this fact is to provide standards-based grades to students. Standards-based grading measures a student's proficiency against each standard. This rating can change as the student learns. Reporting progress in this way allows both the teacher and the learner to see exactly which standards have been mastered and which ones have yet to be attained. By contrast, traditional letter grades make it difficult to decipher which standards each student has mastered.

An additional and important feature of standards-based grading is to allow students to re-take assessments and change the grade for a particular standard. This reinforces the notion that learning is a process where perseverance and grit are rewarded. With traditional letter grades, students generally take a test, get a grade, and the class moves on to the next unit. The traditional model implicitly teaches students that grades (and ability) are fixed and that mastery is not the primary goal.

STEP 3: Promote a Growth Mindset

> "It's really hard to have high tolerance if you believe that your abilities or intelligence are fixed. Because if you believe 'I can't change my own abilities,' then trying hard doesn't make any sense. It's like pounding your head against the wall."
>
> —Eduardo Briceno, CEO of Mindset Works, a company he co-founded with Dr. Carol Dweck

Cha ge S de I e a Dia g e . When students say “I can’t,” teachers should add the word,

California Context

In California, the newly adopted 2023 California Mathematics Framework lays out an approach to curriculum and instruction that builds on students' curiosity and sense of wonder about the mathematics they see around them. It dictates that students should learn that math enriches life and that the ability to use mathematics fluently, flexibly, efficiently, and accurately empowers people to influence their lives, communities, careers, and the larger world in important ways (chapter 1, page 5).

Within the framework, the Drivers of Investigation work to elicit curiosity and motivate students to engage deeply with authentic mathematics. These Drivers aim to ensure that there is always a reason to care about mathematical work. To guide instructional design, the Drivers of Investigation are used in conjunction with the Standards for Mathematical Practice and the Content Connections to open authentic moments for learning, exploring the why (Drivers of Investigation), the what (Content Connections), and the how (Standards for Mathematical Practice) for the mathematical concepts that students will learn (chapter 1, page 21).

Through this approach, the California Mathematics Framework can support teachers in developing a math-positive classroom where each student is actively engaged in making sense of the world around them, allowing their math capacity to grow through immersion and perseverance.

Our culture promotes the notion that mathematical ability is innate. Students absorb this idea from the media they consume, and it is reinforced by an education system that focuses too heavily on grades and standardized test scores. Teachers are encouraged to "cover" math content in a way that emphasizes answer-getting over problem-solving, rote learning over understanding, and boredom over curiosity. Combined, these factors make it extremely difficult to engage TK–12 students in mathematical discovery.

Education research gives us a strong set of actions to take to combat these factors, including promoting engagement, emphasizing the importance of grit, and redefining achievement.

To begin, teachers can leverage Lowenstein's information gap theory for curiosity to help get more students interested in mathematical questions. As discussed, common frameworks for creating information gaps can stimulate student interest. Such frameworks involve leading (and sometimes controversial) questions such as "Would you rather?" or "What if not?"

Once a high level of interest has been created, teachers can focus on helping students develop the grit they need to work toward long-term goals. Often, this means being more hands-off and allowing students to struggle. This also means reporting progress in a way that rewards grit and emphasizes mastery as the primary goal.

Finally, teachers can apply several strategies to help students develop a growth mindset so they can overcome the setbacks that they are certain to encounter in their mathematical learning journey. When students understand that there are two mindsets, they can choose to be more growth-oriented.