Mathematical Mindsets: Unleashing Students' Potential Through Creative Math, Inspiring Messages and Innovative Teaching – Jo Boaler – Jossey Bass, Wiley. ISBN: 978-0-470-89452-1

In “Mathematical Mindsets” Jo Boaler aims to communicate the importance of the adoption of growth mindsets for mathematical achievement. The growth mindset approach, a phrase coined by Carol Dweck in 2006, has recently become popular in the education community, particularly in America. This approach suggests that encouraging students to recognise that intelligence is malleable rather than fixed will increase learning outcomes. Boaler specifically applies the growth mindset approach to mathematics education and suggests that achievement will be raised if students’ perceptions of the subject are shifted from that of a fixed skill to something they can explore and make sense of. Growth mindset approaches emphasise the importance of teacher attitudes and the types of tasks that teachers set in the classroom. In particular, shifting from closed-answer questioning to discovery-based learning is encouraged. Within this book Boaler provides numerous activities that would appropriately engage students; encouraging group discussions, problem solving and enthusiasm in classrooms.

A strength of this book is that Boaler discusses good evidence-based practice such as emphasising the exploration of students’ errors and the use of concrete manipulatives. Careful error analyses allow educators to explore misunderstanding of concepts and procedures and is a strategy that teachers have been encouraged to adopt (Hansen, Drews, Dudgeon, Lawton & Surtees, 2014). In addition, there are a plethora of studies that suggest that adaptive and flexible strategy use is a key component of success in arithmetic (e.g. Geary & Brown, 1991; Vanbinst, Ghesquiere & De Smedt, 2014). The methods that Boaler discusses in the book have the potential to enable opportunities for students to apply these adaptive strategies in a classroom scenario (p59). There is also a growing research literature on the efficacy of concrete manipulatives to improve learning, especially in the early years (Clements, 2000).

Boaler suggests that the growth mindsets literature has proven this type of intervention to be effective: “Research has shown definitively the importance of growth mindsets” (p34). This is a bold statement for an area of intervention and research that is in its relative infancy. It is correct that some studies have shown improvements in achievement following mindset based interventions, for example, Paunesku et al. (2015) observed that growth mindset interventions increased achievement in children who were at risk of dropping out of school. However, educators should recognise that there have also been null results in studies of growth mindset interventions on mathematical achievement (e.g. National College for Teaching and Leadership, 2015; Rienzo, Wolfe & Wilkinson, 2015). Of course, a plausible explanation for the null effects of growth mindset interventions is that the control groups may already be experiencing a growth mindset messages from existing high-quality teaching, but it is also possible that mindset interventions are not as effective as Boaler suggests. It is also important to note that these interventions may not have a positive effect on learning outcomes, but may positively benefit children in terms of decreased mathematical anxiety or increased self-efficacy.

A growth mindset approach may lead to increased confidence, decreased anxiety about learning and thus lead to increased achievement in mathematics (Hembree et al., 1990). However, the way in which Boaler presents evidence for her pedagogical recommendations has to be questioned. There are numerous examples of an inappropriate use of neuroscience to back up educational claims in this book. Of course within the boundaries of a review it is impossible to address all of these statements, therefore I have extracted some clear examples.

The word “neuromyths” describes misconceptions that are perpetuated due to misunderstandings or misinterpretation of neuroscience research (OECD, 2002) and there has been a recent concerted effort by the academic community to address these. Neuromyths are frequently present in the book, for example (citing a presentation by Carol Dweck, p.12), Boaler states that “Every time a student makes a mistake in math, they grow a synapse” (p.11) and subsequently that “Mistakes are not only opportunities for learning… but also times when our brains grow, even if we don’t know we have made a mistake.” (p12). Boaler supports this suggestion with the work of Moser et al. (2011) who measured event related potentials in 25 undergraduate students during a flanker task (a response inhibition task which has no mathematical content) and also assessed their growth mindsets. The authors established that increasing levels of growth mindsets were associated with heightened neural activity in response to errors, concluding that high levels of growth mindset was associated with closer attention to errors on response inhibition tasks. This study tells us nothing about synaptic brain *growth* and has no implications for mathematics teaching or learning (e.g. Neuroskeptic, 2016). However, Boaler perpetuates this ‘mistakes grow synapses’ neuromyth throughout the book to support the adoption of growth mindset methods. In the climate of emphasising evidence-based educational practice it is important that decision makers, both in terms of classroom practice and policy, can make judgments on the best scientific evidence, thus neuromyths should be dispelled in order to facilitate this decision making process.

As academics and practitioners from education, psychology and neuroscience increasingly collaborate to inform intervention and practice, there is a need to understand discipline-specific language. There are examples of misinterpretation of terminology within the book, such as the use of the word “compression” (p37). Boaler states:

“When you learn a new area of mathematics that you know nothing about, it takes up a large space in your brain…. But the mathematics you have learned before and know well, such as addition, takes up a small compact space in your brain…. Ideas that are known well are compressed and filed away”

This statement implies a physical change in the state of the brain. Importantly, Boaler suggests that compression cannot apply to rules and methods, but only to concepts. This assertion appears to create a new neuromyth. First, a typical neuroscience definition of compression would be “information coming from a large number of neurons must be compressed into a small number of neurons” (Allen-Zhu, Gelashvilli, Micali & Shavit, 2014, pg. 16872), but this is entirely different to physical compression of space in the brain. Second, no evidence is provided that only concepts, and not rules or procedures, can be efficiently stored in memory: in fact, longstanding evidence suggests that this is not the case (Baroody, 1983; Campbell & Therriault, 2013). More problematically, Boaler also cites research that cannot support her statements. There is a pertinent example in which Boaler references a study that only measured children’s *behavioural* responses to basic numerical tasks but this study is used to make *neuropsychological* claims about the importance of communication between the left and right brain hemispheres (p. 39), it is important that implications are extrapolated from appropriate eveidence. This section again perpetuates unhelpful neuromyths which have the appearance of scientific evidence, but in fact make evidenced-based decision making in education increasingly difficult.

Boaler suggests that reducing timed assessment in education would increase children’s growth mindsets and in turn improve mathematical learning; she thus emphasises that education should not be focused on the fast processing of information but on conceptual understanding. In addition, she discusses a purported causal connection between drill practice and long-term mathematical anxiety, a claim for which she provides no evidence, beyond a reference to “Boaler (2014c)” (p38). After due investigation it appears that this reference is an online article which repeats the same claim, this time referencing “Boaler (2014)”, an article which does not appear in the reference list, or on Boaler’s website. Referencing works that are not easily accessible, or perhaps unpublished, makes investigating claims and assessing the quality of evidence very difficult. A more nuanced view of the connection between fact knowledge and conceptual understanding surfaces from the mathematical cognition literature. This literature emphasises the iterative developmental process between arithmetic fact knowledge and conceptual understanding (Rittle-Johnson, Siegler & Alibali, 2001). Of course mathematics teachers should highlight “seeing, exploring and understanding mathematical connections” (p70). However, to deny that speedy access to mathematical facts cannot enable this type of processing seems unfounded (e.g., Fuchs et al., 2013). The recognition that a balance between procedural knowledge and conceptual understanding, along with other skills, is required for mathematical success is paramount and has been suggested as a way in which to address declining standards in mathematical achievement in North America (National Research Council, 2001).

In a rather alarmist section in the book (pg. 144) Boaler extends her argument regarding a causal link from assessment to anxiety to include the potential for suicide. Rather than basing this idea on research evidence, this section refers to a documentary “Race to Nowhere”, which explores the impact of academic pressures (such as homework and testing) on the wellbeing of students. Boaler describes the case of a student who received a poor grade on a maths test:

“… the grade she received did not communicate a message about an area of math she needed to work on; instead, it gave her a message about who she was as a person- she was now an F student. This idea was so crushing to her, she decided to take her own life”.

Multiple factors contribute to the complex behaviour of suicide (National Confidential Inquiry into Suicide and Homicide by People with Mental Illness, 2016) and its reporting has come under intense scrutiny in terms of responsibility of communicators (e.g. Samaritans, 2013). Clearly, it is important that such a claim needs an appropriate evidence base, which is lacking in this section.

Finally, some of the presented study findings are made difficult to interpret as some of the graphical information is poorly presented. For example, one experimental study described in the book assessed the efficacy of a mathematical mindset intervention (p51). The results, as plotted in Figure 4.5, pg. 51 appears to show the performance of the experimental group declining compared to the control group, which conflicts with Boaler’s accompanying text. Perhaps if the axis were labelled an alternative interpretation would be revealed, but without the further explanation the reader is left confused. This is not an isolated occurrence and readers could more easily evaluate the information if graphs and figures could be more clearly presented throughout the book. For example, Figures 7.3-7.5 are boxplots where the median line has been omitted, rendering any interpretation impossible.

While “Mathematical Mindsets” includes a rich range of tasks and suggestions for teachers that may be highly effective at creating a positive classroom culture, the way the book presents its case is concerning. As scientists who study learning and achievement it is vitally important that we accurately present scientific evidence and theory to educators who are striving to enable their students to succeed. In view of its promotion and perpetuation of neuromyths, I do not believe that “Mathematical Mindsets” passes this test.

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