I THINK, I TRY, I LEARN

Empowering the Next Generation of Thinkers

MIND EDUCATION

Contents

CHAPTER 1

MY DAUGHTER DOESN'T NEED MY MOTHER'S MATH EDUCATION

My daughter once brought home a practice math test. She's in the fourth grade, doing fractions. I watched her pretty successfully tackle 39 problems, using various procedures to add and subtract tenths and hundredths, convert these fractions into decimals, and then on the very last question she got stuck.

"Tony and Aisha both have containers. They use a marker to make tenths on their containers and fill each of them to a level of seven tenths with orange juice. How can Tony have more Orange Juice than Aisha?"

It got me questioning: **Why is she only being asked to think, to use creative reasoning, on the last question of the last test at the end of a unit on fractions?**

This is symptomatic of a fundamental problem in mathematics education. We assume kids can only tackle conceptual questions after they have mastered the mechanics of an idea. We have it backwards and the consequences are negative and profound. Many students never experience opportunities to think in a math class and as a result they feel no connection to what they are learning. Unfortunately, the majority of students, certainly in the U.S., are measurably not proficient on national assessments and by the end of middle school they come to the conclusion, "I'm not a math person."

For the record, my daughter could not figure it out having never been asked anything like it previously.

(The answer is that Tony and Alisha have different sized containers. Seven tenths of a small container is less than seven tenths of a big one).

How Did We Get Here?

Once upon a time, there was a reason for this educational emphasis on mechanics over understanding. My Mother was born in 1944, and was drilled to perform the traditional algorithms for addition, subtraction, multiplication, division and to convert fluently between fractions, decimals and percentages. In her time, having these skills set her up for a lifetime of successful employment! And she wasn't alone. The need for humans to perform mechanical calculations quickly and accurately was widespread. It helped get us to the moon in 1969! But this systematic educational focus on mechanical fluency came with an "unwritten" rule: perform.

A 1942 memo from the National Advisory Committee for Aeronautics (NACA) sums it up perfectly. It says,

> *"The volume of work often necessitates computers (people) who can perform the routine machine operations (math calculations) with great speed, but who need not have much logical insight into what the results should be."*

Just let that sink in for a minute.

Photo from the 1940's. The "computers" referred to in this room are not the machines; they are human computers, paid to be fantastically good at doing math procedures with both speed and accuracy.

The educational vision of the era was that only a few people needed to understand mathematics, the rest just needed to be able to do it, like a machine.

So yes, my mother's math education with the drill and kill approach worked for her back then. Yet, fast forward to 2024, and my daughter's test with 39 questions is training her to do the exact same thing, decades later! With only one test question, almost as an afterthought, trying to make her reason creatively. Do you know how many jobs she'll be able to get by just being good at procedural math? ZERO. And the number of jobs that will require creative reasoning, problem-solving and flexible thinking is going to be, well, all of them. My daughter doesn't need my mother's math education.

The Need for Change

We need change in math education, and we need it now. It is entirely possible, and hugely beneficial, to ask deep questions that push kids to think creatively about mathematical ideas at the start of any topic. Take the test question as an example. If we introduce it early in the unit and encourage students to explore and discuss it, we can engage them in a meaningful way:

"Tony and Aisha both have containers. They use a marker to draw a line halfway on their containers and fill each of them to the line with orange juice. How can Tony have more Orange Juice than Aisha?"

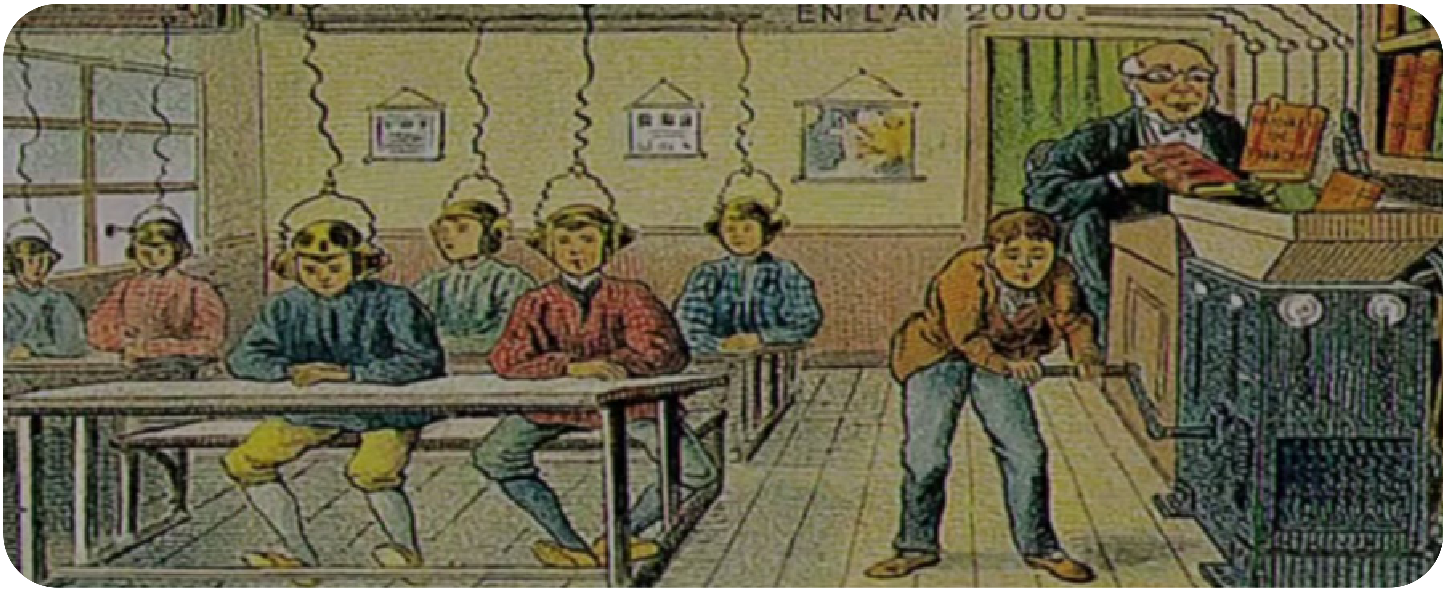
This rephrased question naturally leads into big ideas: fractions must refer to the same whole, fractions split quantities into equal parts, and it not only challenges students to think about fractions in relation to volume, but also integrates their prior knowledge. The new idea is fun, intriguing, something to play with, and helps students grapple with the concept of fractions so that subsequently, the details, the tenths, the hundredths, and the procedures for adding and comparing them etc., have somewhere to fit. Our educational vision must become the opposite of the NACA memo; in 2024 there is no point in being able to perform mechanical calculations unless you understand what you're doing.

If the old way of teaching math was to make you do it like a machine, today we need a new way of learning math so that our kids understand how things work and they can build the machines.

CHAPTER 2

THE OLD WAYS ARE NOT NECESSARILY THE BEST WAYS

When discussing the challenges of moving our math education system more in line with the needs of today's learners, I am reminded of a common refrain I hear from parents at my kids' school: "Why don't they teach math the way I learned it?"



The irony is that despite some shifts away from the traditional "drill and kill" methodology, a significant portion of today's math education still too closely resembles the past. This begs the question:

Why are we so reluctant to let go of outdated teaching methods when they no longer meet our present or future needs?

The Reality in Classrooms

In too many classrooms today, procedural fluency and answer getting is still prized as the goal. As the viral math blog youcubed.org puts it, "We are woefully under-preparing our students to successfully navigate the 21st century. The mathematics we teach is rooted in the 1950s space race and offers little practical utility in the 21st century."

Students will often ask, "Why do we have to learn this?"

This question reflects a real concern: if students are merely required to memorize mathematical procedures, they are very likely missing out on the deeper understanding of concepts. The jobs of today demand much more than the ability to perform rote calculations; they require creative problem-solving skills that our current educational strategies fail to develop.

This discrepancy in our educational methods is more than a theoretical concern—it's reflected starkly in our national performance metrics. In the United States, only 36 percent of 4th-grade students performed at 'proficient' or above in math on the 2022 National Association for Educational Progress (NAEP) Assessment. It marked the largest decline in NAEP scores since 1990, and scores were dismally lower for students of color or economically disadvantaged status.

Creative Problem-Solving

It is no longer sufficient or useful for today's students to be simply masters of mechanical mathematics. The world has changed. We need creative thinkers. We have tools and technology that can perform all the mechanical tasks we need. Our math education system has to change in order to produce the problem solvers of tomorrow—unafraid to use their creativity to tackle unknown, incomprehensibly boggling problems, like harnessing the sun's power, resolving warming atmospheres, or reversing economic pitfalls.

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Jo Boaler, Stanford professor and honored mathematician, is one of a growing body of voices for "a wholly different pedagogy where speed is out, depth is in." It's an approach where "sense-making matters more than memorization and retaining 'math facts' matters less than understanding how such facts interconnect." Students build their own "sense of context, connection, and numeracy." Calculations become building blocks of a "broader strategy for breaking down other problems."

Modern research finds students can only make this leap through a deep understanding of the material. When that happens, students can "creatively and flexibly apply their thinking to both familiar and new" ideas (Baroody et al., 2004), invent algorithms (Hiebert, 2003), and translate them to everyday situations (Baroody et al., 2007).

In other words, if we want to tackle our most pressing problems and foster tomorrow's inventors, students need more practice in creative reasoning than memorization-based learning. They need to know how to apply mathematical concepts to new ideas. In a world that increasingly rewards innovation over imitation, we must work tirelessly to ensure our students are not just robotically memorizing and spitting out math calculations, but mastering the art of creative thinking with it. By building an educational environment that emphasizes understanding and application over rote memorization, we initiate the transformation our schools need, and can prepare them to think outside the box—and perhaps even build a better box.

CHAPTER 3

RULES TO REASONING: THINKERS, NOT MEMORIZERS

Our math education system is at a crossroads. The traditional approach of teaching through telling, memorization and rote procedures is no longer sufficient in preparing students for the complexities of the modern world. We need a major shift towards fostering genuine understanding and critical thinking. I experienced a vivid reminder of this necessity when I asked my 7th-grade son about his Algebra 1 class. They've started a unit on quadratic equations and are factoring polynomials.

"Why?" I asked.

"Don't know," he replied, "but there's this rule we have to use."

I knew where he was going with this.

"No area models, no algebra tiles, no drawings?" I asked.

"Huh?" he said.

That told me all I needed to know, so we had an impromptu math lesson in the car on the way to soccer practice.

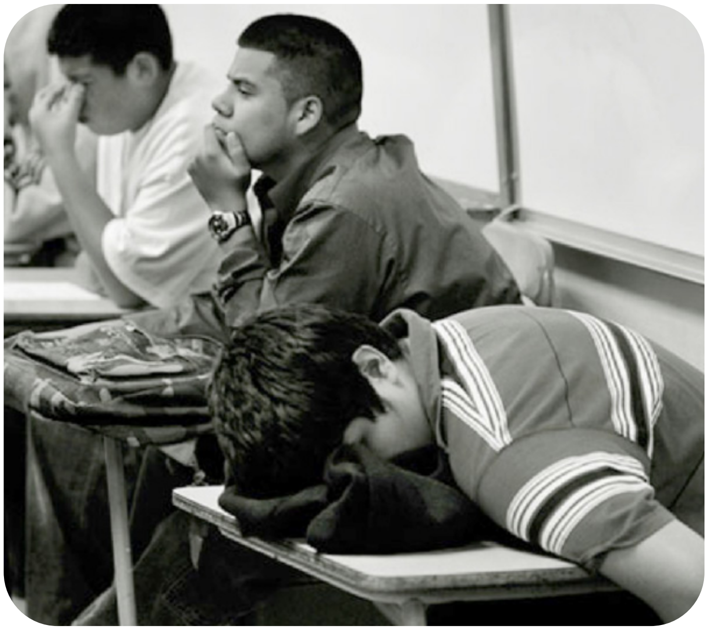
What made all of this even worse was that the next day he came home and told me, "You know that rule we did yesterday? Today they told us it no longer works and we have to use a different rule with these new equations."

Learning math through arbitrary rules, disconnected from any existing schema, works completely counter to the way our brains actually learn. It also turns students off from mathematics as a subject and ignores the creative problem-solving needed for future careers. It's void of why students should care enough to dig deep and think beyond memorization or passing the test. Arguably, the saddest loss is mathematics then becomes something students dread and never fully understand for its fascinating—and beautiful—role in human innovation.

Research on Creative Reasoning vs. Algorithmic Thinking

In chapter 1, we discussed how our kids don't need our grandmother's approach to math—the algorithmic thinking and memorization approach no longer best serves future problem-solvers. Now, we must teach students how to use creative and critical thinking to solve non-routine problems, leaving behind the narrow "answer-getting" legacy of the Industrial Revolution.

Algorithmic thinking, or answer getting, is still the dominant mathematics teaching method in the United States, presenting students with a math problem, providing a solution method for it, and following up with extensive practice (Hiebert, 1999, 2003). The perception is that it saves time, prevents



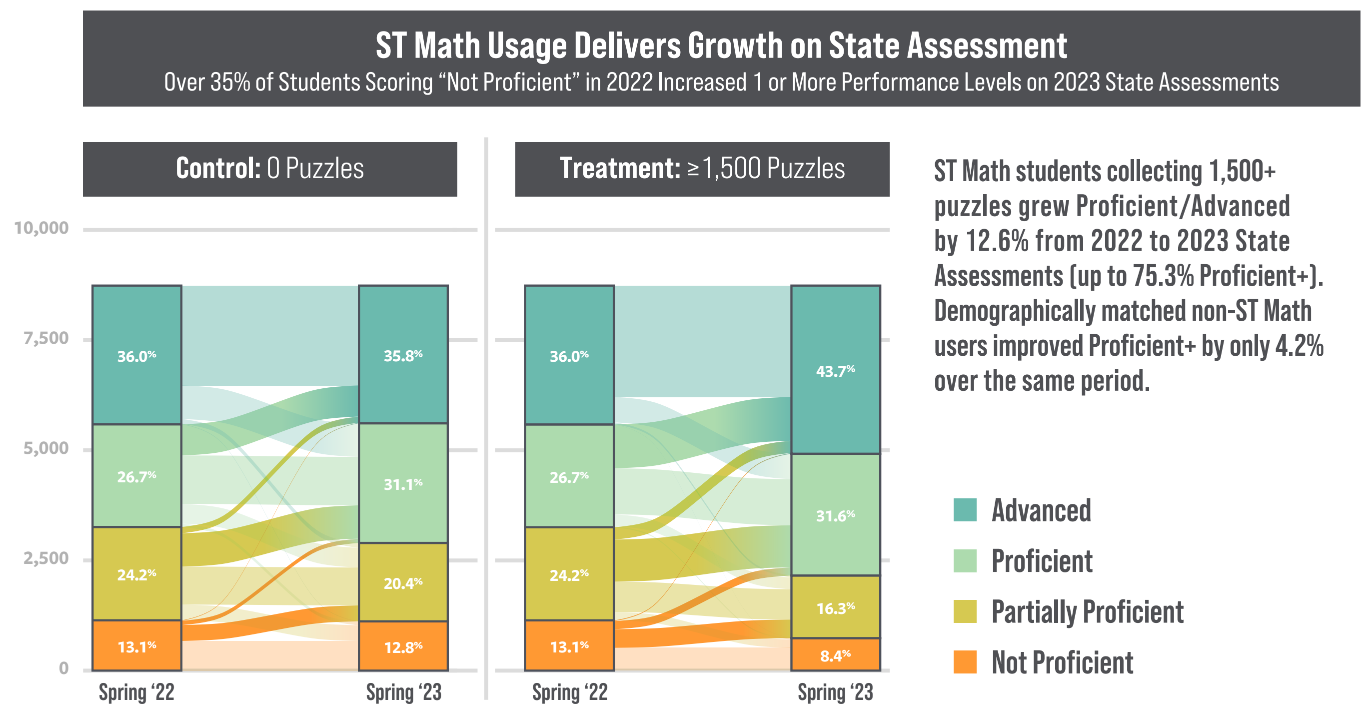
miscalculations, and the skills apply to most school textbook problems (Jonsson et al., 2014, 2016; Norqvist, 2018). But given the demonstrably low math scores nationwide and recent research, it limits student learning (Carpenter, et. al, 1998; Hiebert & Wearne, 1996) and discourages a deeper understanding of math principles. So, students, like my son in his algebra class, superficially do work without any conceptual understanding of why or how to apply it beyond the problem at hand.

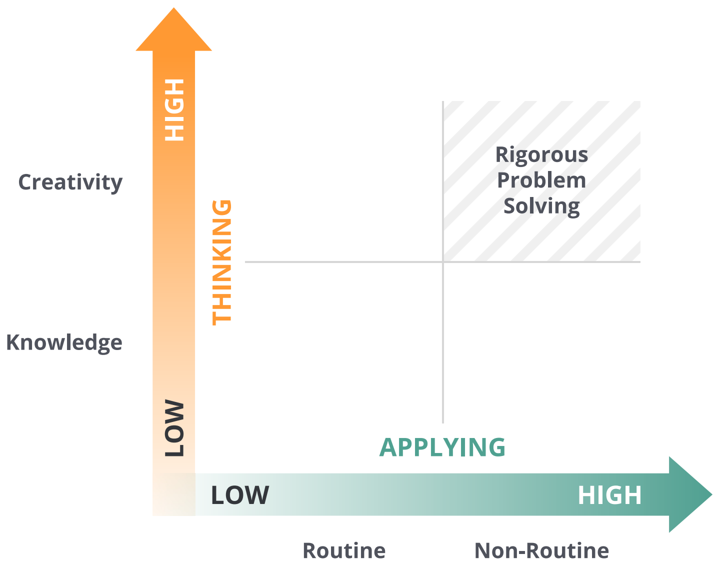
There is another way. In 2014, researchers made an apples-to-apples comparison. The students who had to struggle through and creatively find their solutions not only performed better, retained their knowledge and outperformed again when asked to reconstruct the work one week later (Jonsson et al., 2014).

Further, students who had to find creative approaches registered different brain activity than those with algorithmic thinking, remembering the information more easily. (Karisson Wirebring et al., 2015).

Empirical Evidence Supports this Approach

Study after study demonstrates students theoretically learn more by doing, by being active learners rather than passive receivers of knowledge. But does this approach work in the classroom? Can it work at scale? In Texas, the results were clear. The Texas Education Agency (TEA) made ST Math, a visual math program that uses a game-based, creative reasoning approach, freely available for all Texas students, and then tracked STAAR Math performance growth. Forty-eight percent of students who used ST Math dramatically improved, and remarkably, students at Did Not Meet levels decreased to near elimination. Also, ST Math and creative reasoning helped all students, even English Learners and Special Education students.





The Unique Role Teachers and Struggle Play

So we know creative reasoning works, why isn't it more evident in classrooms? Why is my son's algebra 1 lesson still using the same rules and procedures for solving quadratic equations like it's still 1954? It's a combination of the legacy of old teaching methods and our societal aversion to letting students struggle, and systemic challenges. Facilitating students as they creatively figure things out is ***much*** harder to do than delivering a similar lesson via direct instruction. Managing a classroom where students are engaged in a process of discovery requires letting it get messy but being able to bring it back to focus quickly. It also needs a deep conceptual understanding of mathematical concepts so that the teacher can help guide students to the desired learning no matter where they end up, and it needs a teacher who is very comfortable leading students with questions rather than giving answers.

Neuroscientific research proves meaningful, lasting learning stems from productive struggle. This doesn't mean students are left figuring things out without teacher support or tackling things beyond their ability. We recommend "making sense of mathematical problems that are just within students' reach of understanding as opposed to simply memorizing a presented solution (Hiebert & Grouws, 2007)." Students work more actively to make sense of a situation, forming "better connections to knowledge they already possess." (Hieber & Grouws, 2007). When this happens students can apply what they've learned to solve bigger, modern problems, like how to capture solar energy to power a car.

Teachers have a pivotal role as change agents. Students become more motivated to learn and stay engaged when they feel valued and connected to their teacher. That means when things get tough and struggle happens, teachers help build resilience, open space for "more high-impact teaching practices," and environments where creative reasoning can thrive.

I wish that my son's math class was conducted with the same passion, verve and "learn-by-doing" I observe at his club soccer training sessions. My "neuroscience-in-action" sensor is often on high alert as I watch the coaches skillfully allow kids to struggle, make mistakes, and immediately provide formative feedback asking them "what do you think you could have done differently? OK, now try that.'' Bringing this kind of active learning into math classrooms could be the change we need to inspire and educate future thinkers.

CHAPTER 4

THE AHA MOMENTS THAT TRANSFORM LEARNING

Let's dive into a topic that resonates deeply with all educators: those amazing aha moments when students finally get it, and everything just clicks.

I thought I was doing so well! I'd been teaching High School Math in Los Angeles for about two years and I was excited because today I was going to derive the equation of an ellipse. Mathematically, this is where the connections between geometry, algebra and trigonometry really kick in. I covered the boards with math symbols, expecting to see the class awestruck by the beauty of what had just unfolded in front of them.

Instead, at least half of them were asleep. It was a sobering moment. I realized the hard way, that the only person doing much learning in this classroom was me. That moment became one of my biggest aha moments—if the students aren't engaged in the struggle and the journey, there is no real learning. The aha moments needed to belong to the students, not to me.

The Power of Active Learning

On our best days, we may strive to be more like great coaches: encouraging students to take risks, make mistakes, and think creatively through why something worked or failed. However, the reality is that most classrooms today still rely on rote memorization and applying rules without context, a method that we now know doesn't work. In fact, it absolutely misses the point.

How Learning by Doing Builds Schema

Experiencing those aha moments is the most effective way students build neural pathways, enabling them to think creatively and find new solutions. And major universities are finding our K-12 graduates sorely lack the skills indicative of future creativity and innovation in most career fields, especially STEM opportunities.

When students experience an aha moment, their brains form new connections, or schemas. Strong schemas are adaptable and can be applied broadly and logically (Baroody et al., 2004), allowing students to use their knowledge creatively. In contrast, weak schemas lead to difficulty applying concepts in different contexts.

For example, a student with a weak schema might understand a basic math concept but struggle to apply it in different contexts. In contrast, a student with a strong schema can see the relationships between concepts and use their knowledge flexibly and creatively.

In other words, you can't just push information into students' brains. They need to learn by doing, and making connections on their own.

Goodbye Direct Teaching, Hello Active Learning

In the last chapter, I recommended educators become more like coaches, "skillfully allowing kids to struggle, make mistakes, and immediately provide formative feedback asking them: "What do you think you could have done differently? OK, now try that.'' Active learning involves: productive struggle, creative reasoning, formative feedback, student engagement, and mathematical discourse. This means a math class should be full of discussion, experimentation, and trial and error, with teachers guiding the process and challenging students with questions.

3 Ways to Get Started Today

Here are three activities to help you create those aha moments:

1. The Four 4s Activity - In this activity, students have four 4s and create all the numbers they can with the four 4s. This exercise is ideal for third and fourth-grade students.
2. How many ways to make 1½? - Encourage students to find many ways of decomposing and composing a set of visual fraction pieces to create 1½. Quick Teacher Notes.
3. Visual puzzle-based problem-solving - This puzzle sequence starts very simply but gets deceptively tricky very quickly. Students of all ages can engage with this and try to figure it out!

Put your students in small groups and allow them to work together to find solutions, brainstorm ideas, and outdo their fellow classmates. Watch your classroom buzz with ideas, student discussion, and enthusiasm for. . . math. . . yes, math.

CHAPTER 5

LEARNING MATH FOR A FUTURE-READY WORLD

Let's talk about soccer. Specifically, the coaching my son receives at his club, Dynamo, in Los Angeles.

As a student of the neuroscience of learning, it's been fascinating to observe so many neuroscientific learning principles unfold in the training field in front of me. For example, the kids are consistently driven to be in that "zone of proximal development"—just on the wrong side of their comfort zone—challenged in scrimmages played at great speed to function under pressure and find the right pass and "make the right decision." But it's when they get it wrong that I really start smiling. The coach will stop the scrimmage, ask the kids to reset to where they just were, and replay the moment, but this time standing with the "learner," discussing what they could do differently, demonstrating and allowing them to try something else, a turn to the other side, controlling the ball with the other foot, whatever it might be that can change the game.

This is productive struggle in action, learning the way the brain learns, immediate formative feedback played out with a football (sorry, I'm British), and very importantly, using mistakes as one of the primary drivers of the learning process. Unsurprisingly, for my son, that learning process has been absolutely phenomenal.

How I wish his Algebra 1 class last year had been as full of the same learning by doing. Unfortunately, it was largely procedural memorization and edtech-supported practice. This is basically the equivalent of being made to do endless soccer drills but never getting to play a game or even knowing that the game exists. The game of mathematics is the struggle; it is the problem-solving; it is the drive to creative reasoning and the flash of inspiration that allows you to figure out solutions even when you didn't initially know what to do.

When we over-coach our math students by telling them everything they need to know up front, trying to minimize their struggle, we do them a huge disservice. First, their brains learn really well through the active process of the struggle—and pretty badly from passively trying to absorb a mound of unconnected information—but secondly, to quote the late physicist Richard Feynman, we remove the "joy of figuring things out." And ultimately, it is by building a robust joy of figuring things out and a joy for mathematical creativity that we will arm our younger generation with the tools they need for their future, both as they leave the education world and head into the job market, but also as this generation begins to tackle the looming global crises on their immediate horizon.

Why Math Education Must Evolve

In the first chapter, we probed on the shifts needed from the 1963 mathematics education model, highlighting how that model fails to meet the needs of today's students. The world has changed, and so must our approach to education.

In chapter 2, we explored the urgency for transformation, emphasizing the urgent need for change in our education system. Traditional approaches to teaching mathematics are no longer sufficient to equip students with the skills they need for the future.

In chapter 3, we stressed the importance of developing critical thinkers rather than rote memorizers. In a complex and ever-changing world, the ability to reason and think critically is paramount.

And, we looked at the power of transformative learning experiences that ignite curiosity and understanding in chapter 4. These "aha moments" are crucial for deep and meaningful learning.

But maybe you are still asking, "Does it matter?"

It absolutely matters. Let's explore WHY.

Preparing for Tomorrow

Today's students don't need to be able to solve problems "like a machine"; they need to be able to build the machines to solve problems! As we look ahead to the next decade, the skills in most demand for the future job market, according to Forbes and Totara, include:

- **Critical Thinking:** The ability to analyze and evaluate information to make informed decisions.
- **Creativity:** The capacity to think outside the box and innovate.
- **Emotional Intelligence:** Understanding and managing emotions to interact effectively with others.
- **Problem-Solving:** Tackling complex challenges with strategic solutions.

You may also be aware of the 4C's of 21st Century Learning: communication, collaboration, critical thinking, and creative thinking. It is striking that **NONE** of these skills can be learned by simply listening to someone tell you how to do them. They develop in response to being challenged, and learning by **DOING**, and by actively working with a team to solve problems. And a mathematics classroom (or a soccer field) is a fantastic place for these skills to be developed and to flourish.

If we embrace math learning with productive struggle, immediate formative feedback, and tasks with a low floor but a high ceiling, modern math education can foster these in-demand skills.

Preparing Students for LIFE

Preparing students for the future is about equipping them with the skills needed so that they are better prepared to face life's challenges. This approach helps them become well-rounded individuals capable of making meaningful contributions to society. We have to lean into a vision for our students' future where mathematics education is reimagined to meet these needs. It will require a partnership between all of us—as educators, as parents, and as policy-makers—to seek those experiences for students that push their creativity. Just as we encourage them to step beyond their comfort zones, we must also be willing to step beyond ours.

Together, we can create a better way forward.

The challenge is clear: too many students are struggling with math, affecting not only their academic success but their future opportunities. Cultivating a deep conceptual understanding of math is crucial for fostering the problem-solving abilities necessary in today's ever-changing world. MIND Education's research-driven approach and the demonstrated success of ST Math offer you the tools to enact substantial, enduring transformation in your classrooms.

Discover how these methods can enhance math education for every student, teacher, and school. Experience the transformation firsthand—dive into the games! Empower your district to build a learning atmosphere where all students excel in math and beyond.

Just play at
stmath.com/play

"I love that ST Math allows our students to develop a conceptual understanding of math topics they are already learning in the classroom. It gives all students an opportunity to problem solve through visuals and challenging puzzles, and helps build perseverance and confidence among our students."

— *Tamara Yeghiayan, math coach, Hawthorn School District, California*

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