

Everyone can learn maths to high levels!

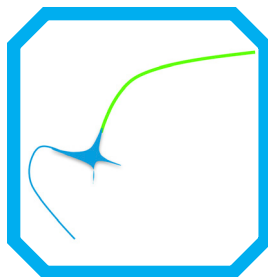
There is a common myth held by millions of students, teachers and parents – that some people have a “maths brain” and some do not. This idea holds people back on a daily basis. But this myth has been disproven by brain science which shows that brains grow and change and that no one is born with or without a maths brain. Mathematical pathways form in the brain through learning.

When learning happens the brain responds in one of three ways:

New pathways form



Pathways are strengthened



Connections are made between pathways



It is very important to communicate this new science to students and help students understand that they can learn any school mathematics if they put in effort and believe in themselves.

You might like to share this video with students to help them learn the new brain science:

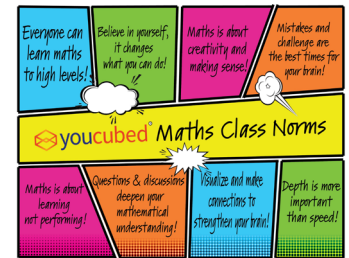
<https://www.youcubed.org/resources/four-boosting-messages-jo-students/>

This short free student online course has been found to significantly increase students’ mathematics achievement and engagement: <https://www.youcubed.org/online-student-course/>

Math or Maths?

You may wonder why our youcubed posters say mathS and not math. There are many countries in the world including the UK where Jo is from, that say maths not math. Also, maths was made into a plural noun because it is short for mathematicS - and the s on the end is important. It captures all the different forms of mathematicS and ways of being mathematical - e.g. drawing, communicating, generalizing, visualizing, connecting. The singular word math sounds more narrow and people in the US often say “do the math” when they mean “do a calculation!” Maths is so much more than calculating so we like the word mathS!

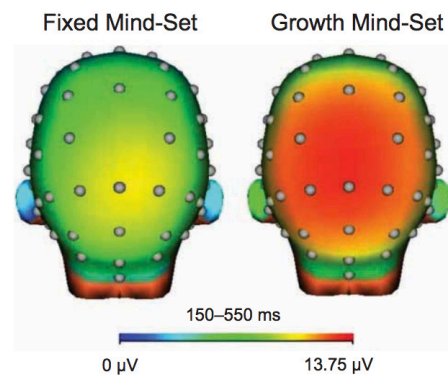




Believe in yourself, it changes what you do!

In a range of studies pioneered by Carol Dweck, it has been shown that people who have a growth mindset – who believe that they can learn anything, achieve at higher levels, in school and in life. Those with a fixed mindset who believe that their potential is limited, are held back by their ideas.

One study by Jason Moser and his colleagues gave insights into how this process takes place in the brain. His team studied brain activity when people took tests and found that when people made mistakes, there was more positive brain activity for those with a growth mindset than those with a fixed mindset. When people believed in their potential it changed the ways their brains operated.

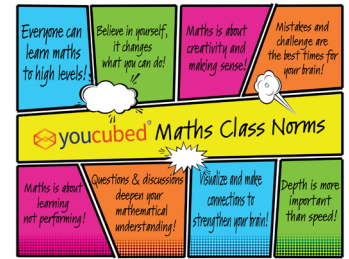


Moser, J. S., Schroder, H. S., Heeter, C., Moran, T. P., & Lee, Y. H. (2011). Mind your errors: Evidence for a neural mechanism linking growth mind-set to adaptive posterror adjustments. *Psychological Science*, 22(12), 1484-1489.

This is a stunning finding that shows how important it is that students – and teachers – believe in themselves, it changes the ways people’s brains work when they encounter challenging material, and it helps us understand why people with a growth mindset achieve at higher levels.

It is very important, as a teacher, to always encourage students to believe in themselves. Show them the impact of having a growth mindset and positive self beliefs. Tell students – all students – that you believe in them, and that you know they can learn anything.

This page shares more information that will be helpful for students and also support you in teaching for a growth mindset, <https://www.youcubed.org/resource/growth-mindset/>

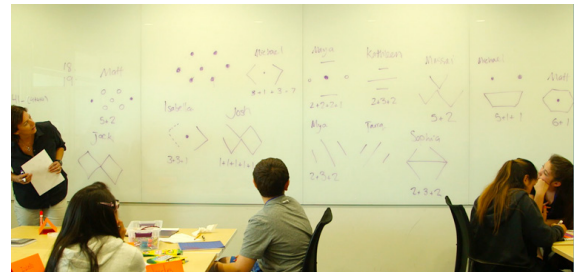


Maths is about creativity and making sense!

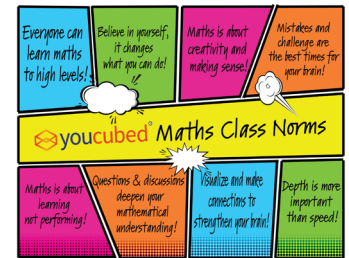
The key to understanding maths is making sense of it. Many students believe that maths is a set of formulas that have to be remembered - this belief is associated with low achievement (see below). Maths is a very creative subject that is, at its core, about visualizing patterns and creating solution paths that others can see, discuss and critique.

Some methods for encouraging sense making and creative mathematical thinking are here:

1. Always ask students – why does that make sense? Ask this whether their answers are correct or incorrect.
2. Value the different ways students see mathematics and the different solution pathways they create. I often share with students that the most beautiful part of mathematics, for me, is the fact that every idea and question can be seen and solved in different ways.
3. Encourage visual mathematics. Ask students to draw mathematical ideas and solutions. Ask them to think about how they see math.
4. Use number talks that value students' different ways of seeing maths and solving problems. Watch this video of me teaching a dot card number talk to 6th graders, and telling them that this shows the amazing creativity in mathematics: <https://www.youcubed.org/resources/jo-teaching-visual-dot-card-number-talk/>
5. When students finish questions, ask them to think of new, harder questions. These could be questions to give to other students. This is a really good strategy for differentiation.



PISA data from 13 million 15-year olds worldwide shows that the lowest achieving students in the world are those who believe that mathematical success comes from memorization. The USA and UK are countries where large numbers of students believe this. More detail can be found in this Scientific American article: <http://bit.ly/2eb7yeN>



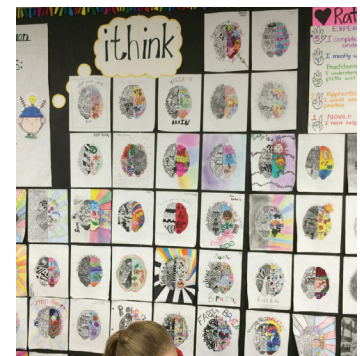
Mistakes and challenge are the best times for your brain!

Many students fear mistakes and when they struggle with work they develop damaging beliefs, that they are not a “maths person”. Yet brain science tells us that the times when people are struggling are the best times for brain growth. The Jason Moser study referenced in norm two (believe in yourself!) showed that brains are more active when people make mistakes than when they get work correct.

In our teaching of middle school students we found that our message to them – that we love mistakes and they help your brain to grow – was transformative for them. This can be seen in this short video: <https://www.youcubed.org/resources/solving-math-problem/>

Here are some suggestions for encouraging positive thinking about mistakes:

1. Ask students with mistakes to present mistakes (especially deep, conceptual ones) on the board so that everyone can learn from them. If one student makes a conceptual mistake, there are probably many others making the same one.
2. When students get something wrong – instead of being discouraging or sympathetic, say “That is really good for your brain! Synapses are firing.”
3. Ask students to read positive brain/mistake messages and choose their favorites that they will take on for the year. E.g. “easy is a waste of time” “working hard grows your brain” “it is really important to make mistakes”. Ask them to draw brains with the messages on them that you can display on your walls, as Kim Hollowell did – use this link to get the brain template <https://www.youcubed.org/resource/posters/>.
4. Crumpled Paper: Ask students to crumple a piece of paper and throw it at the board with the feeling they have when making a mistake. Then get them to retrieve the paper and color in all the lines, these represent synapses firing and brain growth from making a mistake. Ask them to keep the piece of paper in their math folders/notebooks to remind them of this.

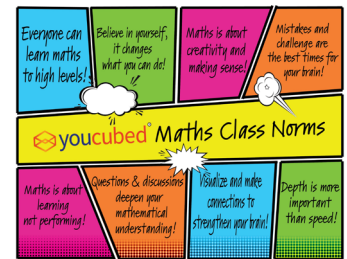


Maths is about learning, not performing!

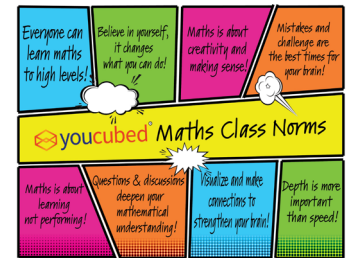
Many students think that their role in maths class is not to learn but to get questions right – to perform. It is important for them to know that maths is about learning, and to know that maths is a growth subject, it takes time to learn and it is all about effort.

Some strategies for making maths a learning, not a performing subject:

1. Grade and test less. Maths is the most over-graded, over-tested subject in the curriculum. Neither grades nor tests have been shown to increase learning, from research, and both make students feel they are performing and not learning. Grades often make students think they are a reflection not of what they have learned but who they are. There is a video reflecting this at <http://youtu.be/eoVLBExuqB0>
2. Instead, give diagnostic comments. These take longer but are extremely valuable and can be done less often. We have worked with teachers who have moved from daily grading to weekly comments with huge improvements from students. Here is an article by Ruth Butler about a study comparing the impact of grades and diagnostic feedback you might want to read: <http://bit.ly/2mpjBZN>
3. Use “assessment for learning” strategies (see sidebar).
4. If you have to grade, then give grades for learning, not for narrow performance eg for asking questions, representing ideas in different ways, explaining work to others, making connections. Assess the multidimensionality of maths, not just a single aspect of it – this is all explained in more detail in my book: Mathematical Mindsets.
5. You may have to give grades to your administration but that doesn't mean you have to give them to the students. Grades communicate fixed messages about learning and are often counter-productive for students.



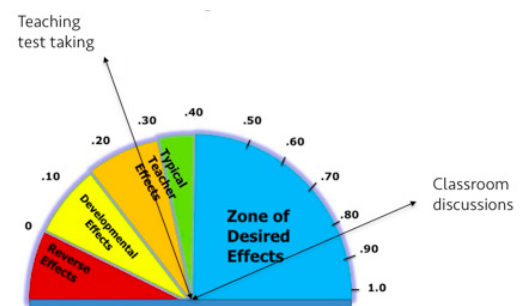
Assessment for learning (A4L) teaching strategies have been shown to drastically increase student achievement, if they are used instead of summative tests and grades. It has been estimated that if teachers in England used A4L strategies the achievement of their students would increase so much the country would move, in international comparisons, from the middle of the pack to the top 5 (Black and Wiliam, 1998). <http://www.youcubed.org/resource/assessment-grading/> shares our favorite A4L strategies.



Questions & discussions deepen your mathematical understanding!

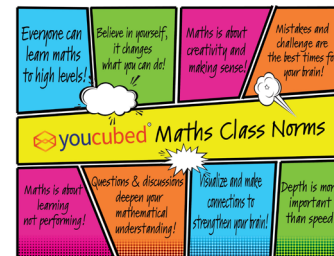
Research shows us that question asking is linked to high achievement – yet as students move through school they ask fewer and fewer questions, for fear of looking bad. It is really important to encourage and value questions. You don't need to be able to answer every question that students may come up with, sometimes it is good to say that you don't know but you will find out, or ask other students if someone would like to answer the question. Brain science also tells us that when we answer a question, and retrieve information from our brain, that information is ever changed in the brain, being more accessible. This points to the value of classroom discussions.

John Hattie examines effect sizes of different classroom approaches and shows a very stark difference between the impact of asking questions through a test and asking questions through classroom discussions. See the image on the right adapted from Hattie's book: *Visible Learning for Mathematics, Grades K-12: What Works Best to Optimize Student Learning* (Corwin Press, 2016).



Some suggestions for encouraging questions:

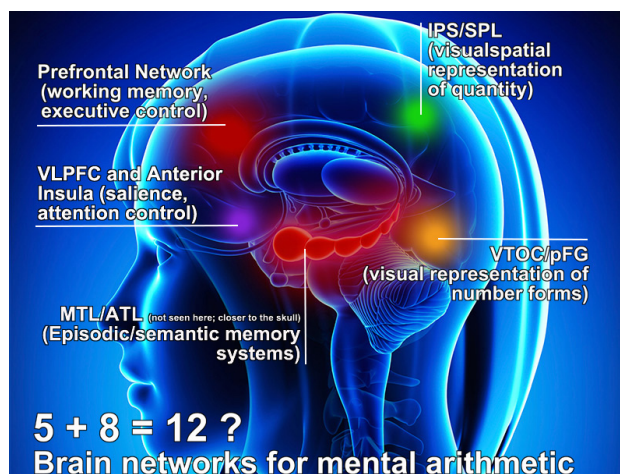
1. Tell your students that you love questions about maths and that they are really important. When good questions are asked, write them in large colored letters onto posters that you post around the room, to celebrate them. Show questions from a range of students.
2. Tell students they have 2 responsibilities in your classroom. One is to always ask a question if they have one, and the other it to always answer a question from classmates if asked.
3. Encourage students to ask questions – from you, other students and themselves, such as: why does that work? Why does that make sense? Can I draw that? Can I build it? How does that method connect to another?
4. Encourage students to ask their own maths questions. Instead of asking questions for them, give them interesting mathematical situations and see what questions arise for them.



Visualize and make connections to strengthen your brain!

New brain research is showing that our brains think visually about mathematics and even when we perform a bare number calculation five different pathways are involved, two of which are visual (Boaler, Chen, Williams & Cordero, 2016). The dorsal visual pathway is the main brain region for representing the knowledge of quantity. When students are asked to visualize in mathematics, their achievement and engagement increases significantly. I like to think about it in this way – our brains want to think visually about maths!

Rather than showing students a visual representation that you have drawn or one that is in a textbook ask students if they can draw ideas, methods or results.

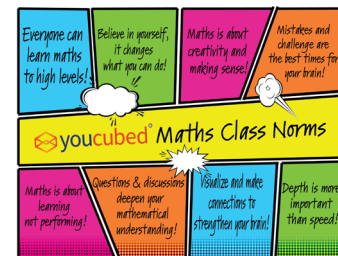


Research is also showing the importance of connecting between different brain areas, which happens when we see mathematics in different forms e.g. words, a picture, a graph, an equation, and link between them. Color coding, is a really good way to highlight connections between ideas.

Mathematical connections are important too. Mathematics is a subject of connected ideas, but students often think it is a set of disconnected methods. We made a video to show some mathematical connections that students love: <https://www.youcubed.org/resources/tour-mathematical-connections/>

Boaler J, Chen L, Williams C, Cordero M (2016) Seeing as Understanding: The Importance of Visual Mathematics for our Brain and Learning. J Appl Computat Math 5: 325. doi: 10.4172/2168-9679.1000325

Depth is more important than speed!

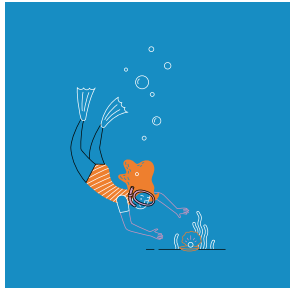


Many people incorrectly believe that being good at maths means being fast at maths. Yet many famous and award winning mathematicians talk openly about being very slow with maths, pointing out that what is important is seeing connections and thinking deeply. It is important that maths classrooms dissociate maths from speed, to unlock the potential of many amazing and slow thinkers. When we value fast computation we encourage a subset of learners who compute quickly and discourage many others, including deep slow thinkers who are very important to maths.

We do not need students to compute quickly (we have computers and phones for this) we need them to think deeply, connect methods, reason, and justify. We also know that we do not help students become faster in examinations they have to take at the end of a year or the end of school by giving them timed tests to practice on. Timed math fact tests are the early onset of maths anxiety for many students and when we give tests like these the faster students stay fast and the slow students stay slow or get even slower, as maths anxiety sets in.

Our popular paper Fluency without Fear: <https://www.youcubed.org/evidence/fluency-without-fear/> not only describes the ways anxiety from speed impacts the brain, impeding its ability to function, but also shares ways to teach maths facts through activities students will enjoy and that lead to deep understanding. Other suggestions are:

1. Tell students you don't value fast work, instead you value creative representations of ideas. Mathematical thinking is about depth not speed.
2. Don't let mathematical discussions be driven by the fastest students.
3. When asking for hands up, don't always take answers from the first students who raise their hand, that gives all students the message that what you value is speed.
4. Don't use flash cards, speed competitions, timed tests, instead value depth, creativity, different ways of thinking about maths,



"I was always deeply uncertain about my own intellectual capacity; I thought I was unintelligent and it is true that I was, and still am, rather slow. I need time to seize things because I always need to understand them fully. Towards the end of the eleventh grade, I secretly thought of myself as stupid. I worried about this for a long time.

I'm still just as slow. (...)At the end of the eleventh grade, I took the measure of the situation, and came to the conclusion that rapidity doesn't have a precise relation to intelligence. What is important is to deeply understand things and their relations to each other. This is where intelligence lies. The fact of being quick or slow isn't really relevant."

- Laurent Schwartz,
*Winner of the Fields Medal
(A Mathematician Grappling with His Century, 2001)*