

Premier's University of Sydney Mathematics Scholarship

A Mathematical Learning Journey toward growth and equity

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# Introduction

The inaugural award of the Sydney University Premier’s Award in Mathematics allowed me to go on a mathematical learning journey. My interest in this journey stemmed from this conundrum. When I and many of my colleagues tell people I’m a mathematics teacher the majority of listeners respond with “maths... I was never any good at that” or worse still, “I hated maths”. However, how many would say to an English teacher “I was never any good at reading”? Why are people proud to say, ‘I'm not good at maths’, and why are females more prone to say it?

According to Max Roser and Esteban Ortiz-Ospina (2016) only 12% of people across the world were literate in 1800 compared with 85% in 2014. This rise has been a response, in part, to the industrial revolution. Interestingly the technological revolution now demands the same rise for numeracy and mathematics.

# Focus of Study

The aim of my journey was to look at ways of tearing down the walls to learning in mathematics classrooms. I was interested in seeing classrooms that were doing this and gathering commonalities about what successful teachers, school leaders and district leaders were doing to facilitate student engagement and learning. I also wanted to listen to current experts in this field to broaden my understanding and put together pieces of the jigsaw.

I thought I would focus on the concept of *Growth mindset,* first expounded by Carol Dweck (2006). If a person has a growth mindset according to Dweck, they focus on their growth rather than their performance and seek feedback to improve from mistakes. However, a performance mindset leads people to associate performance with their ability and hence judge themselves (and believe others do) accordingly. Performance orientation and the anxiety associated with it can indeed be a brick in the wall to learning mathematics.

I was also interested in a social phenomenon prevalent in Australia, the documented decline of girls as compared to boys engaging in the higher levels of mathematics at senior high school level. This is locking girls out of lucrative Science Technology, Engineering and Mathematics (STEM) fields. Could another brick be the linking of a maths gene to gender? This is a belief that boys and girls have different capacities to understand and be good at mathematics. This dangerous notion as outlined by Nosek, Banaji, & Greenwald (2002) leads to the sad conclusion by many, even those who do well in the subject, that math equates with male, me = female, therefore math ≠ me.

# Significant Learning

What has made a difference to student performance and engagement in mathematics classrooms? In my observation, at the school level, explicit leadership in school wide implementation of targeted strategies has been the key to success. In effective schools, such as Dartmouth, Mereworth Community School, Epiphany of Our Lord Catholic Academy, Lenox Academy and Eleanor Palmer School, the language of mindset was embedded in teacher and student usage. This was articulated when they spoke of challenges or making mistakes. At Lenox Academy in Brooklyn NY, Nicole Trubnikov reported that teaching neuroplasticity using the Brainology program and other growth mindset strategies has led students to develop efficacy, including a sense of responsibility for their own learning. Teachers don’t hear "I'm not smart or I'm not good at math" any more and students feel they have more control over their learning.

Students categorise mistakes into types, go back, reflect and fix what they did wrong. At the Epiphany of Our Lord Catholic Academy, situated in a very low socio-economic district in Toronto I met the principal Dale Martel and teacher Stephanie De Re, who has instigated targeted strategies. Apart from showing videos about how the brain is elastic to all students, she introduced journal writing to record student reflections. The school has posters on growth mindset and had a space called the growth wall that was a historical display of famous people who had failed and then succeeded. Students subsequently did their own research on African/ Canadian famous persons who had overcome a struggle to succeed.

De Re describes the impact on mathematics learning for students through the example of Alyssa, a special education student who was completely withdrawn. After the growth mindset intervention, she was given a choice, to decide whether she stayed in a mainstream class or receive more help in a special class. Alyssa chose the mainstream class and worked extremely hard to achieve a grade of 71%. She wrote in her journal “When I started growth mindset I found more ways to think positively about myself”. De Re reports that students are starting to self-reflect. The school is trying to create a community of learners that realise struggle is part of learning. Goal setting in the journals was important and teachers have worked with students to make them measurable so that improvement can be tracked.

Heidi, a teacher I had the privilege to observe at Dartmouth Middle School, uses the strategy of number talks (hand gestures that aid mathematical dialogue) to back up the growth mindset language and help students feel comfortable with taking risks by expressing their mathematical thinking without judgement. Only the teacher writes, to record, clarify and restate student thinking while guiding questions carefully and making connections. In number talks, students use different hand gestures for when they are thinking about the problem, when they have a solution and strategy, when they have a solution and two strategies and when they agree with another student’s solution and strategy. In this way the strategies become just as important as the answer Misconceptions can be addressed. Moreover, when students share strategies it helps to create a productive rather than destructive struggle in the classroom. It was a wonderful opportunity to witness the development of growth mindset in action.

Vicki Lyottes (NCTM Conference) also stresses the importance of mathematical communication and sees mistakes as opportunities to rethink. She recommends using post it notes to make mistakes acceptable and allow errors to live in classrooms in a non- judgemental way. Students’ ideas should be treated as works in progress and time should be spent on types of misconceptions. The focus is not to help students correct something but rather to help the student and the class extend the idea presented to develop a solution collaboratively. She says it is all about transforming the classroom culture.

An example of a school I visited where there had been such a cultural transformation was Eleanor Palmer School in London. Here I met leaders Kate Frood and Fiona Crean. This high performing teaching school provides professional learning opportunities for other schools in the district of Camden. Teachers at the school have a growth mindset to keep learning and to help others learn. The teachers are constantly challenged, and they share ideas in non-judgemental ways, participating in lesson study. This collective responsibility relieves pressure on the executive teachers. A learning walk with two students Natasha and Che validated all that was discussed. When questioned, both students said they like it when things are hard, they enjoy the challenges. When learning gets too tough they know they can ask for help, but they prefer to use resources to help them work it out. Natasha stated, “Mistakes help learning they are good, you are never going to get things right the first time!”

These successful schools did more than educate students, teachers and parents about how the brain learns and the principles of growth mindset, although this was a recognised first step. They invested time in teacher professional development (PD), commonly using coaching and lesson study to embed strategies. The strategies I observed at Dartmouth for instance are the result of initiatives from the school district office. I was fortunate to Interview with Cecilio Dimas from the Silicon Valley Innovation Initiative for implementing change in Mathematics and STEM teaching in this district. The initiative has been so successful in affecting improvement that many other districts and States (Washington, Texas and Canada) are now seeking his and his team's expertise.

Dimas’ main change strategies are teacher professional learning in cluster groups and using lesson study or teacher collaborative observation. The initiative is a response to the overuse of multiple choice assessment methods. He claims the approach of partnering teachers and having them observe each other and giving them an opportunity to reflect on practice is invaluable and essential for change implementation.

The Conferences I attended (NCTM in USA and ATM in UK) reinforced these principles. Interestingly, when speaking to the mathematics guru of growth mindset, Jo Boaler at Stanford University she, like Dimas, warned of the dangers of assessing students using short closed or multiple-choice questions that do not allow opportunities for growth and put constraints on teachers. Her message was simple, communicate brain science to students and validate making mistakes. Crucial to this is not valuing speed over and above depth. Speed according to Boaler is one of the biggest barriers to students working at depth and making connections in their understanding.

Boaler sees two ways you can have a relationship with mathematics, you can see it as a set of procedures or you can see it as a real and creative domain. When presenting the study of mathematics, it is essential to make it appear as a creative subject where you can improve your performance. Teachers of mathematics are often procedural thinkers and have fixed views. If teachers change the way they view mathematics their teaching will shift. She believes “We need to hit the RESET button.” Classroom culture could then change within a relatively short timeframe.

Boaler recommends the course for students [*How to Learn Math*](https://lagunita.stanford.edu/courses/Education/EDUC115-S/Spring2014/about) which is free online and has already been undertaken by over 160 000 students. A preliminary study has shown that these students are engaged in maths classes 68% more than control students. She says we should be encouraging and valuing multiple ways of seeing and solving and that content should be taught AFTER students have explored. She believes that maths is like a prison for students when they do same thing over and over again from a textbook. Part of the liberation is to pose a question first rather than deliver content. She took a group of students under such a freedom model and found that the group increased by 1.6 learning years.

At the Mereworth Community School in Kent**,** growth mindset principles have also been successfully implemented. Leaders, Amanda Lovell and Fay Booth emphasised that while teachers are 100 % on board with the philosophy, if they are not part of the decision making they won’t have a vested interest. It is also important that growth mindset is not undermined by what is valued or rewarded in a school. Is it effort, success or both?

Effective schools also have teachers who presented mathematics in a creative way with meaning and purpose rather than as a procedural pursuit. Here student voice and learning mistakes were valued and this engaged students. Building a positive maths identity for girls is crucial to their engagement with STEM. This was best achieved at Dartmouth Middle School where there has been some investment by the school and the district leadership to ensure the development of a thriving group of female students who are confident and articulate in expounding positivity and efficacy in this important area. According to the principal, Dr Ana Lomas their STEM program has enabled students to utilise the skills obtained in class to help their community, hence making it meaningful. One Dartmouth student has an American patent on her very own design.

It is difficult to ascertain what came first, the amazing can do culture for students and teachers at the school or the manifestations such as involvement in the extraordinary number of after school clubs including Math Club, Science Olympiad, Future Cities, Urban Engineering, Applied Math and Introduction to Engineering. The school invites STEM role models such as Chris McQueen from Google Design Thinking to share their expertise. The School has a club called STEM girls. Anwesha Mishra, an eighth grader states that this club “has really sprouted my deep interest for STEM, I have changed my perspective from singling out the problem to engineering it.” Another student Jadelyn states “I have been on a robotics team for three years, I especially love to push myself, learn new things, and make the world a better place. When I grow up, I want to be a mechanical or software engineer.”

Dartmouth Middle School has certainly worked against the trend, as Professor Lorraine Howard outlined at the NCTM Conference. Howard reported that girls lose interest in maths between grades 4-8. She stresses that girls like relevance and that this needs to start early. Rather than justifying the study of maths with ‘you need to do this for a job when you grow up’ inspire them with ‘what problems do you want to solve in the world?’

Dr Catherine Foley (ATM Conference) from University of Reading also has concerns around girls’ maths identity. In Foley’s study when girls were asked to place people you think of when you think about mathematics in a sociogram (picture) family members were very prevalent. They tended to be people who helped them when they were stuck there was no reference to people who were mathematicians. She asks, “if it was writing, would JK Rowling have come up?”

When asked to draw themselves using maths they were mainly doing number operations and calculations. One wrote “this is easy”, “this is harder”, “confusing” and “help”. All but one drew themselves doing maths at a desk. One girl drew herself outside with her desk!

Many had growth mindsets, however Foley claims this can be problematic causing stress. Many conclude ‘if I’m not doing well then there must be something wrong with me, I have to work harder’. She claims the notion of Productive disposition acknowledging a purpose to doing mathematics is more helpful. It is the inclination to see mathematics as sensible, useful, and worthwhile, coupled with a belief in diligence and one’s own efficacy. (Kilpatrick, 2001)

The view around purposeful tasks is also strongly supported by Dr Karen Cohen-Gazithof McGill University, Montreal. Prior to her coaching and mentoring of 72 teachers, students were unaware of the purpose or meaning of tasks given at her school. She has implemented what has calls *Challenge Based Learning to* embed authentic learning principles and connect assessment to real life. All tasks now start with a challenge and this has led to increased performance growth for the school.

The implications for leadership from district level to the classroom in terms of the necessary change are threefold. Firstly, investment in teacher professional learning, not just in the theory of growth mindset (though this is important and existent in all these schools) but in situ through lesson study. This involves teachers observing each other as well as having a critical friend as coach and mentor. While many teachers can articulate growth mindset principles, it is another thing to follow it through in the classroom, often when the going gets tough teachers give up. Teacher resilience is as important as student resilience. It takes time, effort and assistance and the schools that best supported teachers in this pursuit reaped the benefits for their students. The most important aspect of growth mindset according to Dr Cohen-Gazithwas that students can't develop and grow unless they encounter challenges and then struggle to eventually overcome them. The bump in the road is of no use unless it is overcome. If a teacher gives up on the student and moves on there is a lost opportunity. Teachers must make sure the student achieves the task even if the learning is scaffolded. It is important that the student do the work, not the teacher!

Gary Hall (NCTM Conference)claims that teachers are people pleasers,we feel responsible for others, but this can lead us to be unintentional enablers of anxiety.We can change by being honest with students about our own past and present struggles and require the maths to be done without dumbing it down. Sandra Heusel (Arrowsmith Program) concurs that in schools, challenges are typically taken away. So, if they experience failure for the first time at Arrowsmith many will have meltdowns.

Secondly the backward design approach of looking at assessment first and investing in quality tasks that engage and challenge is important. According to Geoff Krall (NCTM Conference) students start to identify as mathematicians when they are given quality tasks that ignite curiosity.Some such problems were modelled by Nrich (ATM Conference). They were conducive to developing a growth mindset by encouraging mathematical resilience, curiosity and collaboration.

Just as important is making sure that students get the message that whether they are above or below average if we look at their incremental learning, they are indeed growing over time in their knowledge and skills in mathematics. This message would be helpful to many students. So often, though not failing, they see their results as poor in comparison with other subjects and they give up.

Thirdly, as mathematics teachers, we must first do no harm. Natalie Poirier (the senior maths teacher at Arrowsmith) reports that many students are anxious about maths when they arrive. Their most negative previous experiences have been with mathematics teachers. Some with shattered self-esteem, see whoever else is in the role as an enemy. Poirier, like Boaler thinks reform of content is not as important as how we present and approach mathematics, providing challenge and curiosity, eliminating confusion and making it safe to make mistakes.

Professor Lorraine Howard (NCTM Conference) put forward a strong case for proactively strengthening girls’ maths identity.Mathematics identity refers to a person’s beliefs, attitudes emotions and dispositions about mathematics, motivation and approach to learning (Martin, 2000). How they think about themselves in relation to mathematics and the value of mathematics, “I'm a maths or not a maths person”. There is a need to improve girls’ maths identity and to break the mindset in society about who belongs in this STEM field.

Sue Chapman (NCTM Conference) proposes that our internal questions determine our mindsets. Teachers’ mindsets matter. Teacher identity as a maths learner and their personal definition of mathematics feed into each other. It will shape students’ identities as maths learners. Chapman calls on teachers and leaders to model mindset awareness and management. Making mindset visible through informal and formal opportunities to coach supports the metacognition necessary for teachers to recognise mindset and switch. Professor Chris Willingham (NCTM Conference) in a study with preservice teachers found that having the desire or espousing growth mindset, while a prerequisite, is not sufficient to result in growth mindset behaviours. Encouraging though is that interactions with those displaying strong growth mindset characteristics can influence the behaviour of others.

This was exemplified in another session which reportedan intervention which changed teacher mindset from fixed to growth. The district adviser used coaching questions to get teachers to reflect on what and how they were teaching. Students were given the opportunity to engage in number talks (like Dartmouth) to encourage student discourse. The teacher learned to ask rather than tell to pinpoint misconceptions

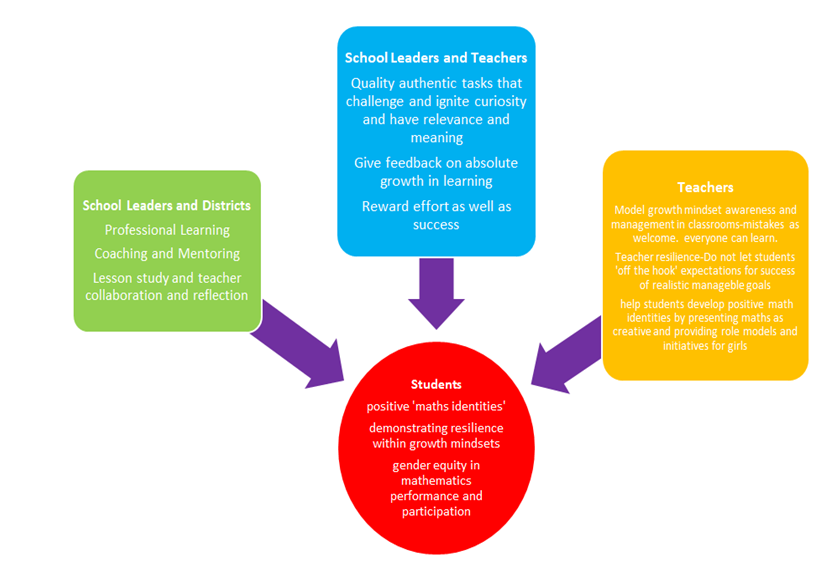
The teacher learned to ask purposeful questions, the value of extended time and having clear expectations by not letting students get away with non- participation!

# Conclusion

Although inadvertently, teachers’ own attitudes and beliefs about mathematics and the way we present mathematics have given many students negative maths identities that have led some to acute anxiety associated with the subject we purport to love so much. There is also an important emerging theme of continuing to challenge students. This means teachers need to rise to the challenge and be resilient in the face of initial failures for those students most in need. There needs to be a balance created between continual challenge and manageable realistic goals for each student.

Teachers also need a mindset which focuses on growth rather than performance and on building a positive math identity for all students. The amazing learnings from the schools I visited and the experts I talked with and listened to have given me encouragement that breaking down the walls to learning in maths classrooms is not just a dream but an achievable goal that has been successfully modelled as I have summarised below:

* **School Leaders and Districts**
  + Professional Learning
  + Coaching and Mentoring
  + Lesson study and teacher collaboration and reflection
* **School Leaders and Teachers**
  + Quality authentic tasks that challenge and ignite curiosity and have relevance and meaning
  + Give feedback on absolute growth in learning
  + Reward effort as well as success
* **Teachers**
  + Model growth mindset awareness and management in classrooms mistakes as welcome. Everyone can learn.
  + Teacher resilience – Do not let students ‘off the hook’. Expectations for success of realistic manageable goals.
  + Help students develop positive math identities by presenting maths as creative and providing role models and initiatives for girls.
* **Students**
  + Positive ‘maths identities’
  + Demonstrating resilience within growth mindsets
  + Gender equity in mathematics performance and participation



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