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What does it mean to be *GREAT* at maths?

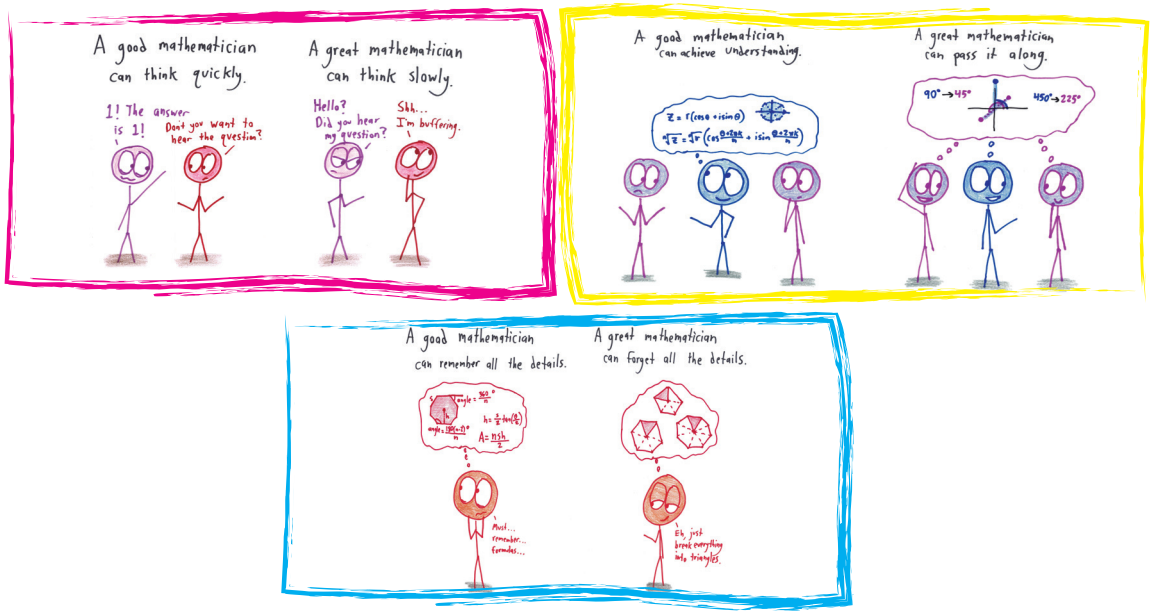
Jo Boaler, Stanford Professor + youcubed

Many people have the wrong idea about math - or maths as I call it. They think that it is all about rules and that to be good at maths you have to think quickly. They don't think the subject needs creativity or deep thinking. To help erase these damaging ideas, this lesson shares some cartoons from Ben Orlin, and introduces students to some inspirational mathematicians to help them think differently.

Our idea for this resource is that you share the following pages with students and encourage them to discuss the myths, the mathematicians and their own experiences. If you are a teacher of younger students you may want to display the cartoons and share some information about the mathematicians. We have included photographs of the 4 mathematicians that you might want to display for students.

If you would like to share what you do with this resource, please use #limitless and tag me @joboaler and @youcubed.

And as always, Viva La Revolution!



Reference: Orlin, B (2018). Math with Bad Drawings: Illuminating the Ideas that Shape Our Reality. Black Dog and Leventhal. https://mathwithbaddrawings.com

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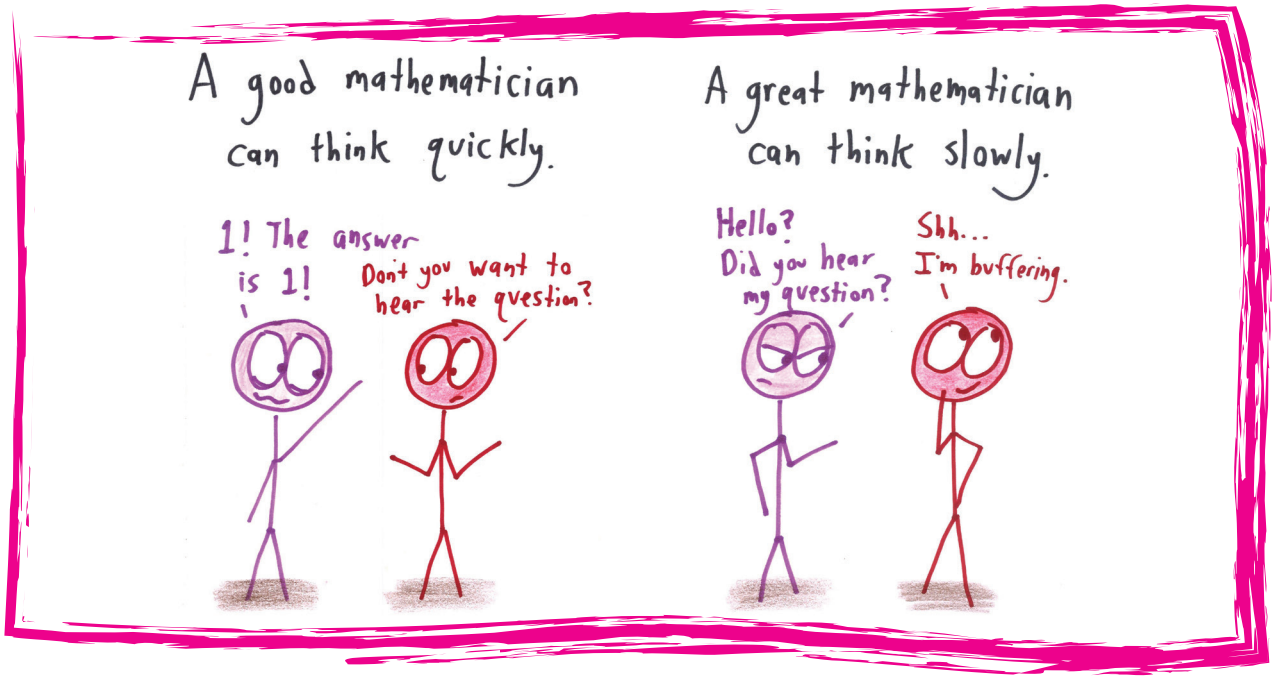
1. Mathematical thinking is not about speed



Maryam Mirzakhani, a Stanford mathematician, was the first woman in the world to win the Fields Medal, the greatest honor in mathematics. She described her thinking as slow and deep. She described mathematical work as like writing a novel, with different characters that you get to know as you work. Her work was almost entirely visual and very creative. Neuroscience shows us that visual thinking is really important to mathematics. Maryam spoke of people who solve problems faster and said she did not feel intimidated by them – she knew her slow, deep thinking would pay off. In 6th grade her teacher told her she was bad at math. Fortunately for the world she continued on, to become one of the greatest mathematicians of all time.

Tai-Danae Bradley is another cool mathematician – she is currently a PhD student at the City University of New York. Tai-Danae writes on her blog post that she is not a speedy learner: "It turns out, though, that learning how to learn doesn't necessarily mean you'll learn faster. I am still no good at symbol-pushing or speed-computing, but my goals as a student changed long ago. I want to understand mathematics well. I want to see it with clarity. That requires work, and the work takes time."

Tai-Danae has a blog post to share with others how to learn maths well: https://www.math3ma.com/

Discuss: have you ever thought you were not good at maths because someone else worked more quickly? How do you think slow thinkers like Maryam and Tai-Danae became great mathematicians?

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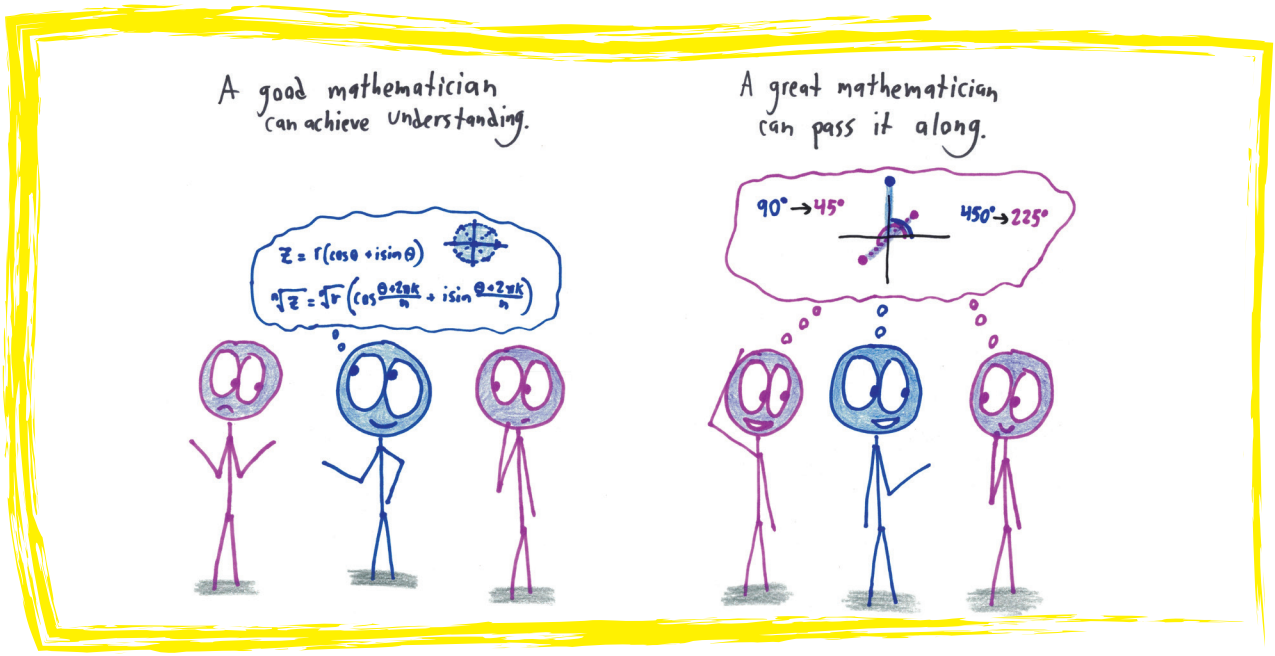
2. Mathematical thinking is about communicating and reasoning



Communication is really important in maths – scientists prove things by finding cases or disproving cases, but mathematicians prove ideas by reasoning. Mathematical reasoning is the act of explaining an idea, the logic behind the idea and the connections with other ideas. In the modern world employees most want to hire people who can reason and explain mathematical ideas, not just answer questions correctly. Mathematical discussions are also really good for learning - When we connect with someone else's idea it both requires and develops a higher degree of understanding.

Some mathematicians work to explain complex mathematical ideas to others – and perhaps the greatest mathematical communicator of our time today is Steve Strogatz. Steve is a Cornell mathematician who loves to teach. He learned about inquiry based teaching from mathematics educators and now uses it in his mathematics classes at Cornell (https://as.cornell.edu/strogatz-helps-students-find-magic-math)

Steve also describes himself as a slow, deep thinker. He has written amazing books, such as The Joy of X and my more recent favorite, Infinite Powers, which is a book about the big ideas of calculus.

Discuss: What do you like, or not like, about working on maths with others? What could help maths discussions be better?

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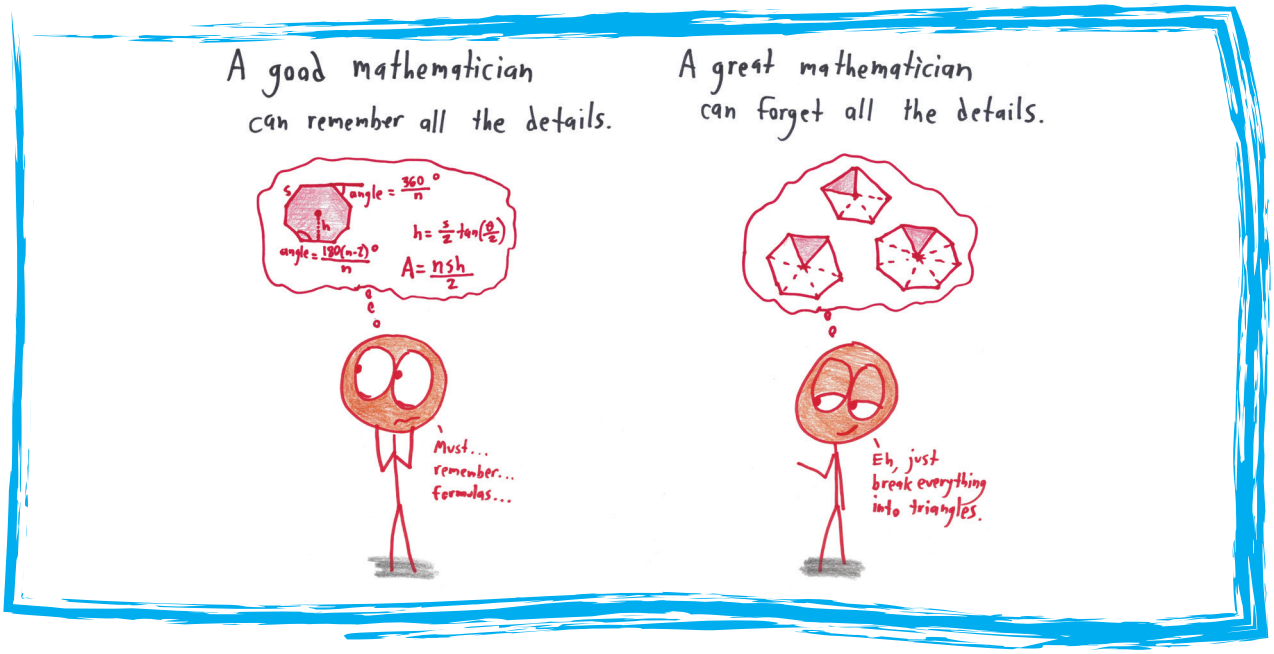
3. Mathematical thinking is not about memorizing methods



Sylvia Serfarty is a French mathematician who works at New York University, Courant Institute. Like Maryam, she has also won many important mathematical awards. Sylvia remembers starting to think she might be a mathematician when she was in high school and she solved a problem in a creative and different way. She said her solution was more general than the one the teacher was expecting. In her career she started working on a difficult problem that she eventually solved 20 years later. Like Maryam she compares working on maths problems to hiking, "You hike uphill and it's tough and you sweat, and at the end of the day the reward is the beautiful view."

Tai-Danae Bradley, the CUNY mathematician I mentioned in the first idea, also talks about the need to get past details and jargon to see the important big ideas: "Quite often, I'd find that the ideas of math are hidden behind a dense fog of formalities and technical jargon. Much of my transition process was (and still is!) learning how to fight through this fog in order to clearly see the ideas, concepts, and notions which lie beneath. Throughout this process I learned that writing —and drawing! —helps immensely. https://www.math3ma.com/about

Mathematics is not about remembering lots of details, it is about thinking deeply, and making connections. Many school students get the incorrect idea that maths is all about memorizing methods but an international study of 15 year olds showed that a memorization approach is the least effective approach to learning mathematics (https://www.scientificamerican.com/article/why-math-education-in-the-u-s-doesn-t-add-up/). Great mathematical breakthroughs often come from creative, flexible thinking – drawing, building, and writing all help with mathematical ideas.

Discuss: Can you think of a creative approach to a maths problem that you or someone else has used? What would help you think creatively about maths?

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Now it's your turn, can you draw a cartoon of a good and a great mathematician? Highlighting a myth about learning that you think is important?

A Few Great Mathematicians

Tai-Danae Bradley

Maryam Mirzakhani

Sylvia Serfarty

picture copyright Stefan Falke

Steve Strogatz

and his dog Murray