FORUM
Volume 55, Number 1, 2013
www.wwwords.co.uk/FORUM

Ability and Mathematics: the mindset revolution that is reshaping education

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ABSTRACT Recent scientific evidence demonstrates both the incredible potential of the brain to grow and change and the powerful impact of growth mindset messages upon students' attainment. Schooling practices, however, particularly in England, are based upon notions of fixed ability thinking which limits students' attainment and increases inequality. This article reviews evidence for brain plasticity, the importance of mindset and the ways that mindset messages may be communicated through classroom and grouping practices.

In 2006 a trade book appeared on bookshelves that would ultimately have one of the biggest impacts on education of any research volume ever published. In *Mindset: the new psychology of success* (2006a) Carol Dweck summarized key findings from her research on the nature and impact of different mindsets. The book quickly became a *New York Times* best-seller, a BBC news headliner, and was translated into more than 20 languages. In it Dweck summarized her research evidence from decades of research with differently-aged subjects showing that when students develop what she has called a 'growth mindset' then they believe that intelligence and 'smartness' can be learned and that the brain can grow from exercise. The implications of this mindset are profound – students with a growth mindset work and learn more effectively, displaying a desire for challenge and resilience in the face of failure. On the other hand, those with a 'fixed mindset' believe that you are either smart or you are not. When students with a fixed mindset fail or make a mistake they believe that they are just not smart and give up. Such students frequently avoid challenge, preferring instead to complete easier work on which they know they will succeed.

Dweck's studies show that around 40% of US students display a growth mindset and 40% a fixed mindset, while the remaining 20% show mixed profiles. When students undertake an intervention to move them from a fixed to a growth mindset they immediately start performing at higher levels in school

(Dweck, 2006a). The student intervention that has been developed is an online program targeted at middle school students (ages 11-13) that shows them the plasticity of the brain and the impact of brain exercise on the growth of intelligence.[1]

Neuroscientists now have extensive evidence of brain plasticity, some of the evidence coming from people who have suffered major brain lesions, who have gone on to learn reading, writing, bike riding and other abilities that required the brain to grow in response to effort (Bunge et al, 2007; Beilock, 2011). What scientists now know about brain plasticity has serious implications for teaching and grouping structures that are based upon ideas of fixed ability and limited student potential (Boaler, 2010).

Numerous studies have shown the effects of growth mindset interventions on students' achievement, at all ages. Aronson et al (2002) looked at the impact of a growth mindset intervention on college students, comparing two control groups –a multiple intelligence intervention and a no-treatment control – with students receiving a growth mindset treatment. While the control groups showed no change in achievement, the growth mindset intervention led to a clear gain in achievement, particularly for African American students. After the intervention, achievement differences between White and African American students disappeared. In addition, the African American students in the growth mindset group showed a significant increase in their valuing and their enjoyment of courses.

Blackwell et al (2007) performed a growth mindset intervention with minority students in the USA (African American and Latino) making the transition to 7th grade, many of whom were already showing declining grades. The control group received eight sessions of training in study skills, while the growth mindset group received eight sessions of study skills plus training in the growth mindset. The key growth mindset message was that effort changes the brain by forming new connections, and that students control this process. The growth mindset intervention halted the students' decline in grades and started the students on a new pathway of improvement and high achievement.

Good et al (2003) also created a growth mindset intervention for 7th grade students and compared it to a control group. In both groups, mentors met with their students in person for 90 minutes in mid-November, and then again for 90 minutes at the beginning of the second semester (end of January); all other communication between mentors and students occurred through e-mail. The growth mindset intervention led to a 4.5-point gain in mathematics achievement test scores and a 4-point gain in reading achievement test scores. In the control group, there was a highly significant gender difference in mathematics, but in the growth mindset group the gender gap was largely eliminated.

Research evidence that has been collected over the last decade leading to new understandings of the brain, ability and learning has important implications for schools, in particular the ability-based practices and messages that prevail. The most successful countries in the world base schooling and grouping

practices on growth mindset messages and beliefs, communicating to students that learning takes time and is a product of effort (Stigler & Hiebert, 1999; Sahlberg, 2011).

Many Asian countries, particularly those in the Pacific Rim, have education systems that are based upon the idea that learning is a process determined by effort, rather than fixed notions of ability (Stigler & Hiebert, 1999). The idea of separating students into different levels is thought to be undesirable or even unacceptable, as reflected in the following commentary about education in Japan:

> In Japan there is strong consensus that children should not be subjected to measuring of capabilities or aptitudes and subsequent remediation or acceleration during the nine years of compulsory education. In addition to seeing the practice as inherently unequal, Japanese parents and teachers worried that ability grouping would have a strong negative impact on children's self-image, socialization patterns, and academic competition. (Bracey, 2003, pp. 332-333)

But schools in other countries that score significantly lower on international tests, including England and the United States of America, frequently base their schooling practices upon ideas about ability that have now been shown to be incorrect. Whereas research shows the plasticity of the brain and the ability of students to develop smartness through hard work and challenge, some schools bombard students with the messages that ability is fixed and that some students have talent and intelligence while others do not. This chasm between research evidence and practice is most clearly reflected in the ability grouping practices used in schools that communicate to students that their ability is fixed, initiating the harmful fixed mindset beliefs that research has shown detract from students' learning opportunities throughout life (Boaler, 2005; Dweck, 2006a).

Developing Growth Mindset Schools

Over the last few years I have worked extensively with schools, teachers and districts in the United States of America to help teachers communicate growth mindset messages to students and to teach using practices that enable students to develop growth mindsets. This work started after discussions with school principals who told me that their teachers had all read Dweck's book, and were 'totally on board' with the ideas, but did not know what it meant for their subject teaching. I have particularly, although not exclusively, worked in mathematics – the subject area that communicates the strongest fixed ability messages and thinking (Boaler, 2010).

The awareness that ability is malleable and that students need to develop productive growth mindsets has profound implications for teaching. Teachers and schools constantly communicate messages to students about their ability and learning (Marks, 2013, this number pp. 29-42), through the practices in which they engage and the conversations they have with students. A true

commitment to the communication and teaching of a growth mindset probably requires examination of all aspects of teaching. Even the tasks that teachers choose allow different opportunities for messages to be communicated to students. In mathematics for example, if students are working on short, closed questions that have right or wrong answers, and they are frequently getting wrong answers, it is hard to maintain a view that high achievement is possible with effort. When tasks are more open, offering opportunities for learning, students can see the possibility of higher achievement and respond to these opportunities to improve. This change is consistent with other work in formative assessment (Black & Wiliam, 1998).

The following diagram represents the areas of teaching that I have concentrated upon in my work with teachers in the USA. In the remainder of this article I discuss two of these – ability grouping and mistakes.

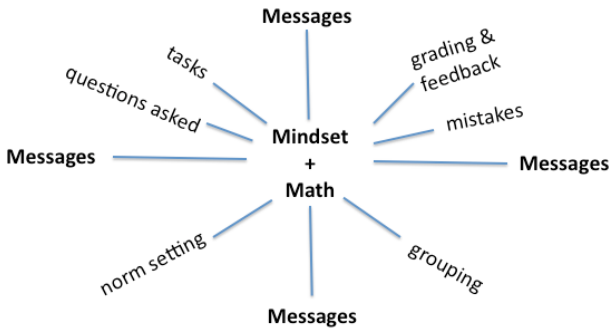

Figure 1. Aspects of Classroom Teaching that Communicate Mindset Messages.

Ability grouping.

In the USA ability grouping is not as prevalent or as severe as the practice in England. It is rare for elementary schools to divide students by ability and many elementary teachers are highly resistant to the idea of labeling students through their teaching, particularly in the younger years. In the USA, the idea that students are put into different groups for mathematics in the first few years of school, as is common in England (Blatchford et al, 2008), is met with expressions of shock. The more typical time for grouping students by ability and telling them that they are average, above average or below average is 7th grade. But whenever ability grouping happens – whether students are told about the grouping and its implications or not – students' beliefs about their own potential change in response to the groups they are placed into. Some schools believe that innocuous names for different groups, such as red and blue, can mask the meaning of the groups for students. In one primary school I attended in England that placed students into different groups for mathematics in Year 1, one of the students simply told me that 'all the clever students had

gone into a different class now' (Boaler, 2010). Students are well aware of ability grouping practices at whatever age they happen and they take a very clear message from such practices – some students are clever and some are not.

Dweck has found that fixed mindset messages prevail among students across the achievement range and some of the students who are most damaged by fixed ability beliefs are high-achieving girls (Dweck, 2006a, b). Such students have often been praised for their work from an early age, with praise that Dweck has shown to be damaging, calling attention to the idea of being 'smart' or clever. The problem with such fixed mindset praise is that as soon as students fail at a task they infer that they are not smart after all. The damage of fixed ability thinking harms all students; it is communicated through the practice of ability grouping, even when the idea that is communicated is that members of the group are smart. High-achieving girls, often placed in top set or top track classes, frequently suffer from the idea that they are smart and need to maintain the image of smartness, leading to fear of challenge and inability to cope with failure (Boaler, 1997). In one of Dweck's studies, in which researchers gave challenging work to 5th grade students, researchers found that girls had more difficulty when they scored highly on IQ tests, whereas for boys the opposite was true. In another study Dweck and colleagues found that gender differences in mathematics performance only existed among fixed mindset students. These studies show that girls, in particular, are damaged by fixed ability messages that imply some students are smart and some are not, which contributes to the low numbers of women continuing in mathematics and science (Dweck, 2006b).

Numerous studies on the impact of different ability grouping practices have shown that when schools abandon ability grouping practice and move to mixed or heterogeneous grouping, achievement and participation improves significantly. In the US, for example, Burris et al (2006) compared six annual cohorts of students attending a middle school in the district of New York. For the first three years of the study students were taught in tracked classes with only high track students being taught an advanced curriculum. In the next three years all students in grades 7-9 were taught the advanced curriculum in mixed ability classes and all of the 9th graders were taught an accelerated algebra course. The researchers looked at the impact of these different middle school experiences upon the students' achievement and their completion of high school courses, using four achievement measures, including scores on the advanced placement calculus examinations. They found that the students from de-tracked classes took more advanced classes, pass rates were significantly higher and students passed exams a year earlier than the average in New York State. The increased success from de-tracking applied to students across the achievement range – from the lowest to the highest achievers.

In England researchers followed 14,000 children through Years 4 and 6 comparing those taught in sets with those grouped heterogeneously over the period of a year. They found that setting hindered the progress of students, and that those taught heterogeneously performed significantly better on tests of

mathematical reasoning (Nunes et al, 2009). The independent Primary Review in the United Kingdom (UK) (Alexander, 2010), considered the impact of ability grouping and concluded that 'the evidence suggests that there are no consistent effects of structured ability grouping, such as setting, on attainment, although there can be detrimental effects on social and personal outcomes for some children' (p. 290). The researchers conducting one of the reviews commissioned by Alexander and his team recognised that primary teachers choose to group children according to notions of 'ability' because they thought that they could offer more appropriate work for children when they were in such groups. However this review found that 'the allocation of pupils to groups is a somewhat arbitrary affair and often depends on factors not related to attainment'; it also found that although teachers think they are giving children in low groups more appropriate work, 'the evidence suggests that many pupils find the work they are given is inappropriate; often it is too easy' (Blatchford et al, 2008, pp. 27-28).

In addition to studies that track large cohorts of students through classes with different groupings, more detailed studies of students attending schools in sets and heterogeneous groups have found that ability grouping reduces achievement for students overall. This takes place through two processes – limiting opportunities for success by teaching high level content to only some students (Porter & Associates, 1994), and discouraging students through communication of the idea that only some students are high achievers, and that ability is fixed (Boaler et al, 2000, 2005). Boaler conducted longitudinal studies of students progressing through schools with contrasting grouping arrangements, in both the UK and the US (see Boaler, 2010). In England Boaler followed 500 students through three years of two schools in England and in the USA she followed 700 students through four years of three schools in California. In both studies the students who worked in schools in mixed ability groups performed at higher levels overall than those who worked in setted or tracked groups. The schools teaching to mixed ability groups also achieved more equitable outcomes. In a follow-up study of the students who had attended the different schools in England, some eight years later, the adults who had been in the school employing ability grouping were in less professional jobs, and the adults interviewed linked the limits in their job prospects to the ability grouping used in school (Boaler, 2005).

Linchevski and Kutscher (1998) conducted two different studies in Israel, investigating the impact of grouping upon student achievement. They found that students of average and below average attainment achieved at higher levels when taught in mixed ability classes and high attainers achieved at the same level as those taught in same ability classes. This finding – of high students achieving at similar levels in same or mixed ability classes and low and average students achieving at higher levels in mixed ability classes – is one that has been reported in different studies (Slavin, 1990; Hallam & Toutounji, 1996).

The weight of evidence from countries across the world indicates that ability grouping harms the achievement of students in low and middle groups

and does not improve the achievement of high-attaining students (Boaler, 2013). Despite this evidence, ability grouping continues to be widespread in some countries – particularly England and the USA. Ability grouping as a practice rests upon fixed mindset beliefs – it is implemented by schools and teachers who themselves have fixed beliefs about learning and potential and it communicates damaging fixed ability beliefs to students. But the ways in which schools group students are difficult for individual teachers to change, even those who are aware of the negative impact of ability grouping and who are dedicated to implementing growth mindset messages and practices. Such changes require positive leadership from governments, local authorities, head teachers and heads of department. If such leadership is absent and schools continue to group students using fixed notions of ability then it seems likely that under achievement and low participation will continue (Dweck, 2006b; Vorderman et al, 2011).

Mistakes and Mathematics

An important and powerful aspect of teachers' practice concerns the ways in which they treat mistakes in mathematics classrooms. Research has shown that mistakes are important opportunities for learning and growth, but students routinely regard mistakes as indicators of their own low ability. Indeed mistakes, like ability grouping, are aspects of learning in which research and practice are severely misaligned (Steele, 2011). Dweck proposes that every time a student makes a mistake in mathematics, new synapses are formed in their brain (2012). When students think about why something is wrong, new synaptic connections are sparked that cause the brain to grow. This small scientific fact has profound implications for teaching and learning. It suggests that students and teachers should value mistakes and move from viewing them as learning failures to viewing them as learning achievements. The prevalence of fixed mindset beliefs among students has led to students wanting opportunities to produce pages of correct mathematics work in classrooms. But, as I explain to teachers, if students are producing pages of correct work then their brains are not growing and opportunities for development are missed. Students need to be working on challenging work that results in mistakes; their mistakes should be valued for the opportunities they provide for brain development and learning.

In my work with teachers we find ways to significantly reposition mistakes in mathematics classrooms, with teachers grading students not by marking a mistake with a cross but with a gold star or a smiley face and the words, 'It is great that you made this mistake; this is a really important opportunity for learning and I am glad you are thinking about this'. We also watch together highly effective teachers who value the mistakes students make and show them to all students for everyone to think about, recognizing their importance as sites for learning.

Conclusion

Research studies of learning and the brain, from the fields of education and neuroscience, have been brought together in the last decade to produce findings that are critically important for schools. These findings include:

- *The plasticity of the brain*: ability and intelligence grow with effort and practice.
- *The importance of students' mindsets for learning*: when students believe that everybody's ability can grow, their achievement improves significantly.
- *The importance of teachers' mindsets for teaching*: when teachers believe that everybody's ability can grow, and they give all students opportunities to achieve at high levels, students achieve at high levels.
- *The effects of ability grouping in all its different forms*: these grouping practices communicate damaging fixed mindset beliefs to students.

These findings are the basis of the 'Mindset Revolution', the optimistic phrase that stands at the head of this article. However it must also be said that divisive and deeply-held cultural beliefs about learning, and about what it means to be 'smart', are very difficult to change. For this reason progress towards higher achievement for all students has been very slow in some countries. But the findings briefly presented here, supported by a decade of scientific evidence, can no longer be ignored; they should be at the centre of all school improvement initiatives.

Fixed mindset beliefs contribute to inequalities in education as they particularly harm minority students and girls; they also contribute to overall low achievement and participation. Schools should be encouraging growth mindset beliefs as a matter of urgency. The encouragement of a growth mindset culture will require schools to move to grouping practices that do not label or send negative messages to students, and teaching approaches that value the thinking, struggles and varied learning pathways of all students.

Notes

[1] http://www.mindsetworks.com

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