Teaching Math in the 21st Century: Changing the Focus from Calculations to Critical Thinking

By Chris Ozarka Posted March 14, 2016 In Classroom Practice

(Scroll down to see the video version of this post).

Math class can be a traumatic experience, and for whatever reason, people tie math closely to intelligence. Many people think if you're smart, you can do math and, if you're not smart, you cannot.

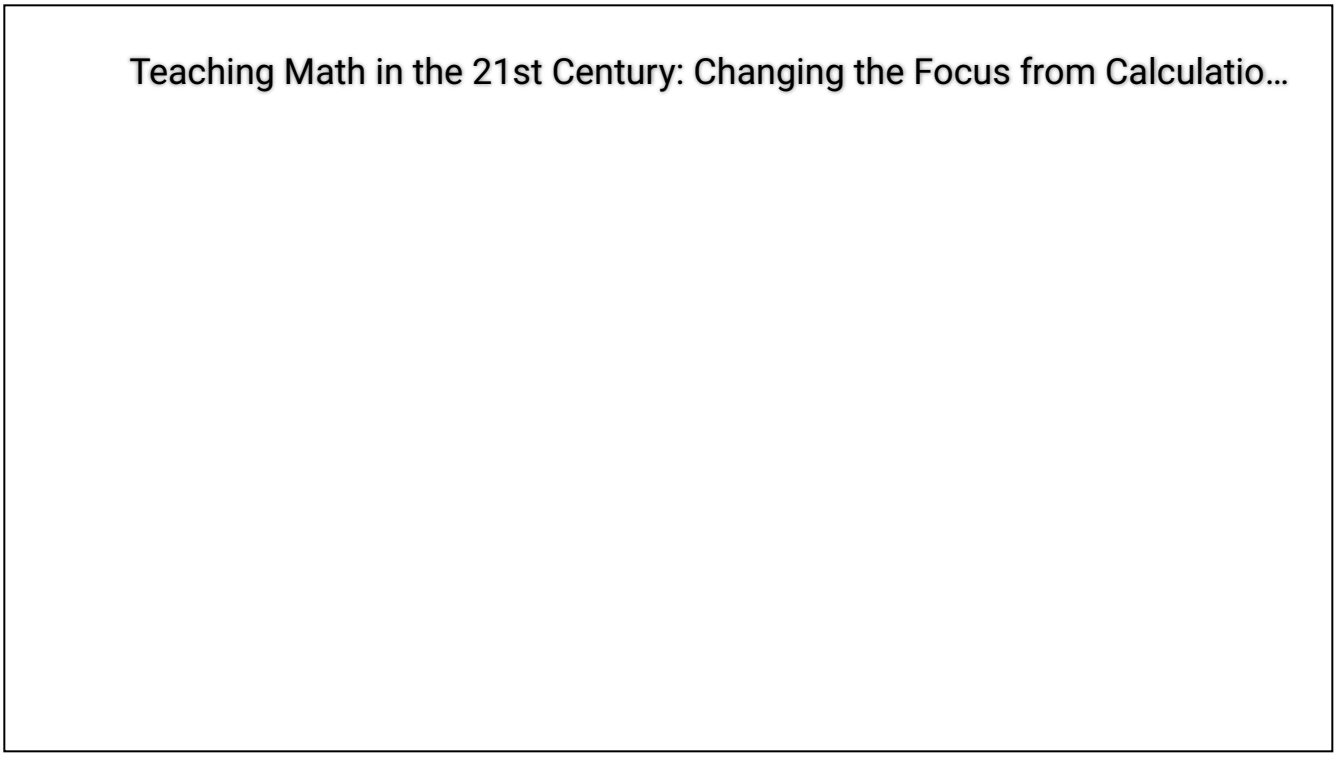
According to statistics from the Carnegie Foundation, about half of all students in the U.S. go to two-year colleges. Over half of those students are required to take remedial math courses (often for no credit) which are essentially the same classes as what they took in high school. About 10% of those students complete the remedial math courses while the remaining 90% are not able to and simply drop out of college.

Based on this data, what would you say is the top reason? Are there too many math standards? Do students not have the ability? Are teachers to blame? Is math not for everyone?

I believe that math content is not the problem nor is it the students, but rather the way it is commonly taught. Math involves logic, reasoning, critical thinking, and tenacity. These are all things that people absolutely love to do. Give a riddle to a person and you will find that many people love trying to solve them. Sudoku puzzles enthrall people for hours. The same is true of board games, video games, etc. The human mind likes thinking, reasoning, and figuring things out. The main problem with mathematics is that it is not taught this way at all. It is not viewed as a riddle to be solved and, oftentimes, math problems are not explained in a way that allows students to thoroughly understand what they are looking for and why it is important. Other times, math is shown as a series of steps to be memorized and followed rather than understood and applied to new situations.

These skills needed for mathematics are real-world 21st century skills that students will need regardless of what they end up doing with their lives. Many students believe they “dislike” math because they will never need a particular algorithm or equation outside of school. This is true, but the skills of reasoning and critical thinking that should be the focus of math courses will always be needed.

So, if you were asked the best way to teach math, what would you say? A colleague asked me that very question. This post and video represent my response.



What a Good Math Teacher is NOT

A good place to start might be what a good math teacher is not.

Teacher ≠ Teller

Math teachers should NOT be math “tellers”. Rather than challenge students to build their own understanding of concepts, “tellers” tell students how they are supposed to understand.

You may be a math “teller” if you tend to show students how to solve a problem. Being a math “teller” is almost like giving students a puzzle already completed rather than having the students put it together themselves.

This brings up a fundamental issue with understanding what good teaching consists of. Most students, parents, and even teachers think that if you explain concepts in a clear, concise way, then you are being a good teacher. What this actually means is that you are a good “teller”. The problem with telling is that students are not being challenged to think mathematically. In essence, the “teller” is doing all of the thinking for them. The students are more focused on becoming good at calculations, instead of discovery.

Please note, this is not to say that teachers should not be helping students, but helping students is not the same thing as showing them how. This notion of teachers “making things easier to understand” goes against what research in education has shown us. Research in education identifies one of the most important things that teachers do to affect student conceptual understanding. That is to make sure students are engaged in what is called a productive struggle. This involves not simply telling students how something can be made easier but instead focuses on providing students with challenges that contain clear instructions and providing enough time to figure things out. Probably the biggest role of a teacher is to promote 21st century skills, create excitement, and build students’ confidence toward learning and thinking. None of this is promoted if teachers are simply the medium in which students get easier explanations.

Solving a Type of Problem ≠ Problem Solving

Another attribute of what a good math teacher does NOT look like includes teaching students exactly how to do a certain type of problem and then giving them the same problem over and over with different numbers. This type of rote, basic skills learning can be done by a simple computer. The last thing we need is students thinking and acting like a computer.

There needs to be a human element to the learning. An aspect of discovering new concepts collaboratively, making mistakes, debating answers, attempting problems that are completely novel, etc., must be present. Doing calculations is not the same as doing math. Unfortunately, most assessments are simply assessing calculations while ignoring the concepts.

Math ≠ Race

One of the biggest gripes I have about tests like the ACT is they are timed and more focused on calculations than actual thinking. Math (among other subjects the ACT assesses) is meant to be deeply thought about. Instead, students learn how to take the test. This gaming of the system does not provide any in-depth thinking beyond the test itself. Assessments in math classes should not follow the ACT's lead. It is much more beneficial to have concentrated thinking about problems rather than students robotically completing problems as fast as they can in order to finish a test. If a concept is important enough to be tested on, then it is important enough to get the appropriate amount of time to be thought about.

Note: I am not saying that students should be given as much time as they want on a test, but they should not feel rushed to finish a test. Showing mastery of a concept does not require a race against the clock.

As a society, we do not need speedy executors of process anymore. Calculations can be done with computers. We need mathematical modellers, predictors, justifiers, communicators, and problem solvers. We need more people that program and work with computers than people that act like them. These types of people are what will make up the future STEM jobs.

The heart of math is to deeply understand concepts and how they are related to each other in order to solve other problems. This type of thinking is the basis of intelligence and time should not limit this.

Math ≠ Memorizing Algorithms

With the ubiquity of the information due to the advancements in technology, memorizing facts, formulas, and equations has become more and more obsolete. Valuable learning time should be spent working on higher order thinking rather than rote memorization.

What Good Math Teaching Looks Like

Learning math can promote cognitive strengths that cannot be found in any other discipline. The kinds of thinking that I am talking about involve logic and reasoning. In this type of learning, numbers take a back seat to thinking.

However, such thinking is not part of most curriculum. Instead, we get an unsteady collection of seemingly unconnected skills and procedures, which many teachers proclaim to reteach every year as if the students had never seen them before. Time and time again, research has shown that most students who are considered to be "good at math" under the traditional math setting often cannot apply a single thing they have learned in a novel setting. As math teachers, we tend to focus on what to teach rather than how to teach it. This makes math class more like a checklist of processes and algorithms for students to memorize rather than mathematical thinking.

So what needs to change?

Inform Students on How Learning Works

As discussed previously, a teacher's role is to inspire students to not only think, but want to think. In my opinion, too many students think they hate math. In reality, they hate what they think is math. A better way of describing it might be "memorized mathematical procedures". This makes sense if you know anything about control theory. People tend to focus more on what is controlling their learning than the learning itself. For example, if you are rewarding students with points or a grade for their learning, they tend to focus more on the points and grade than on the learning. I tell students this on the first day. I explain to them the psychological ideas behind a lot of the teaching and how it can affect them. That way they can be informed enough to attempt learning in a different, more productive way that focuses on intrinsic motivation.

Provide Clear Instructions

Oftentimes, students are not confused about the mathematics. They are confused about the setup of the class, the instructions of a lesson, what they are trying to solve for, and sometimes even the way that a teacher's website is arranged. The biggest confusion in class should be from the mathematics, not the learning environment. When giving students a challenge, have them repeat back the instructions that you gave to make sure they understand what you mean.

Ditch the In-Class Lecture and Focus on Self-Paced, Collaborative Learning

Self-paced learning provides students time to create their own understanding of the material while collaborative learning has been shown to increase understanding of concepts due to different student perspectives.

Lecturing to an entire class assumes that all students are equally understanding the content. It also does not provide a lot of opportunities for student collaboration. Videos are a great alternative to lecturing and provide an excellent medium for students to utilize self-pacing of learning. They are able to learn at their own pace, pause, re-watch, collaborate, and ask more specific questions.

In-class challenges should be completed at a student's own pace. Oftentimes, concepts that they struggle with in the beginning make sense at the end of the course allowing them to catch up to their peers. Also, mastering all units in a course except a few is much more valuable than kind of understanding all of them.

Be Inspiring and Informative with Feedback

Some students come to class finding math simple, while others find it difficult. However, this does not reflect their potential for future understanding. Students have been gaining different experiences since childhood. Some of those experiences cause synapses to fire and others do not. As teachers, we need to change the path for those students that never had those synapses. Students need an environment that is personally challenging. Neuroscience shows that every child has the ability to excel in math. The potential of the brain to grow is huge, and despite the belief in fixed math ability, every learning experience can change your math capabilities. Fixed ability language should be used as least as possible. This includes saying things like “you’re so smart”, “you’re so good at math”, “you struggle with math”, etc. While it may seem nice to tell students positive fixed ability comments, research shows that once students do something that they perceive as not smart, they think that what you said was incorrect. Instead, the focus should be on effort and actionable feedback. When giving feedback, make sure students know that you are critiquing them because you believe in their ability and potential to succeed. Starting any feedback to a student with a positive statement makes feedback even more powerful. Make sure to praise what students have done rather than their intelligence.

Timely feedback as needed is best, but difficult when teachers lecture. Teachers must be free to socialize with students during class time to give them not only retrospective feedback regarding past understanding but also constitutive feedback related to the future understanding.

As Grant Wiggins said, “Learners need endless feedback more than they need endless teaching.”

Focus on Students Actively Creating their Own Understanding Collaboratively

Simply put, if you don’t ask students to think, they won’t.

How something works is vitally important, but the further applications of a concept become more extended when one understands the “why”. The problem that most teachers face is that the “why” does not come immediately for most students. As teachers, time is always against us and most classes are not even close to being self-paced. So, rather than spending time on understanding the “why”, teachers give students the easy way out by telling them what to do. The procedures are learned and then forgotten about easily and, since they were never fully understood, are never connected to new concepts.

This is part of the reason why mathematics may seem fragmented instead of a connected web of concepts. This is not to say that students do not need to know the how to do basic skills. What I recommend is, instead of telling the students, have them discover it on their own through activities and problem-solving exercises. Having students use past understanding of concepts to help them solve new problems helps tie old concepts to the new. This provides a deeper understanding for the students. It is important to note that not all students can discover concepts on their own. This is where the teacher comes into play. By providing hints, you urge students to understand concepts, but by challenging themselves at their own pace.

As research shows, students who participate in informal quantitative reasoning are able to complete formal math assessments with much greater ease. Similarly, students who are asked to give reasons for their thinking are better at using logic to explain an argument.

Research has shown that when math is taught with a focus on problem-solving skills, logical reasoning, multiple forms of representation of concepts, and question formulation, students perform at higher levels, take more advanced math courses, and equitable achievement is created. When these aspects of math are promoted in class, rather than repeating procedures, students’ intelligence and ideas are more valued, which leads to higher confidence in math. Furthermore, the main skills that math focuses on is reasoning and justification for that reasoning.

Differentiate

Confidence is a huge factor in doing well in math. Students need to be completing problems at their level and finding success. When helping individual students, try not to have predetermined questions. Instead, think about students' current understanding, listen to their ideas, and try to create interesting questions that relate directly to their ideas to push the limit of their understanding.

Avoid routines in questioning and the construction of student problems. If you want students thinking outside of the box, then they must be challenged accordingly.

Each learner is different and in order to help all of them, teachers need more passion and patience. Although these absolutely help, there need to be well-thought-out strategies for each student. Their prior knowledge, confidence level, and motivation all need to be taken into account.

Make Sure Students are Making Mistakes (when learning, not summative assessments)

Recent brain evidence shows the value of students working on challenging work and even making mistakes. However, many students are afraid of mistakes and think it means they are not a math person. If mistakes are designed into the learning process rather than the grading process, students will look to them as a way of learning rather than an assessment of their abilities. Research shows that mistakes cause more synapses in the brain as well as more growth.

Provide a Collaborative Work Environment

Feedback also needs to come from multiple sources including peers, teachers, experts online, and most importantly, self. Peer-to-peer feedback has been shown to increase student understanding in both the student giving feedback as well as the student receiving feedback. Also, collaborative work environments also provide for more detail in the work produced and expected. Furthermore, collaborative work environments promote the usage of the 21st century skill of communication.

How Do We Get There?

Don't Think All or Nothing

Don’t think you have to change an entire course to match the style of math teaching described. Chances are that you already do a lot of what I described. If you simply make small changes and proceed to add more and more throughout the years, you will have a course that focuses on mathematical best practices. You can choose to modify a unit in a year or maybe one lesson a week. Like learning, teaching in new ways requires a self-paced timing for teachers as well. Comfort level and learning curve for teaching the prescribed way are different for each teacher.

Have Backup

Make sure you have a support system in place to help you. I’m lucky enough to have an administrator that supports the way I teach and allows me to come to him if I ever need any help or ideas. Other teachers (even in other subjects) can also be a great source of support as well.

Make Mistakes!

Don’t be afraid to make mistakes. Often teachers avoid the possibility of making any mistakes so as to not create an ego disturbance. They view themselves in a certain way and do not want to try something new that would cause this view to be altered. As a professional, we must get over such discomforts for the sake of our students.

Conclusion

Teaching math this way is rewarding, exhausting, and completely necessary. The world is changing more now than it ever has. We need logic thinkers, creators, and modellers of abstract ideas and concepts. Mathematics provides an excellent way of promoting those skills. We, as teachers, need to make sure we teach it that way.

References

Hiebert, James, and Douglas Grouws. “The effects of classroom mathematics teaching on students’ learning”. N.p., 2016. Web. 21 Feb. 2016.

Bay-Williams, Jennifer. “Takeaways From Math Methods: How Will You Teach Effectively?”. Edutopia. N. p., 2014. Web. 21 Feb. 2016. Cisco.com,. (2016). Retrieved 22 February 2016, from https://www.cisco.com/c/dam/en_us/solutions/industries/docs/education/Multimodal-Learning-Through-Media.pdf

YouTube,. (2016). e-Learning Affordance 4a: Recursive Feedback. Retrieved 22 February 2016, from https://www.youtube.com/watch?v=3LOjul-kJyc

Achievingthedream.org,. (2016). Retrieved 22 February 2016, from http://www.achievingthedream.org/sites/default/files/resources/PathwaysToImprovement_0.pdf

Sciencedirect.com,. “Modelling Reality In Mathematics Classrooms: The Case Of Word Problems”. N. p., 2016. Web. 15 Feb. 2016.

Koretz, Daniel M., and And Others. “The Effects Of High-Stakes Testing On Achievement: Preliminary Findings About Generalization Across Tests.”. Eric.ed.gov. N. p., 1991. Web. 15 Feb. 2016.

Wolfram, C. (2016). Teaching kids real math with computers. Ted.com. Retrieved 28 February 2016, from https://www.ted.com/talks/conrad_wolfram_teaching_kids_real_math_with_computers

Moser, J. S., Schroder, H. S., Heeter, C., Moran, T. P., & Lee, Y. H. (2011). Mind Your Errors Evidence for a Neural Mechanism Linking Growth Mind-Set to Adaptive Posterror Adjustments. Psychological Science, 0956797611419520.

Dweck, C. (2006). Mindset: The new psychology of success. Random House.

Youcubed at Stanford University,. (2016). When You Believe In Your Students They Do Better. Retrieved 28 February 2016, from https://www.youcubed.org/think-it-up/when-you-believe-in-your-students-they-do-better/

Xkcd.com,. (2016). xkcd: Forgot Algebra. Retrieved 28 February 2016, from https://xkcd.com/1050/

Mangels, J. A., Butterfield, B., Lamb, J., Good, C., & Dweck, C. S. (2006). Why do beliefs about intelligence influence learning success? A social cognitive neuroscience model. Social cognitive and affective neuroscience, 1(2), 75-86.