Closing the mathematics achievement gap: Exploring the applicability of growth mindset in South Africa

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DECLARATION

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ABSTRACT

Growth mindset interventions have been shown to give small but significant boosts to mathematics performance. These interventions are both brief and cheap, making them attractive for boosting mathematics performance. Is it possible that South African students can benefit from a growth mindset intervention? Mindset assessments and interventions have predominantly been developed in the United States. There have been applications of the assessments and interventions to other cultural contexts, often with minimal adaptions. Adaptions are not reported in detail (or thoroughly evaluated) in existing research literature. In a series of four studies, I establish that South African high school students do have mathematics mindsets akin to the fixed and growth mindsets reported elsewhere. Using an iterative design process and item analysis, I modified a mathematics mindset assessment for use with disadvantaged students in South Africa. In two correlational studies I established validity and reliability for a mindset assessment I call "Thinking About Maths". I examined the contribution of mathematics mindsets to mathematics performance, in comparison with mathematics anxiety, study attitude and study milieu (or environment). I found that whilst mindsets do contribute to performance, the contribution is minimal compared to other variables measured. Additionally, I found that in an impoverished study environment males have high mathematics anxiety which inhibits mathematics performance whereas females have high study attitude, boosting mathematics performance. With assistance from students and teachers, I developed a mindset intervention that is culturally appropriate and relevant. 305 Grade 9 students participated in a field-based quasi-experiment, which had a passive control group. The intervention was delivered on WhatsApp over four weeks. Each week contained a growth mindset message, a YouTube clip, advice on a learning strategy, and an integration activity. The groups were facilitated by young adult mentors. It was clear that WhatsApp groups were an effective mode of delivery and there was good evidence of participation from students. Mathematics performance at the intervention school improved significantly beyond that of the control school. The strength of the intervention seems to lie in the combination of mindset messaging and the teaching of effective strategies.

Key words: cultural context, growth mindset, high school, mathematics performance, South Africa

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CONTENTS

CHAPTER 1 – INTRODUCTION

Research Framework

Mathematics mindsets are ‘lay beliefs’ encapsulating an individual’s response to mathematics challenges (Yeager & Dweck, 2020). These beliefs exist on a continuum between growth and fixed mindsets. Individuals with growth mindsets are characterised by the willingness to embrace challenge and failure as part of the learning process and to interpret difficulty as indicating an activity that is worthwhile. They believe that mathematics ability can be changed and improved with effort. Individuals with fixed mindsets interpret failure as meaning that they are not intelligent enough for the task at hand. They interpret difficulty as evidence that they should stop trying. Their response to challenge might include avoidance or helplessness (Bernecker & Job, 2019).

Mathematics growth mindsets correlate with mathematics performance (for an example see Claro, Paunesku & Dweck, 2016). Short and cost-effective interventions are successful at promoting growth mindsets with positive effects on performance, particularly for high school and college students (for an example, see Bettinger, Ludvigsen, Rege, Solli & Yeager, 2018). Mindset theory and intervention frameworks have been developed primarily in the United States of America (USA), but in this thesis I examine whether mathematics mindset theory and interventions, can be applied in South Africa, and whether they will similarly boost mathematics performance.

South Africa has a profound and persistent problem with mathematics performance as indicated by consistent underperformance on the four-yearly Trends in International Mathematics and Science Study (TIMSS) (Letaba, 2017; see also https://timssandpirls.bc.edu/). This problem is not uniform but falls loosely along racial and poverty lines with the poorest students producing the lowest results (Spaull & Kotze, 2015). Unlike the USA, people of colour are the majority (92%)[1] of South Africa’s population. Better performing schools in South Africa have students achieving comparatively well on the TIMMS, however access to these better schools is determined by ability to pay school fees, which are often high (Christie, 2014). It is an ongoing injustice that poverty continues to preclude the majority of the population from a good quality mathematics education and hence from participation in many of the higher paid careers that are dependent on mathematics competency.

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[1] www.statssa.gov.za

The Department of Basic Education (DBE)[2], is active in seeking solutions through curriculum change, teacher training and various school-based interventions. However, change is slow to come with these costly and time-consuming interventions. To this end, a short and relatively cheap intervention such as that offered by growth mindset protagonists, could be part of the systemic change that the DBE is working towards. Indeed, growth mindset theory formed one of the four pillars of the Western Cape Department of Education 2019 "Transform to Perform" strategy[3]. This was a comprehensive strategy aimed at influencing actions and behaviour of all education role players in the Western Cape in the hope of improving student performance.

Given the socio-educational context that South Africa finds itself in, it is unsurprising that much of the previous research focus has been on the deficits in the system, on teachers, on student's families and communities, and on the students themselves (for example, Spaull & Kotze, 2015). A small body of research focused on resilience and achievement against the odds is emerging, though (for example, Wills & Hofmeyr, 2019). Still, very little of this is specific to mathematics performance or high school students. Whilst there has been local interest in the possibilities of growth mindset interventions boosting performance (see for example, Porter, Martinus, Ross, Cyster & Trzesniewski, 2020), application has sometimes been ad-hoc. There has not always been proper regard to assessing whether mathematics mindsets exist, developing a mindset assessment tool that is valid within local culture and language use, or developing an intervention that is appropriate and engaging for South African youth.

The research described in this thesis is important to the South African education landscape because it focuses on the potential to acquire beliefs and behaviours that promote performance in mathematics. Whilst poverty accounts for a large portion of the variance in mathematics performance, it is very difficult to rectify poverty, but beliefs and behaviours may be. This research is specific to youth from disadvantaged backgrounds who have historically been denied access to good quality mathematics education (Spaull, 2013; Taylor 2007). It carefully takes into account the experiences of culture and language through consultation with students and teachers and uses these in the construction of a localised mindset assessment tool, and the development of localised mindset intervention.

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[2] The government department that oversees primary and secondary education in South Africa.
[3] https://wcedonline.westerncape.gov.za/transform-perform

This research also has significance for research on mindsets in other parts of the world. As emerging research on mindsets is showing, mindset theory and application is not homogenous across contexts, either within or between countries. The research reported in this thesis attempts an in-depth understanding of problems that might emerge should one try to "transplant" ideas directly from one context to another. Moreover, it applies iterative design processes that could be replicated in other cultural adaptations of psychometric tests and interventions.

My thesis consists of four studies completed in the period 2019-2021 in Cape Town, South Africa. The work was conducted in high schools attracting youth mainly from disadvantaged backgrounds. The studies are mixed-method and the specific design of each was informed to a large extent by the results of the preceding study in the sequence. My ultimate aim was to develop a culturally sensitive mathematics mindset intervention targeting a mindset expressed by local students.

Summary of Studies

There is a substantial body of evidence regarding the reciprocal relationship between mathematics anxiety and mathematics performance (Foley, Herts, Borgonovi, Guerriero, Levine & Beilock, 2017). That is, anxiety about mathematics is associated with poorer mathematics performance, and vice versa. I introduced the known relationship between mathematics mindsets and mathematics performance earlier, however the relationship between mathematics anxiety, mindsets and performance has not been explored. Hence, I hypothesised that mathematics anxiety and mathematics mindsets would interact, as follows: As mindsets move towards growth, the anxiety experienced when difficulty is faced would be interpreted in a positive light, as a visceral response - the body getting ready to do something difficult but worthwhile. In this I drew on Oyserman's theory of Identity Based Motivation (IBM), particularly on the concept that an individual is willing to do challenging things that are consistent with current or future identity (Oyserman, 2015)[4].

My work was influenced by design theory. I used the Theory of Change, which belongs to the domain of Program Evaluation (Darnton, 2008) to describe the expected change process, the conditions under which change would happen, the inhibitors and any assumptions that the change relies on. Yeager's descriptions of applying design theory to

[4] An examiner has noted that the inclusion of actions that follow beliefs does not adhere to the original mindset theory, as developed by Dweck. However, subsequent research in the mindset field has emphasized the importance of teaching mindsets and study tools so my proposed development seems to be reasonable.

developing interventions shaped the development of the final intervention (Yeager et al., 2016). I gained important insights from social network marketing into how social networking sites (SNS) could be utilized to influence beliefs and behaviour (Yang, 2017). The intervention finally developed was delivered over WhatsApp[5].

In Study 1, I met with 50 Grade 9 students from four Cape Town high schools to discuss their understanding of mathematics performance and see whether mindsets would emerge in these discussions. I used a semi-structured interview format and recorded the discussions, which were later analysed using thematic analysis (Braun & Clarke, 2006). I found that students did identify growth and fixed mathematics mindsets but did not identify racial or gender stereotypes regarding mathematics or any other clearly defined mindset. Hence, I took an existing mindset assessment tool and presented it to groups of students to use, discuss and revise. This was an iterative process as each group took the previous group's work as a starting point and provided their own input. At the conclusion of Study 1 I had a mathematics mindset assessment tool that was worded such that students generally agreed on the meaning and found the phrasing understandable.

In Study 2, I presented the newly developed mindset assessment tool, "Thinking About Maths" to 199 Grade 9 students from the same four schools and correlated their results with their school assessed mathematics performance. I did this 6 months prior to the mindset assessment and shortly after the assessment. In addition, I tested the learners with the Study Orientation to Mathematics (SOM), developed in South Africa to assess behaviour and attitudes towards mathematics and consisting of five sub-scales: study attitude, mathematics anxiety, study habits, problem-solving behaviour and study milieu (Maree et al., 1998). I was particularly interested in the mathematics anxiety scale, hypothesising that higher mathematics anxiety would be detrimental to mathematics performance and that anxiety would also correlate with fixed mindsets. I was also interested in the relationship between the study attitude scale and maths performance, and study milieu (or environment) as a proxy control variable for socio-economic status (SES). The mindset assessment results correlated positively and significantly with performance, as expected on the basis of findings from extant studies. This established validity for the assessment tool. I built regression models of maths performance and found that whilst mindset was related to mathematical performance, its contribution was small in comparison to other variables in the model. Additionally, in this

[5] Internationally available freeware providing instant messaging and voice-over-IP service.

sample where there was disparate SES, I found an unexpected difference between males and females in terms of which combination of variables best explained performance. Males reporting the poorest study environments had higher mathematics anxiety and poorer mathematics performance. It appears that their study environment was demotivating. Females reporting the poorest study environments also had positive study attitude and stronger mathematics performance. Combined with the focus group findings in Study 1, it appears that females are motivated to mathematics achievement as a pathway out of poverty.

Study 3 was not a traditional study in terms of scientific procedure. Instead, I followed a collaborative design process to produce a mathematics mindset intervention appropriate for use with Cape Town youth. During stage 1, 12 teachers and 32 Grade 10 and 11 students assisted with developing the elements for the intervention, including selecting growth mindset messages and strategies as well as modes of delivery that students would find engaging. During stage 2, 32 students in four groups (one group per high school) participated in and evaluated the intervention. The intervention firstly delivered three mindset messages via YouTube[6] clips and short lessons taking 35-45 minutes. The key concept in the lessons centred on the notion of 'neuroplasticity', or the ability of the brain to grow and change. Students were then sent 16 WhatsApp messages over two weeks, reinforcing the messages and introducing follow-through strategies. Finally, the groups met to produce a short video presenting their favorite message or strategy to a 'new high school student'. Students provided feedback on the content and delivery of the program, indicating that they found it both valuable and enjoyable.

In Study 4, I aimed to repeat both Study 2 and run the intervention developed in Study 3 at a larger scale. in a quasi-experiment field-based design. Unfortunately, Covid-19 restrictions prohibited me from delivering a face-to-face intervention. I innovated and took the core structure from the original program and delivered it entirely on WhatsApp over a four-week period. 305 Grade 9 students from two high schools participated in this study, with students at one school experiencing the intervention condition and students at the other school the passive control condition. Group mentors facilitated conversation within the groups, and teachers were asked to show the YouTube clips during class time. I again observed a correlation between mindset and performance (as shown in Study 2), establishing a degree of reliability for the "Thinking About Maths" assessment tool. Students were

[6] Online video sharing and social media platform.

receptive of WhatsApp as a medium for intervention delivery and there was good evidence of participation. Mixed linear regression modelling showed that mathematics performance at the intervention schools was significantly stronger than the control school after accounting for the baseline mathematics performance and controlling for SES.

Chapter Outline

Chapter 1 – Introduction: The focus, purpose and direction of the research is established. The four study aims, method and results are outlined. A chapter outline and glossary of key terms is provided.

Chapter 2 – Literature Review: Literature pertaining to mathematics mindsets and mathematics anxiety is described. There is an outline of the history of mindset concepts showing how theory has developed. Criticism of the theory is examined.

Chapter 3 – The South African Context: The state of mathematics education in South Africa is described. Literature pertaining to resilience research in South Africa is reviewed. A theoretical model of change is developed.

Chapter 4 – Study 1, 2019: The aims of this study were to establish whether mathematics mindsets exist in South Africa and develop a South African mindset assessment tool. Ethics and permissions for all four studies are described in this chapter.

Chapter 5 – Study 2, 2019: The aims of this study were to establish validity for the mindset assessment tool and to explore the relationship between variables that might account for variance in mathematics performance.

Chapter 6 – Study 3, 2019: This study outlines the consultative design process for developing a South African mindset intervention and incorporation of previous intervention ideas. The study concludes with a pilot of the intervention.

Chapter 7 – Study 4, 2020-2021: The first aim of this study was to reproduce Study 2 and establish reliability for the mindset assessment tool. The second aim was to run a field based quasi-experiment examining the impact of the mindset intervention on mathematics performance.

Glossary

Apartheid - A government-imposed system that increased existing political and social segregation in South Africa from 1948, and which was legally dismantled in 1994. The system was held in place by minority White government rule and further entrenched White superiority and privilege. During apartheid, Black African and Coloured people were segregated into specific residential neighbourhoods, and schools, often remote from centres of economic business. Many of these families still live in these segregated areas and still experience remoteness from economic centres, travelling far for work and access to services.

Bachelor Pass - A Bachelor Pass is the highest final school matriculation pass in South Africa, technically allowing a student to go on to study for a bachelor's degree at university level. Students can pass matriculation at lower levels. A matriculation pass must include two languages, mathematics (pure), or mathematics literacy, 'life orientation', as well as three other subjects. Four subjects must be passed at 50% to obtain a bachelor pass.

Black African – A term often used in South Africa (not without controversy) to denote people of colour descended from the Nguni and related tribes and now the most populous group in South Africa. Under apartheid, Black African people had the least social, economic and political privilege.

Coloured – A term often used in South Africa to denote people of colour descended from a) slaves captured primarily by the Dutch Trading Company and settled in Cape Town and surrounding areas, b) indigenous Khoi and San peoples living mostly in the Cape at the time of European colonization, and c) mixtures of a), b), European settlers, and Black African peoples. Coloured people had more privilege than Black African people under Apartheid, but less than White people.

Entity theories – An older term that equates fixed mindset, the belief that intelligence is a personal quality that is fixed and cannot be changed.

Fixed mindset – A belief or set of beliefs that intelligence or ability is a personal quality that is fixed and cannot be changed.

Growth mindset – A belief or set of beliefs that intelligence or ability is malleable and can be changed through effort.

Incremental theories – An older term that equates growth mindset, the belief that intelligence is not fixed and can be improved through effort.

Maths – This is the locally used diminutive term for 'mathematics'. In this thesis I use 'math', or 'mathematics', unless quoting a study participant or quoting the language used in the delivery of each study.

Matriculation (Matric) – The final set of exams written at the end of high school, in Grade 12.

Mindset – Lay beliefs encapsulating an individual's response to challenge.

Other focused theories - Mindset theories can be self-focused or other focused. An example of other-focused theories is "I believe that people can learn new things, but they can't change their basic intelligence".

Outlier - In Education in South Africa, the term 'outlier' refers to schools or individual students that perform beyond the expected trajectory, considering the socio-economic situation.

Quintile - The South African government, Department of Education, classifies schools according to the wealth of the area in which they are situated, using quintile ratings. Quintile 5 schools are the "middle-class" schools referred to by Reddy, Prinsloo, Arends, Visser, Winnaar, Feza, ... & Maja, (2012). They generally charge moderate to high fees, with fees being determined by the parent body and they care for the wealthiest 20% of students per province. Quintile 1-4 schools are the "poor" schools referred to by Reddy et al., (2012), with quintile 1-3 charging no fees and quintile 4 charging low fees. Fee classification is based on income, literacy, and unemployment levels in the community. The intention of the policy is to provide economic access, redress and equity (Parliamentary Monitoring Group, 2020). The designation of quintile is controversial and inexact (White & Van Dyk, 2019).

Self-focused theories – Mindset theories can be self-focused or other-focused. An example of self-focused is "I believe that I can learn new things, but I can't change my basic intelligence".

White – A local language convention to denote fair skinned people of European origin, the minority people group in South Africa. Under apartheid, White people had the most political, social and economic privilege. Asian people were included in the term and referred to as "honorary whites".

CHAPTER 2 – LITERATURE REVIEW

In this chapter I introduce the key terms: mathematics mindset, mathematics anxiety, and explain key components of a mindset intervention. I review the literature relating to mathematics mindsets, mathematics anxiety and achievement. I examine the history of mindset assessments, interventions and theory development including the recent controversy over the efficacy of interventions, raised by Macnamara and colleagues (Sisk, Burgoyne, Sun, Butler & Macnamara, 2018).

Mathematics Mindset

Mindset theory is a theory about personal response to challenges and setbacks (Yeager & Dweck, 2020), based on lay beliefs about human attributes such as personality or intelligence (French, 2016). It is measured on a continuum between fixed and growth beliefs. Fixed beliefs (previously called entity beliefs) are beliefs that human attributes are fixed and mostly unchangeable (Bernecker & Job, 2019). For people holding fixed beliefs, the response to challenge might include avoidance or helplessness. Growth beliefs (previously called incremental beliefs) are beliefs that attributes can grow, change, and improve. The responses to challenge in this belief system might include perseverance, asking for help and looking for strategies. There is fluidity in the mindset continuum both for individuals across contexts and for individuals across time (Yeager & Dweck, 2020).

Table 2.1

Example Items for Measuring Growth Theories[7].

Attribute	Example Item	Orientation
Intelligence	You have a certain amount of intelligence, and you can't really do much to change it.	Self-focused Fixed belief
Intelligence	No matter who you are, you can significantly change your intelligence.	Self-focused Growth belief
Personality	Someone's personality is a part of them that they can't change very much.	Other focused Fixed belief
Personality	Anybody can change their personality a lot.	Other focused Growth belief

Traditional mindset assessments have included 3-4 fixed-oriented items and 3-4

[7] Older research tends to use the terms 'implicit' and 'entity', rather than 'growth', or 'fixed'. For the purpose of clarity going forward, I will use the terms growth/fixed even when the research I discuss has used the older classifications.

growth-oriented items (Dweck, 2000) which are self-rated on a Likert scale. Over time these have been simplified to 1-3 growth-oriented items (Yeager & Dweck, 2020.) Items can be oriented towards self-beliefs which apply a lay theory to the self or towards other beliefs which apply a lay theory to other people. Example of self and other oriented intelligence and personality items described by Dweck (2000) are given in Table 2.1. Dweck (2000) also developed items for the domains of moral character, groups (stereotypes), and the world (the way it functions).

There are a group of mindset beliefs that are particular to the mathematics domain. Mindsets link into beliefs about inherent mathematics ability or intelligence, and beliefs about race, gender or poverty and mathematics ability. In the USA, Dweck and her colleagues have developed sets of mindset assessment questions targeting beliefs about intelligence (Levy, Stroessner & Dweck, 1998; Dweck, 2000). These questions which were originally non-domain specific have later been used to develop mathematics focused assessment questions.

A second set of questions targets "stereotype threat". This refers to the beliefs or suspicion that others hold beliefs about mathematics ability based on their intelligence, race, gender or poverty, then that may become a stressor that impacts on actual mathematics performance (Sherman & Hartson, 2011). For example, perceived societal belief that African Americans are bad at mathematics may lead an African American to feel stressed when faced with a mathematics problem. Stress negatively impacts performance "proving" the stereotype (Aronson, Fried & Good, 2002).

Beliefs about intelligence are important in the USA as school students are assessed and streamed based on intelligence (Boaler, 2015). Students who are streamed into a mathematics remedial class and who believe that they can't do anything to change their level of intelligence will likely experience higher levels of physiological arousal when faced with a difficult mathematics problem (Dweck, 2000) and will be likely to interpret this as meaning that the work is too hard for them. This stress has compounding effects in hindering the ability to concentrate and in inhibiting help seeking strategies that might assist with the solving of the mathematics problem. This is discussed further in the section following.

Lee, Ning and Goh (2014) examined the interaction between achievement goals, working memory and performance. They and many other mindset theorists describe two types of achievement goals – those that focus on performance, equating to getting good grades, and those that focus on mastery, equating to learning key skills. Dweck and her colleagues have shown that growth mindset is associated with mastery goals whereas fixed mindset is associated with performance goals (Elliott & Dweck, 1988; Komarraju & Nadler, 2013). Lee et al., (2014) found that students with performance goals also had less effective working memory and poorer grades. Conversely, students with mastery goals had better working memory and better grades. In test anxiety literature, the processing efficiency model implies that anxiety uses up working memory (Lee et al., 2014*)*. The authors deduce that the anxiety caused by performance goals reduces memory capacity and negatively affects grades.

Recent work by Oyserman (2015) adds to Dweck's developments. Oyserman, influenced by Vygotsky (1978), explains that the way a challenge is interpreted will affect whether it is acted upon. If the experience of challenge is interpreted as worthwhile then people may engage with the challenge. If the challenge is interpreted as something that is too hard, they will not engage with the challenge. Additionally, the process of engaging with the challenge and the future expected outcome need to be congruent with the person's sense of identity. Oyserman has called this Identity Based Motivation (IBM).

Boaler (2013) has contributed substantially to the understanding of mindsets and mathematics performance. As a teaching graduate, Boaler brings a classroom perspective to teaching and assessment practices that contribute to the development of mindsets. Dweck (2006) notes that in the US 40% of tested students show fixed mindsets. Boaler, attributes this to the persistent testing and grading practices of US schools, which elicit performance goals[8] rather than mastery goals (2013). Boaler's work is dedicated to improving mathematics education practices in the United States and the United Kingdom.

Beyond the development of mindset theory is a set of work pertaining to mindset interventions. Mindset interventions contain three key components (Yeager & Dweck, 2020). Firstly, there is a teaching component promoting the idea that abilities can be developed and based on the idea of neuroplasticity. Aronson et al.,'s (2002) metaphor "the brain is like a muscle" has become a hallmark of this phase of the intervention. Secondly, concrete actions or strategies are taught, such as to persevere, ask questions, and try things in a different way (Dweck, 2013). Finally, there is an integration phase where participants are invited to engage in a "seeing is believing" exercise, such as writing a letter to a younger learner supporting

[8] As with fixed mindsets, performance goals are not consistently maladaptive and not associated with poor academic performance in all settings. See, for example, Lee & Bates (2017).

growth mindset theory. This helps participants to internalise the message by creating a cognitive dissonance[9] between what they previously believed and the belief they are expressing in the exercise, (Aronson et al., 2002).

Yeager and Dweck (2012) describe successful and low-cost interventions with scaling up possibilities. Their own intervention involves the teaching of a short single lesson. In the lesson they use scientific research about neuroplasticity to present the idea that the brain can change and grow. Notwithstanding the empirical basis for their claims, they argue that intelligence is not fixed, it develops over the lifetime. As people face challenges and learn new things, new neural pathways grow in their brains. Similarly, they argue that personality is not fixed. It also changes and develops over the lifetime. They draw on evidence from neuroscience[10] to show that people can adapt and grow. In this way they promote a growth mindset for young people faced with academic and social challenges. However, the authors do not consider the effect of extremely inhibiting environments on individual beliefs and academic performance, as experienced in many areas of South Africa. It is possible that paucity of resources in some schools renders even the most growth-oriented young person helpless to effect change (Cohen, Garcia, Apfel and Master, 2006).

In addition to mathematics intelligence beliefs and stereotype threat, described above, I also allowed that young people may have mathematics belief sets based on perceived lack of resources and opportunity. I term this "opportunity threat" and explored it during Study 1. I hypothesised that opportunity threat may arise when young people do not see tertiary study or future work options modelled by others in a person's groups of belonging. Hence, whilst they might believe that they can improve their mathematics, there does not seem any point in doing so as mathematics achievement is not congruent with their future sense of self.

Mathematics Anxiety

Mathematics Anxiety was described by Mary Fides Gough as "mathemaphobia" in her 1954 cornerstone article "Mathemaphobia: Cause and Treatments" (p. 290). An early mathematics anxiety rating scale (MARS) was developed by Richardson and Suinn (1972). The original scale has 98 items. There have been many adaptions of the scale since then

[9] Cognitive dissonance refers to inconsistent thoughts, beliefs or attitudes. The dissonance is experienced as unpleasant leading the person to try and resolve it by bringing consistency. Cognitive dissonance can lead to behaviour or attitude change (Festinger, 1964).

[10] The use of neuroscience in the intervention is a tool to introduce the perception of the possibility of change. It is not a theoretical basis for why change occurs.

including reducing the items on the scale whilst maintaining reliability and adapting the scale to culturally specific contexts (Carey, Hill, Devine & Szűcs, 2017). Conceptually, mathematics anxiety is defined as negative thoughts and emotions about doing mathematics with accompanying physiological arousal. Stress causes a multi-level response. Simplistically, in the brain the amygdala sends a signal to the hypothalamus which activates the sympathetic nervous system by sending signals to the adrenal glands. These glands release epinephrine (adrenalin) resulting in physical changes including dry mouth, elevated heart rate and sweaty palms (Rozek, Levine & Beilock, 2019). The pulse rate and blood pressure go up and the rate of breathing increases. This is the activation of the Sympathetic-Adreno-Medullar (SAM) axis, a rapid response to stress. A second axis is slower to activate, the Hypothalamus-Pituitary-Adrenal (HPA) axis. When activated, cortisol is secreted. The HPA axis involves the amygdala (emotional processing), hippocampus (memory) and prefrontal cortex (decision making) (Godoy, Rossignoli, Delfino-Pereira, Garcia-Cairasco, de Lima Umeoka, 2018). This axis is important to the setting and consolidation of memories.

Mathematics anxiety is likely to have two dimensions- cognitive (worry thoughts) and affective (nervousness and tension). Mathematics anxiety correlates with test anxiety at approximately $r = 0.3 - 0.5$, and with general anxiety at $r = 0.35$ (Dowker, Sarkar & Looi, 2016). Responses to stress can include a variety of emotions but anxiety is usually the primary emotion. These physical and emotional responses are interpreted by students and likely mediated via their mindset theories. With a fixed mindset, these responses are interpreted to mean that the task is threatening and should be avoided, or that the task is too hard and pursuing it will be hopeless (Dweck, 2000; Oyserman, 2015). With a growth mindset, these responses are interpreted as functional and adaptive. The stress is present to promote activity (Jamieson, Nock & Mendes, 2012). Students with a growth mindset believe that the task is worthwhile because it is hard.

There is emerging research supporting the interpretation of arousal as being critical to performance rather than the physical experience of cortisol levels. This can be applied to the situation of a mathematics challenge as follows. If the stress caused is interpreted as a threat, and fixed mindset beliefs indicate a high chance of failure based on lack of ability, then the young person will not draw on learning strategies available but will rather avoid and give up the task. The result will be that mathematics performance will decline, strengthening the fixed mindset theory for the student. Lee, Jamieson, Miu, Josephs, and Yeager (2019) have shown that students with fixed mindsets have higher cortisol levels when mathematics grades are declining. If the stress is manageable or even helpful and the hard work required is interpreted via a growth mindset as worthwhile (Oyserman, 2015), then the young person will draw on available resources and strategies (Yeager & Dweck, 2012). Mathematics performance will be maintained or improved for these young people, confirming the growth mindset theory in a reinforcing loop.

Foley, et al., (2017) ask the following questions: does mathematics anxiety impair mathematics performance? or does poor performance create anxiety? or is the relationship bi-directional? They review several studies and cite research where anxiety is induced, and this then impacts on performance. They also review studies that show that poor basic mathematics skills contribute to anxiety (Foley, et al., 2017). The authors conclude that the relationship between mathematics anxiety and performance is bi-directional.

Lee et al., (2019) have recently shown that a growth theory of intelligence in USA adolescents successfully predicts higher cortisol levels and daily stress reports when grades are declining. They also found a lag effect of daily stressors on the following day's cortisol levels. Study participants were in their first few months of high school and kept a daily diary of stress events as well as having their cheeks swabbed for cortisol measurement. For young people with fixed mindsets, bad grades or unexpected homework tasks were not viewed as a temporary difficulty but as global signs that they were unable to cope and were fundamentally "not smart" (Lee et al., 2019, p.28). Young people with a growth mindset showed more resilience, with overall lower levels of cortisol and reduced lag effects the following day. Their research adds evidence to the previously assumed link between the biological stress response, mindset and grades. It also contributes to the question of why some young people find the transition to high school more stressful than others do.

Researchers note that whilst sufficient basal levels of cortisol are needed for cognitive engagement, too much cortisol impairs performance (Levy et al., 2016). Students with high levels of working memory tend to do better on academic tasks because they can store pieces of information in a problem whilst working on a different section of it. These students are the ones who are most hurt by mathematics anxiety, which impacts on working memory (Beilock, Shaeffer & Rozek, 2017). Neuroimaging shows that people with high mathematics anxiety must expend energy controlling this negative emotion (Young, Wu & Menon, 2012).

Ashcraft and Kirk (2001) demonstrate the disruptive impact mathematics anxiety has on working memory by asking students to hold a group of letters in mind whilst completing a complex mathematics problem. They found an increase in errors along with slowed reaction time. The authors suggest that mathematics anxiety causes a disruption in central executive processes, leading to reduced effective functioning. Ramirez, Gunderson, Levine and Beilock, (2013) found that mathematics anxiety disrupts mathematics achievement for first and second graders with high functioning working memory. Students with low working memory showed no significant effects of mathematics anxiety. The high working memory students relied on inefficient strategies when facing anxiety inducing situations. These studies add weight to the claim of a relationship between mathematics anxiety, working memory and mathematics performance.

Findings from PISA (Foley et al., 2017) showed that countries with generally higher mathematics anxiety performed worse than countries with lower mathematics anxiety. Mathematics anxiety correlates negatively with scores on mathematics tests. Ashcraft et al., (2001) suggests that people with higher levels of math anxiety are more likely to avoid activities and situations that involve mathematics. Mathematics anxiety might influence performance by overloading working memory.

There has been significant interest in mathematics anxiety and gender, with females being more likely to report mathematics anxiety. Recent research shows that males and females in countries with gender equal access to education show little or no actual difference in performance, however females rate themselves lower and express more anxiety about mathematics (Dowker, Sarkar, Looi, 2016). This difference only develops at adolescence. Females report higher trait anxiety than males (‘it is part of me’) in many studies (Dowker, et al., 2016).

One possible conclusion is that females do not in fact experience more mathematics anxiety than males, but that due to gender stereotypes they expect to experience more mathematics anxiety, and this may discourage them from pursuing mathematics activities and courses (Dowker et al., 2016). Another possibility is that females may be more willing to report anxiety, with anxiety being a perceived “normal” trait for females but abnormal for males (Flessati & Jamieson, 1991). Sokolowski, Hawes and Lyons (2019) additionally note that females seem less willing to engage in spatial tasks that would assist them with complex problem solving.

In South Africa, mathematics performance in the final year of school shows females outperforming males, once the higher proportion of male drop-out is accounted for. Although the average final mathematics score is lower for females than males, males are 30% more likely to drop out before their final exams, artificially inflating their average score (Spaull & Makaluza, 2019). In 2018 there were only 80 males for every 100 females completing final high school exams (Spaull et al., 2019). Omar, who co-researched in Study 1 & 2 with me, found that female students in Cape Town did not feel under pressure from negative gender stereotypes (Omar, 2019).

Mathematics Anxiety interventions involve students expressing, re-evaluating and/or normalising their worries. Students are taught that the elevated heart rate etc during a test is beneficial, ensuring that they can focus and work quickly as blood is being pumped to their brain (Jamieson, Crum, Goyer, Marotta & Akinola, 2018). Jamieson, Mendes, Blackstock & Schmader, 2010) looked at the benefits of reinterpreting arousal as a challenge response, with arousal improving performance. In a laboratory setting students wrote the U.S.A. GRE-Mathematics section. One to three months later they provided their actual GRE scores. Participants who had been taught to reinterpret outscored controls in both the lab setting and in the actual exam. Other successful interventions include having students write about their anxieties for 10 minutes before a test (Park, Ramirez & Beilock, 2014) and undergoing growth mindset interventions (Rozek et.al., 2019).

Arousal increase can indicate anxiety or threat, or the body mobilizing resources to meet task demands. How one construes bodily responses such as arousal has important behavioural consequences. The link between physiology and behaviour may, in addition, be strongly dependent on our cognitive appraisals of internal states.

Mindset History and Development

Although Dweck now stands out as the modern-day “grandmother” of mindset theories, the concept that people can change and grow reaches back into the Renaissance era. Leonard da Vinci is believed to have said “Learning never exhausts the mind” (Insperity, 2021). In the early 1900s Binet developed the precursor to the modern-day Intelligence Quotient (IQ) test, to help highlight areas where school students had fallen behind so that attention could be given to supporting improvements[11] (Boake, 2002). Although the IQ test has later come to be used to predict student success or failure and facilitate class streaming into gifted and talented or remedial and is assumed by many to be a fixed endowment, this was not its original intention.

French (2016) offers a comprehensive history of the origin of mindset ideas which I draw on in the following analysis. In this history, French argues that three streams - cognitive, social, and positive psychology, each have contributions to make to the understanding of mindsets.

French (2016) explains that in the early 20th Century, the Würzburg School of cognitive psychology discovered that intense involvement in solving a given task boosts task completion. The created mindset or cognitive framework equals the sum of activated cognitive processes, most likely to lead to task completion (Gollwitzer & Bayer, 1999). The Würzburg School psychologists called this the mindset theory of action phases. This theory forms the basis for Gollwitzer's own theoretical developments and research in the 1970s-1990s. The cognitive psychology stream consistently describes mindsets as "the sum total of the activated cognitive procedures" in completing a task (Gollwitzer & Bayer, 1999, p405).

The second stream listed by French (2016) was social psychology and organisational leadership. This school of thought defines mindset as a specific filter used throughout the individual's or organsation's cognition. That is, as a predisposition to see the world a particular way. This has recently been developed by Oyserman in her Identity Based Motivation Theory (2015). Oyserman explains that when people are confronted with a difficult task, they interpret that difficulty, and that interpretation or filter impacts the way the task is engaged with. For example, the experience of difficulty might mean that the person is not able to do the task and should not engage with it. Conversely it might mean that the task is worthy of extra effort and attention.

French (2016) locates Dweck's work in the third field - positive psychology. Positive psychology emphasises optimal conditions for people or groups of people to function. Mindsets are described as "just beliefs" or "lay beliefs" about human attributes (Dweck, 2006, p16). Simply put, mindsets describe personal beliefs about thinking and behaviour. These beliefs may contribute to or inhibit personal growth across a wide variety of domains.

Whilst recognizing that the history of psychology can locate mindset theory in these three streams, noted above, the intention in this chapter is to focus on the origin of Dweck's work in the 1970s and its development over time. Dweck and Yeager (2019) offer their own personal history of the development of mindset theory and subsequent research which I draw on here.

As a young psychologist, Dweck was influenced by Seligman's (1972) learned helplessness studies (Dweck & Yeager, 2019). In this research, dogs were repeatedly shocked over a lengthy time period, when they tried to escape an enclosure. The dogs then stopped trying to escape. Even when the shock was removed, the dogs still did not try to escape. Hence, they had learned a form of helplessness, and this condition was named 'learned helplessness' by Seligman (Maier & Selligman, 1976). This understanding of how beliefs form about failure became Dweck's starting point of what is now an extensive and still growing body of mindset research across academic, interpersonal, and occupational domains (Bernecker & Job, 2019).

Psychology in the 1970s had entered the cognitive revolution, emphasising mental events over behavioural explanations as the dominant psychological framework. Despite this, Dweck preferred to take an integrated approach valuing affect, cognition, motivation, and behaviour as an integrated area of study, rather than separate concepts (Dweck, 2011).

Dweck noticed that children had various reactions to challenges and setbacks, and she became curious about this. Dweck and her colleague, Mary Bandura, noticed that children's views of ability led to them interpreting failure as something either inherent and permanent or as something that could be changed. Dweck set about integrating the understanding of learned helplessness in dogs with attribution theory in humans (Dweck & Yeager, 2019).

Attribution theory proposes that peoples' explanations for success or failure shape their reaction to that event (Weiner, 1974). Students with similar abilities could attribute challenge or failure to uncontrollable factors such as their own innate ability or to relatively more controllable factors such as their own effort. Later, achievement goal theory added to attribution theory by explaining why students tended towards the various attributions made (Elliott & Dweck, 1988). Achievement goal theory proposes that students are motivated either by performance (inclusive of good grades, praise and public recognition) or by learning. Students motivated by performance are less likely to engage in a challenging task as it might make them look bad or lead to a poor mark. Students motivated by learning will engage in a challenging task as they regard the effort as worthwhile to the overall learning process (Yeager & Dweck, 2020). Whilst both are important to understanding mindset theory, I have chosen to focus on attributions only. Should mindset theory, assessment and intervention prove to be of use in the South African context, it will be important to add in the dimension of goal orientation to future research.

By the year 2000, Dweck had accumulated a substantial body of research which she published in summary in the book "Self-Theories" (Dweck, 2000). Several pivotal studies were completed in the years 2002-2010 and new researchers entered the field. Aronson et al., (2002) applied mindset ideas to reducing stereotype threat in African American college students, leading to improvements in their academic performance. Blackwell, Trzesniewski and Dweck (2007) ran a longitudinal study with students transitioning to high school, showing that growth mindset predicted a successful transition.

In due course it became evident that mindset interventions could offer a high return on investment, particularly when compared to other educational programs. Mindset interventions tend to be short (even as short as 30 minutes) and cheap, with measurable improvements in performance that are sustained after the intervention period. David Yeager was at the forefront of exploring the scalability of short mindset interventions (cf., Yeager & Walton, 2011).

Mindset interventions at scale can create substantial change, even when the resulting shift is small. Yeager then wondered if saturating the learning environment could lead to much larger changes (Dweck & Yeager, 2019). Saturation interventions incorporate the core mindset lesson but also educate teachers, school leaders and parents about how to create a growth mindset environment and incorporate visual aids, such as posters, into the classroom. To date, these interventions have not proven successful due to the difficulty in getting teachers to both change their own mindsets, and to change their teaching and assessment practices to be in line with growth mindset ideas.

Controversy

As mathematics mindset interventions have developed there has been a commercialisation of the ideas. Product sales including school intervention programs, teacher training, books and other resources have given mindset interventions a very public face. Amongst the plethora of resources for sale, see for example, The Big Life Journal[12], Brainology[13], YouCubed[14] or even Stanford Online[15]. The widescale sale of such programs to schools lead researchers to compare the intervention to other educational interventions.

Recently, Macnamara and her colleagues (Sisk et al., 2018) completed two meta-analyses of mindset research. Macnamara concluded that compared to other educational interventions the effect size of mindset interventions, at $d = 0.20$ for grades or test scores, was too small to be practically useful (Macnamara, 2018). The findings were made popular by the media and a debate ensued and is still running. Dweck countered the initial controversy with her own analysis of United States educational interventions, showing that they were generally

[12] www.biglifejournal.com
[13] www.mindsetworks.com
[14] www.youcubed.org
[15] https://online.stanford.edu/courses/xeduc215n-mathematical-mindsets

costly, lengthy and yielded a similar effect size to mindset interventions (Dweck, 2018).

The calculation of effect size became pivotal to Dweck's rebuttal. The education studies touted by Macnamara as examples of strong effect sizes (Hedges weighted effect size, g_u = .57) did not examine effects on actual grades or standardized tests, rather relying on performance on a non-standardized quiz administered shortly after the intervention. Dweck stated that a whole year of learning, from Grade 9 – 10, has an effect size of d = 0 .22, (Lipsey, Puzio, Yun, Hebert, Steinka-Fry, Cole, Roberts, Anthony & Busick 2012) hence an intervention yielding a d = 0.20 effect on grades is worthy, particularly if it is quick and cheap (Dweck, 2018).

Yeager and Dweck further argued that meta-analysis is an inappropriate tool for evaluating mindset effects (2020). Rather, large, rigorous, randomized controlled trials should be used to settle debates. Contextual heterogeneity can be better explained with replications of intervention and target group across a variety of contexts. For example, Yeager, Hanselman, Walton, Murray, Crosnoe, Muller … & Dweck (2019) evaluated a short, online growth mindset intervention with a population sample of 9th graders in the United States. Compared to a control condition, low achieving students who participated in the intervention were more likely to improve grades. Overall, the intervention increased the likelihood of choosing more challenging mathematics classes and staying in those classes. Yeager and Dweck (2020) report that this research was independently evaluated and internationally replicated. Careful replication in different contexts is a better way of understanding mindset more deeply.

Criticism from Macnamara and colleagues spurred theory development. Yeager and Dweck (2020) responded by taking a deeper look at the existing research, noting that mindset associations and interventions seemed to be potent under some conditions but not others. When, why, and under what conditions can mindset effects be expected to appear? What could be learned from the research where no effects were found?

Costa and Faria (2018) completed a meta-analysis intended to model the link between implicit (growth mindset) theories and academic achievement. They found that correlations differed between countries. In both Australia and Asia growth mindset correlated with performance, as expected, but fixed mindset did not correlate negatively with performance, as originally expected. In Europe, fixed mindset correlated negatively with performance and growth mindset correlated positively with performance. In North America, only fixed beliefs correlated negatively with performance. These contextual differences show that all mindset research cannot be evaluated with the same set of expectations.

Li and Bates, at the University of Edinburgh, tried to replicate previous mindset research (2017), over a series of three studies with Chinese school children. They were unable to replicate expected effects, and this contributed to the ongoing controversy about mindset interventions. However, their different social context (China versus the United States) highlights the dependency of mindset effects on social contexts. The first study sought to replicate Mueller and Dweck's (1998) study on giving different types of praise. Praise can be given for hard work undertaken in completing the task (process-oriented praise) or for being smart and doing well on the task (performance-oriented praise). Mueller and Dweck (1998) found that giving a child praise for hard work (process oriented) was positively correlated with persisting with difficult tasks. Being smart (performance oriented), was negatively correlated with persistence on difficult tasks. They found that their study did not replicate Mueller and Dweck's results. They made two adjustments to improve the power of their study and reduce ambiguity of testing. They still were not able to reproduce the effect of praise.

What could be happening? Emerging evidence pointed to culture as relevant to the motivating forces of mindset (Yeager & Dweck, 2020). The 2019 Programme for International Students Assessment (PISA)[16] results contribute to our understanding of culture and mindset. PISA collected mathematics results and mindset scores from 72 countries (Gouëdard, 2021). Whilst many countries showed correlations between mathematics results and mindset scores, some did not. The expected correlation between growth mindset and mathematics performance was not found in China. This led the researchers to speculate that cultures with a strong emphasis on learning and achievement and accompanying long school days, may not be able to squeeze any additional performance out of students. However, mindset is still relevant in these contexts as a fixed mindset is associated with self-regulatory behaviour and academic distress (Burnette, O'Boyle, VanEpps, Pollack & Finkel, 2013; Schleider, Abel & Weisz, 2015).

Patterns of correlations within student populations are also not homogenous. It has been evident for several years that lower achieving students who participate in a broadscale Mindset intervention tend to get the largest benefit from changing mindsets, with grades stabilizing or improving in the following semester (Yeager & Dweck, 2020). Newer research also indicates that the prevailing perspective of peers and teachers (school culture) makes a

[16] PISA for Schools –a voluntary assessment produced by Organisation for Economic Co-operation and Development.

difference to the effectiveness of interventions. Mindset interventions are more meaningful for under-achieving students in a school which promotes growth mindset (Yeager & Dweck, 2020 referencing Yeager et al., 2019, not available).

The mindset controversy and debate has led to clarification of the contexts in which mindset gains are noticed and a new focus on replicating randomized controlled trials. Parameters have been developed for what constitutes a meaningful effect in comparison to other education interventions. Low cost and swift delivery continue to be hallmarks of the mindset interventions.

In this chapter I introduced the concept of mathematics mindsets. A mindset is a set of lay beliefs or personal theories. In relation to the mathematics domain, a mathematics mindset is a set of beliefs about personal attributes regarding mathematics learning and challenges. A fixed mindset indicates a set of beliefs that the person is unable to change their mathematics achievement. A growth mindset indicates a set of beliefs that indicates that a person can grow and change in their mathematics achievement. I reviewed the literature pertaining to mathematics mindsets, anxiety and performance, explaining the development of mindset assessments and interventions. Mindset Theory and research spans the past fifty years. I reviewed the developments in the field with an emphasis on the work of Carol Dweck. As mathematics mindset interventions have developed there has been a commercialisation of the ideas. Product sales including school intervention programs, teacher training, books and other resources have given mindset interventions a very public face. As such, they have also attracted a good deal of controversy. Current mindset proponents, Dweck and Yeager, have sought to establish mindset interventions as low cost and effective when compared to other educational interventions. It has become clear though that mindset theory and interventions cannot be homogenously applied. Culture and context do make a difference and future researchers are advised to take this into account.

CHAPTER 3 –THE SOUTH AFRICAN CONTEXT

In this chapter I provide context for research into mathematics achievement and disadvantaged youth in South Africa. I explain the current state of mathematics education in South Africa and give some of the history behind the current problems. I review South African resilience literature focused on how young people succeed academically despite challenges within their school system and broader community. I present my own theoretical model explaining the relationship between mathematics mindsets, mathematics anxiety and mathematics performance. Finally, I note the context specific challenges of researching growth mindset in South Africa.

Mathematics Education in South Africa

South Africa's mathematics achievement levels have been the subject of close investigation by researchers, policy writers and educators. The Trends in International Mathematics and Science Study (TIMMS)[17] studies have revealed South Africa, not just as lacking, but as close to the worst mathematics performing country participating in this international study (Letaba, 2017). Whilst a small number of top South African students do perform comparably well against international counterparts, performance for the rest is very low. Efforts to reduce the achievement gap within South Africa have included policy and syllabus changes, teacher training and provision of resources. The gap remains. Top and bottom performers are largely delineated by family income and historic racial segregation, (Christie, 2014; Spaull & Kotze, 2015). Our achievement gap has strong resonance with that observed in the USA (Boykin & Noguera, 2011) with this one startling difference: our bottom achievers are not the minority of students, they are the majority.

What is meant by underprivileged or disadvantaged in the South African context? Recent world inequality rankings placed South Africa amongst the most unequal countries in the world (Beaubien, 2018). The top 1% of South Africans own 70.9% of the nation's wealth. Young people from these families access good quality education by paying substantial fees for the service (Christie, 2014). 55.5% of people live below the national poverty line of R992/month or US$66 (StatsSA, 2017). Young people from these families access free or low fee schools with a markedly different educational result. It is as if South Africa has two school systems, with the privileged system returning results comparable to international

[17] TIMMS provides internationally comparable data on the trend in mathematics achievements of students from Grade 4 to 8. Participation is voluntary. South Africa participated in 2015 and 2019 at the Grade 5 level (HSRC, 2020). See https://timssandpirls.bc.edu/ for more information.

standards but the underprivileged system returning very poor results (Spaull & Kotze, 2015). To a large extent the two school systems still represent historical racial divides with Black African and Coloured families being more likely to access quintile[18] 1-4 schools and Indian and White families being more likely to access quintile 5 schools, (Spaull,2013; Taylor, 2007).

Why should we be interested in under-achieving, underprivileged students? In South Africa, the answer is simple. The sheer numbers of underprivileged students heavily outweigh the numbers of privileged students, and these students are known to struggle with mathematics. Grade 9 students in the most privileged quintile band are approximately four years ahead of their counterparts in the least privileged schools (Spaull & Kotze, 2015). Nationally, each quintile band represents 20% of students, hence the 20% of students in quintile 5 dramatically outperform the 60% of students in quintiles 1-3 (WCED Online, 2013). Notwithstanding the many complexities for poorer communities, research indicates that supporting underprivileged students in their approach to mathematics may change their actual mathematics outcomes. In a nationwide sample of high school students in Chile, mindset was found to predict achievement across all socio-economic groups. Students in the lowest economic groups were more likely to have fixed mindsets. However, those who had growth mindsets were buffered against the expected negative effects of poverty on mathematics performance, performing similarly to fixed mindset students in the 80th income percentile. (Claro et al., 2016).

Mathematics is a gateway subject for entry into tertiary education courses in South Africa, particularly courses in Science, Technology, Engineering and Mathematics (STEM) subjects (van Broekhuizen, van der Berg and Hofmeyr, 2017). In South Africa, young people from Black African and Coloured racial groups are less likely to access tertiary education of any type with only 3% going on to tertiary education as opposed to 18% of their white counterparts (General Household Survey 2013, 2014).

[18] The South African government, Department of Education classifies schools according to the wealth of the area in which they are situated, using quintile ratings. Quintile 5 schools are the “middle-class” schools referred to by Reddy et al., (2012). They generally charge moderate to high fees, with fees being determined by the parent body and they care for the wealthiest 20% of students per province. Quintile 1-4 schools are the “poor” schools referred to by Reddy et al., (2012), with quintile 1-3 charging no fees and quintile 4 charging low fees. Fee classification is based on income, literacy and unemployment levels in the community. The intention of the policy is to provide economic access, redress and equity (Parliamentary Monitoring Group, 2020). The designation of quintile is controversial and inexact (White & Van Dyk, 2019).

How Underprivileged Students Succeed in South Africa.

"Underprivilege" in South Africa refers to historic disadvantage based on race as well as current poverty. Under apartheid, Black African, Coloured, Indian and Asian people experienced discrimination at varying degrees, with people classified Black African experiencing the most discrimination. Discriminated groups had reduced school budgets, reduced subject options, reduced living area options, and reduced employment options, as well as other restrictions, (Kallaway, 2002). Although poverty and wealth no longer fall along strictly racial lines (Seekings, 2015), lagging apartheid effects do remain, particularly in the education sector.

Under apartheid, the Group Areas Act legislated forced removal of families to remote locations, based on race (Banerjee, Galiani, Levinsohn, McLaren & Woolard, 2006). Over time, these locations have built up into economic centres generally termed "townships". High schools in townships tend to be low fee or free as the surrounding population cannot afford fees. Although there is a level of government support it is not sufficient to properly resource these schools and attendance at a low quintile school is associated with education of a poorer quality (White & Van Dyk, 2019). In addition, it is difficult to attract good teachers to township schools as the working conditions offered cannot compete with those in fee supported schools. This problem is most stark with Mathematics and Science teachers. These teachers are in short supply, so it is very difficult for an underprivileged school to attract and retain these teachers when more lucrative and comfortable positions are available in fee paying schools (Newman & De Lannoy, 2014).

The weightiness of the problems in the education system leads researchers in South Africa to ask deficit laden questions about underprivileged youth and STEM performance. For example, Spaull and Kotze (2015) published an article entitled "Starting behind and staying behind in South Africa: The case of insurmountable learning deficits in mathematics". Their results point to very large gaps in mathematics performance between the poorest students and the wealthiest students, which exist when students start school, and which increase for every year of education. Much is known about the scope of the problem but very little is known about what helps underprivileged students to achieve. Focusing on deficit leaves out the potential learning available from schools or students who succeed against the odds. This alternative line of questioning, asking what works, informs resilience research. A balanced development of the problem will need to consider both the systemic problems (including lack of resources) and the ways that schools and individuals have managed to circumvent these problems.

Resilience can be defined as overcoming adversity to achieve success (Wills & Hofmeyr, 2019). Theron and Theron (2010) and Theron (2012) completed a substantial literature review of South African youth resilience studies covering 1990-2012. The researchers noted that Indian and Coloured[19] children/youth are least well represented in the corpus of studies, with qualitative studies focusing primarily on Black children and youth. Risk contexts in the reviewed studies included HIV/AIDS, sexual assault, violent communities, and rural communities, and their relationship to overall adaptive functioning. Academic achievement in general and mathematics achievement are rarely covered in resilience research literature in South Africa.

The ongoing failure of the South African education system must be acknowledged (Masten, 2011). However, during large-scale educational challenges there are low-cost schools that succeed (Christie, 2014). There are also individuals who succeed at mathematics, against the odds (Wills, 2017). Whilst not discounting systemic failure, these success stories point to existing answers that may inform preventative and remedial strategies.

In 2014, Blank and Jansen launched a project called "How to Fix South African Schools – Lessons from Schools that Work". This project identified schools in disadvantaged communities that had performed beyond the expected trajectory given their contexts. The challenges faced by these schools include community poverty, gang violence and under-resourcing. Blank and Jansen set out to interview teachers, principals, students, and families about their explanations of the school's relative success. The findings were not published in a peer reviewed journal. Rather, they were presented in practitioner focused films and workshops around the country. Some of the "things that work" noted by Blank and Jansen (2014) refer to structure – firm routines and discipline. Others refer to relationships – parents involved in the life of the school. Other common themes shared by successful schools seem to include underlying mindsets that enable growth. Links between "things that work" (in Blank and Jansen's schema), and mindset themes, are described in Table 3.1.

[19] Coloured people are the largest segment of the population in Cape Town, comprising 42% of people, (World Population Review, 2021).

Table 3.1

Links Between "Things that Work" and Mindsets

"Things that work", Blank and Jansen (2014)	**Possibly underlying beliefs that enables growth**
Schools extend time for learning	Hard work pays off
Teachers teach every day and are in every class	
Students are confronted with high expectations	Challenge leads to growth
Principals are visible in their leadership	Success of others is inspirational
Principals and some teachers are social entrepreneurs[20]	
Students are offered a life beyond school (sense of possible career and future)	Goal-oriented achievement is incremental, success is not just a good mark on an exam.

Most local research focuses on the role of schools, school leadership and teachers in promoting academic achievement, for example, Bester and Kuyper found that additional educational support boosts resilience and academic performance in adolescents (2020). Very little local research focuses on student-centred variables and academic performance amongst underprivileged students (Wills, 2017).

Amongst the earlier examples of resilience focused South African research was that completed by Dass-Brailsford (2005). Dass-Brailsford asked how young university students, from an underprivileged township, were able to achieve academic success. Her study was conducted in a township in Kwa-Zulu Natal and involved extensive ethnographic interviewing. The subjects were 16 first year university students. Her study examined stressor factors as well as resilience promoting factors. She found that individual predictors of academic success included goal orientation, self-agency and strong motivation.

Mampane completed three studies in South African townships (Mampane & Bouwer, 2006; Mampane & Bouwer, 2011; Mampane, 2014) in which they primarily build a

[20] Social entrepreneurs instigate practices to bring change to their social context. For example, raising money to feed hungry children or building a partnership with a local university psychology department to provide free counselling to students.

description of resilience. They found individual traits of resilient high school students included independence, responsibility, assertiveness, sense of control, self-efficacy, planning and resourcefulness (Mampane & Bouwer, 2006). Like Bester and Kuyper (2020) they find that supportive teaching environments promote resilience and that resilient students were more likely to utilize offers of extra assistance, than their non-resilient peers (Mampane & Bouwer, 2011). In 2014, Mampane studied resilience among 291 township high school students using a self-report questionnaire. She found that resilience was associated with self-confidence, internal locus of control, commitment, being achievement-oriented and having access to social support.

Tsanwani (2009). Tswanwani asked why some mathematics classrooms in disadvantaged communities are successful, and some are not. This mixed methods research was based in Limpopo Province, one of the poorest areas of South Africa, and compared high-performing rural schools to low-performing rural schools. Students were from similar home backgrounds. The strength of Tsanwani's study lay in detailed classroom observations over 6 weeks and teacher interviews, but there was very little student level data, consisting only of three focus groups, n=18. Teachers and students reported that effort, perseverance and self-discipline led to mastery of mathematics, indicating a possible relationship between growth mindset and achievement. There is a need to confirm this with detailed, student level research.

Recently a new multi-university South African collaboration developed to research resilience in high-functioning township and rural primary schools. The collaboration aimed to develop a counter-narrative to the frequent negative reports about South African education. The researchers formed a multi-disciplinary team from Stellenbosch University (SU), University of Cape Town (UCT), University of South Africa (UNISA) and the research organisation JET Education Services. Using national systemic testing data one of the researchers, Wills, (2017) identified outlier schools[21]. There are primary schools in which students appear to excel despite inhibiting home and school environments. Based on 2011 Pre-PIRLS[22] data Wills estimates the presence of one or two high achievers in over half the

[21] In Education, the term 'outlier' school refers to schools that perform beyond the expected trajectory, taking into account the socio-economic situation of the school.

[22] PIRLS – Progress in International Reading Literacy Study, an international reading assessment administered every five years since 2001.

classrooms tested in African languages. Wills notes that further detailed research is needed to understand the factors that contribute to the success of these youngsters.

Porter, et al., (2020) tested a growth mindset intervention in poorly resourced primary schools in the Western Cape, n=354 . Their intervention used growth mindset videos developed by ClassDojo[23] and an active control group that watched National Geographic nature video. Unfortunately, they faced many disruptions in their planned delivery, leading to the program running over two school years and only 14% of the original participants completing the planned program. Unfortunately, the study was under-powered statistically, and although there was a trend toward an effect of the program on mindset and achievement, wide confidence intervals meant that a null effect could not be ruled out.

The most substantial South African studies contributing to understanding of academic success in the face of multiple performance constrictions, comes from Wills (2017) and Wills & Hofmeyr (2019). The 2017 study stands out due to several factors (Wills 2017). The study was well-powered, with a sample size of over 2600 participants. The data is longitudinal and contains both school and individual protective factors. The data is clearly related to academic performance and is not simply descriptive of resilience. They find that after controlling for socio-economic and language differences, academically achieving students differ from their peers on several dimensions, primarily socio-emotional skills. The student attitude index in the 2019 study most strongly associated with mathematics excellence was confidence in academic subject (Wills & Hofmeyr, 2019). Additionally, resilient, academically successful students are female and younger (Wills, 2017; Wills & Hofmeyr, 2019), and more likely to have attended pre-Grade 1 (2017). Their parents are more likely to be employed (Will, 2017) and they are more likely to have their own storybooks to read (Wills, 2017; Wills & Hofmeyr, 2019). They are more likely to speak English at home and to attend school in an urban rather than rural area (Wills, 2017). They are also likely to be regular school attenders (Wills & Hofmeyr, 2019).

Context Specific Challenges.

Prior to the research reported in this thesis I completed preliminary field work, correlating mindset scores with mathematics performance over 3 years. My sample were top performing mathematics students who were initially tested at the end of Grade 6 as part of a 'high stakes' exam contributing to scholarship selection. I used a set of six Likert-style

[23] ClassDojo is an app that connects teachers and parents available at www.classdojo.com

questions developed by Dweck (2000). The mindset assessment was not predictive of ongoing mathematics performance for either the full set of six questions or the reduced set of three. To ascertain whether students understood the word “intelligence”, I added in open ended questions about intelligence and ability such as “How would you describe an intelligent person?” I coded the open-ended answers for growth or fixed mindset attributes. The open-ended answers did not correlate with the Likert-style mindset questions. This indicated that my students did not understand the wording of the questions in the assessment.

Some mindset assessment questions are negatively worded such as: “Your intelligence is something about you that you can’t change very much” (Dweck, 2000). Many South African students speak English as a second language. In my field work, they seemed to struggle with negatively worded statements, and I hypothesised that this may affect their understanding of the statement. My observation is backed by Weems, Onwuegbuzie and Collins (2006) who note that negatively worded items are particularly difficult for poor readers. If intelligence theories and personality theories are important to young peoples' mathematics performance in South Africa, the assessment tools need to be adjusted to the local context.

Dweck’s assessment questions developed in the U.S. are predictive of mindset and grade performance in many other international contexts but not uniformly so. South Africa differs from the U.S. system in that intelligence testing and streaming into gifted and talented or remedial rarely occurs. Hence children and teenagers may have a very different experience of the meaning of the word ‘intelligence’ and the consequence of being labelled intelligent. Field talk from AFRA[24], a South African Non-Government-Organisation (NGO) implementing the Big Life Journal[25], concurred that there are problems in understanding “intelligence”, and they reworded the content accordingly. Porter et al. (2020) in their preliminary work in South African townships also used an adjusted mindset assessment question set (based on Blackwell et al., 2007) to avoid the use of the word ‘intelligence’, and to simplify the language.

In South Africa there may also be a previously unidentified mindset about perception of opportunity to succeed at mathematics careers. Whilst young people may believe that they are all equally able to succeed at mathematics, regardless of their race, gender, or socio-economic status, they may also believe that there is unequally distributed opportunity to

[24] Association for Rural Advancement
[25] Big Life Journal: Growth Mindset for Kids & Teens www.biglifejournal.com

succeed in STEM careers. This belief about lack of opportunity may result in a fixed mindset that inhibits mathematics achievement. Despite legislative efforts to correct racial balance in company ownership and employment, Hoffman and others write that the White minority continues to hold the majority of economic power (Hino, Leibbrandt, Machema, Shifa & Soudien, 2018; Hoffman, 2008). A fixed mindset may develop if young people do not have positive role models, in STEM careers, whom they can relate to.

There are antecedent variables related to risk and resilience for young people from underprivileged backgrounds (Ebersöhn, 2017). Poverty has an impact on access to resources in the family, community, and school (Spaull, 2015). Poorer communities in South Africa are exposed to higher levels of violence and this impacts on stress levels (Milam, Furr-Holden & Leaf, 2010). Compared to other countries, South Africa has one of the strongest correlations between students' home background and academic performance, accounting for roughly 60% of the learning gap between rich and poor (Shepherd, 2016). For these reasons, 'Study Milieu' is included as a control variable in both the quantitative studies – Study 2 and Study 4. Study Milieu is a subset on the South African developed "Study Orientation to Mathematics" test and refers to the study environment at home and school (Maree et al., 1998).

Mindset ideas, themselves, may pose a risk to South African youth if the beliefs are not carefully connected to concrete strategies. Disadvantaged South African youth tend towards believing that they can 'be anything' - achieve any level of academic or career outcome. They hold onto that belief as a panacea against the stark reality of very different evidence (Morse, 2019). This belief is supported by politicians, teachers and parents who all want to inspire young people to achieve but do not necessarily provide the structures or resources required to achieve. Inevitably this leads to bitter disappointments. Bray, Gooskens, Moses, Kahn and Seekings (2011) found that young people held onto unrealistic expectations of tertiary education long after the time that it should have been evident that they were not going to study further. When the researchers asked participants about this, they started to cry, and the line of questioning was terminated (J. Seekings, personal communication, March 3, 2016).

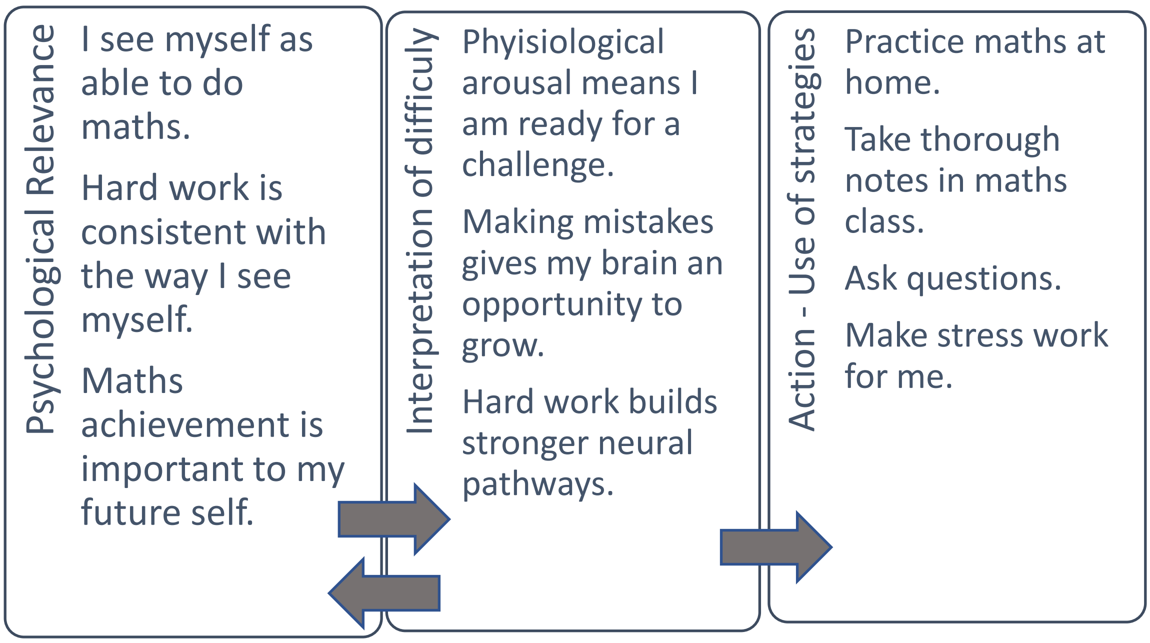
Theoretical Model of Change

A theoretical model needs to account for both individual level behaviour and group level behaviour. Oyserman's (2015) Identity Based Motivation (IBM) provides an explanation of specific individual behaviour. Theory of Change models used in program planning, development and evaluation since the 1990s, provide a structure for explaining changes in group behaviour over time (Darnton, 2008). In building my own model of expected change processes, I integrated both an IBM based model and Theory of Change. The two models are complementary and offer a deep understanding of the process of change. Within this framework, I also acknowledge that human behaviour is complex, and all models will therefore be simplistic and limited in their application (Darnton, 2008). Whilst the inclusion of mathematics anxiety in my model is an attempt to account for some of the individual complexity, it is to be expected that a large degree of unexplained variance will remain.

Oyserman's framework tracks a process from assessing psychological relevance, to interpretation of difficulty and finally actions taken, (Oyserman, 2015). It was developed for generic use rather than mathematics domain specific use; however, it can be adapted as follows:

Figure 3.1

Framework for Understanding Individual Change in Mathematics Interactions Based on IBM (based on Oyserman, 2015).



In this model (Figure 3.1), the action of engaging with strategies will only occur if these actions are congruent with the current or future self-identity and with interpretation of difficulty. This resonates with previous expectancy value theory of "utility". Utility value refers to internal regulation based on the usefulness of a current behaviour to future goals (Eccles &

Wingfield, 2002). In my model, the relationship between psychological relevance and interpretation of difficulty is reciprocal. The key step relevant to my intervention is the interpretation of difficulty. In both mindset theory and IBM, re-interpretation of the meaning of a challenge is critical. IBM focuses on the re-interpretation of physiological arousal or stress as an indication that the body is readying for a challenge. Mindset interventions focus on the re-interpretation of difficulty as an indication of opportunity to grow new neural pathways.

A Theory of Change (TOC) adds to the understanding of individual change by specifying how the change happens. The program intervention or campaign should be planned to align with the expected mechanisms of change (Rogers, 2014). Both process indicators and outcome indicators are important. Process indicators measure the expected mechanism of change and outcome indicators measure results. Within the TOC framework, the process is iterative. The model is built using research findings combined with personal experience of the target population, including the barriers and opportunities they may experience (Rogers, 2014).

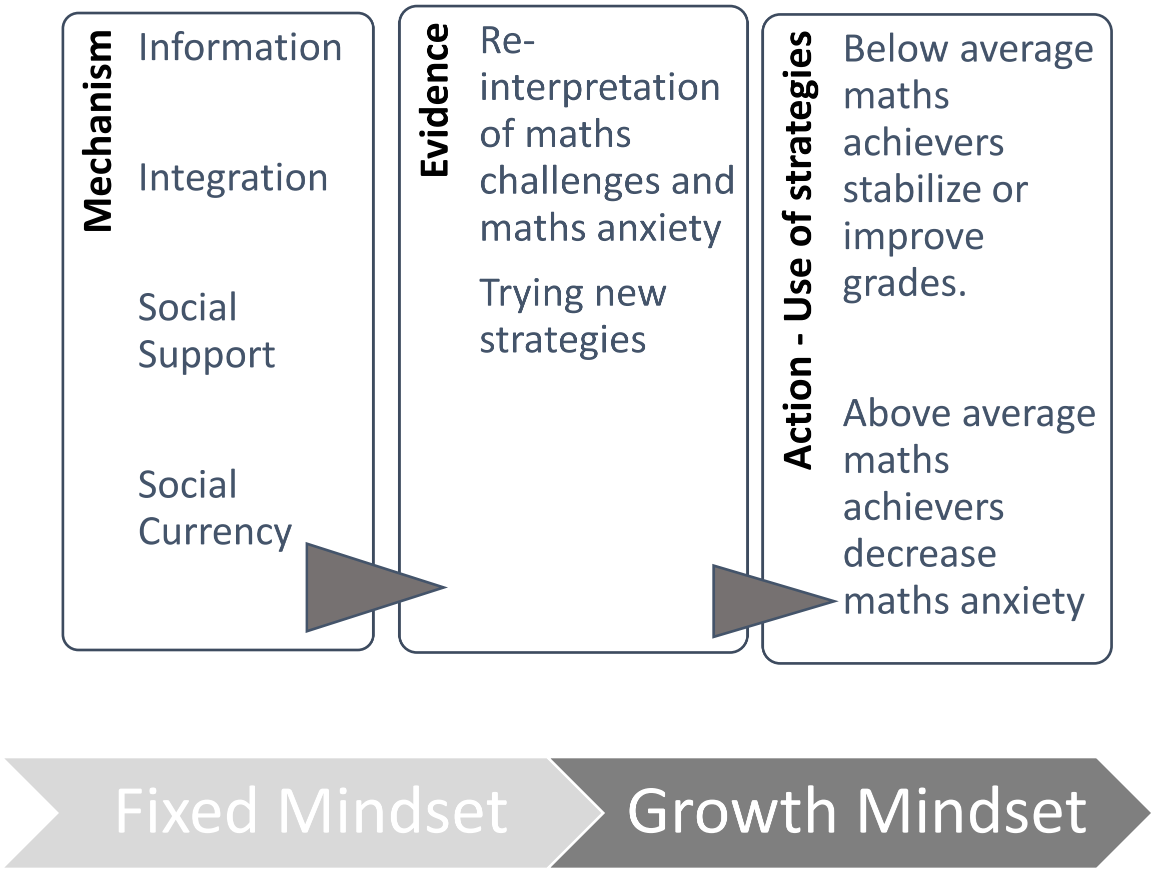
Previous growth mindset research shows that the group most likely to benefit academically from a broadly targeted intervention are the low achievers with fixed mindsets (Cohen, et al., 2006). Following a successful intervention under normal schooling conditions, this group can be expected to stabilize a declining trajectory or move to a positive trajectory, (Yeager, Romero, Paunesku, Hulleman, Schneider, Hinojosa, ... & Dweck, 2016). As mathematics anxiety has a reciprocal relationship with mathematics performance, (Foley et al., 2017) it is expected that mathematics anxiety will decrease if mathematics performance is stabilized.

A second group of interest are the high performers with fixed mindset. Previous research has shown that mindset changes do not reap the same benefits in performance for high achievers as they do for low achievers (Cohen et al., 2006). However, as this study is also considering mathematics anxiety, I hypothesise that high achievers who change mindset may also benefit from a reduction in mathematics anxiety. Although there will be no obvious immediate effect, other researchers have suggested the possibility that a growth mindset plus reduced mathematics anxiety may lead to future willingness to engage with more challenging mathematics concepts or better mental health outcomes (Costa & Farier, 2018). Whilst this study will not track that long term possibility, it addressed the relationship between mathematics anxiety and mindset.

How does change happen for fixed mindset students? Study 4, Chapter 7, describes a Mathematics Mindset Intervention. In this study, the vehicle of change is the Social Network Service (SNS), WhatsApp. The mechanisms of change illustrated in Figure 3.2 are information, integration, social support, and social currency.

Figure 3.2

Theory of Change for a WhatsApp based Mathematics Mindset Intervention



Information is delivered over four weeks in the form of short neuro-biology lessons on WhatsApp, brief supporting videos and descriptions of strategies to promote students engaging with mathematics. Integration of information is encouraged via WhatsApp conversations, inviting students to witness and engage in conversation about mindsets. The engagements invite personal application. Whilst it is not expected that every student will contribute to the conversation, it is expected that most students will read the conversation messages. Information plus integration tasks are the standard formation of social psychology interventions (Cohen et al., 2006). Social support theory prompts participants to encourage one another (Cohen & Wills, 1985) Levels of engagement are associated with the success of programs built on SNS (Yang, 2017). Social support is modelled by group mentors who are active on the group for 30 minutes per day over the 16 days of the program. Finally, social currency refers to the number of times the promoted ideas get mentioned both on the WhatsApp group and off the group. The more social currency the ideas get, the more likely it is that the group will implement them (Wendel, 2020).

Table 3.2

TOC Assumptions and Associated Risks.

Assumption	Risk	Result
1.Dose of information and integration is sufficient	Dose is incorrect - too little or dose or too high	If too little – no change If too high – no change psychological barriers result with students rejecting the message
2.There will be students in the sample group who have fixed mindsets and below average mathematics performance resulting in a "can't do mathematics" identity	The intervention target school is a mathematics and science focused school with selective intake. It is possible that successful mathematics identity is already ingrained in the school culture.	The intervention is irrelevant.
3.Brief strategy prompts will be sufficient for students to engage with new strategies	Strategy prompts will not be sufficient.	Specific teaching and support will be required to successfully modify behaviour. This detracts from the simplicity of this brief social intervention, increases cost and decreases scalability.
4.Mathematics assessments will have internal consistency	Mathematics assessments may be inconsistent due to different teachers setting and marking the work and/or difficulties with teaching during	The dependent variable cannot be reliably measured, undermining the study.

	the 2020-2021 Corona Virus pandemic.	
5.The relationship between high mathematics achievement, low mathematics anxiety and growth mindsets is correct.	The relationship between variables is different to expectation.	The validity of this study is questioned.
6.The effect of confounding variables is minimized.	The relationship between dependent and independent variables is confounded by uncontrolled variables.	The reliability of the study is questioned.
7.WhatsApp will be an appropriate method for delivery of a social psychology intervention.	The intervention will be compromised by an insufficient method of delivery.	The intervention will be unsuccessful.
8.WhatsApp group will be a safe and supportive chat mechanism	Students negatively associate the group with school performance	Students do not share openly affecting the mechanisms of integration, social support and social currency

Theories of Change have underlying assumptions. Examining these as well as the more visible variables helps to identify possible errors in the model. Assumptions and risks are described in Table 3.2. Establishing a Theory of Change is an iterative process, so identifying failed assumptions assists with building strength in the model. This resonates with one of the ideas in Vygotsky's Social Constructivism, where building useful knowledge structures requires interaction with shared experiences (Vygotsky, 1978).

Some risks were mitigated in the preparation for Study 4. That the concept of mathematics mindsets is relevant to South Africans was established in Study 1. The wording of mathematics mindset assessments was modified via an iterative process with groups of students in Study 1. Correlations between mathematics mindsets and mathematics performance were established in Study 2, establishing validity for the revised mindset assessment tool. Teachers and students engaged as consultants in the development of content for the intervention and in recommendations for delivery of the content in Study 3. Whilst risks remain, transparency about these risks adds integrity to this study. In some cases, the results of incorrect assumptions can add knowledge to our understanding of brief social psychology interventions. To my knowledge, this is the first brief social psychology intervention to be offered via WhatsApp. If it is successful, it offers the possibility for cheap and fast roll-out with a broad user base. However, even if this study does not show statistically significant results, it will add knowledge to the field by evaluating social media as a delivery method for psychological interventions.

To date, and to the best of my knowledge, there has been no systematic exploration of the validity of U.S. based mindset construct and assessment in South Africa. South Africa has a very different socio-economic and educational context to the United States. There needs to be careful identification of South African youth beliefs about mathematics. Can South Africans learn from the mindset theory and interventions developed in the U.S. to narrow South Africa's own achievement gap? In this research I identify the key mathematics mindsets affecting underprivileged South African teenagers. I adapt a set of mindset assessment questions for use in South Africa and test the tool on my target group. Finally, I develop a contextually appropriate and relevant intervention, based on the existing body of research and in consultation with teachers and students, and test it experimentally in a field-based experimental intervention with high school students.

This chapter reviewed the social and educational context of learning in South Africa. The majority of underprivileged youth live in areas with underperforming schools and hence they also tend to underachieve. Whilst there has been a plethora of research in South Africa about what is wrong with these youth, their communities and schools, very little research has focused on how these young people might succeed academically, against the odds. Yet, some of these youth do succeed. A deeper understanding of the factors contributing to academic resilience could help identify ways to improve outcomes in these difficult contexts. The promotion of growth mindset theory and helping young people reinterpret difficulty in a favorable light may be one of the ways that outcomes can be improved. I introduced a model of change based on Oyserman's (2015) Identity Based Motivation for individuals and Theory of Change as outlined by Darnton (2008) for explaining change in group behaviour. I explored some of the assumption risks in my model and outlined how I mitigated for these in the design of my research.

CHAPTER 4 - STUDY 1, 2019

Introduction

Researchers have found that young people engage with mathematics through a mediating set of beliefs or mindsets (Dweck, 2000; Dweck 2014; Elliott & Dweck, 1988; Yeager & Dweck, 2012). In Study 1, I aimed to assess whether disadvantaged South African youth described the mindsets or stereotype threat as described in literature from the United States. Research from the United States has focused on mathematics mindsets to do with (mathematics) intelligence beliefs and beliefs leading to stereotype threat. Mathematics intelligence beliefs are lay beliefs attributing meaning to the experience of mathematics challenge. Beliefs are categorized as 'fixed' if the person believes that there is nothing that they can do to change their intelligence, or 'growth' if the person believes that they can change their intelligence. Similarly, beliefs leading to stereotype threat are categorized as fixed if the person believes that people don't change their perceptions of others and growth if the person believes that people do change their perceptions of others.

The second aim of this study was to develop a mathematics mindset continuum assessment tool for use in South Africa, containing words and syntax that youth participants have a shared understanding for. There is a growing movement in the fields of teaching and educational research to encourage critical reflection on the "white supremacy and colour-blindness" of classroom practices and academic motivation theory and practices (Usher, 2018; Gray, Hope & Matthews, 2018, p.139). In South Africa, I have observed the practice of taking ideas and programs developed in mainly White and privileged contexts and applying these directly into mainly Black and underprivileged classrooms. At the time that I began my research, in 2019, the Western Cape Provincial Department of Education was launching the "Transform to Perform" strategy, which incorporated a Growth Mindset Program. They planned roll-out to all Western Cape classrooms without establishing validity of the concept or intervention, rather relying on the U.S. based reputation and a small pilot study, (B. Shreuder, personal communication, 4 February, 2019).

Kumar, Zusho and Bondie (2018) recommend Culturally Responsive and Relevant Educational Practices (CRRE). Their framework for enabling meaningful learning states that content should reflect students' cultural diversity, the process of learning should align with cultural modes of learning, and there should be sociocultural congruence between school and home. In the light of the growing awareness of culture and relevance, particularly and recently in classrooms in Cape Town[26], my first study was critically important.

Aim 1 - Assess whether disadvantaged South African high school youth have the same mindsets as described in literature from the United States (Dweck, 2000; Levy, Stroessner & Dweck, 1998; Yeager & Dweck, 2020).

1. Do South African youth understand variation in mathematics performance in terms of mindset beliefs about:
    - Intelligence or
    - Stereotypes?
2. Do they have alternative understandings for variations in mathematics ability that are not indicative of beliefs in fixed and growth mindsets?

Aim 2- Develop a mathematics mindset assessment tool for use in South Africa to identify growth and fixed mindsets in the domain identified by South African youth.

a) How do South African youth understand the questions used in Dweck's (2000) mindset assessment?

b) What adjustments need to be made so that growth and fixed mindset questions are interpreted consistently, across young South African school students?

I completed Study 1 with a co-researcher, Layla Omar.[27]

Ethics & Permissions

Ethics clearance was granted by the University of Cape Town, Department of Psychology, Ethics Review Committee – ref: PSY2018-066, see Appendix A. The Western Cape Department of Education granted research permission for term 1-3 (Jan-Sep) of the school year – ref: 20181121-8975, see Appendix A. Term 4 was excluded as it is traditionally an assessment term with reduced teaching time. The school principals at each participating school also gave permission to research. Permission forms were sent home to parents and

[26] In 2016-2019, Cape Town school protests centred on the issues of insensitive, White dominant, hair, and uniform rules, as well as school language policies. There were concurrent protests at university level about the decolonization of education content and delivery. A further round of school protests in 2020 centered on the experiences of Black students in predominantly White and privileged schools.

[27] Omar, L., (2019). *Stereotype Threat, Gender, and Mathematics Performance in Four Western Cape Schools.* ASCENT Laboratory, Department of Psychology, UCT Thesis.

both the parent and student were asked to give written consent. Parent and student consent was sought at the start of Study 1, incorporating studies 1-3, then at the start of Study 4. Additionally, teachers gave written consent for their participation in Study 3.

Participants

Grade 9 students at four target high schools, were invited to participate in this study, as well as in the follow-up, study 2. At schools one, three and four, the whole grade was invited to participate. At school two, half the grade was invited as the school grade size was double that of the other schools. Permission forms were sent home with students, and parents and students were both asked for consent. The participants for Study 1 were 50 Grade 9 students from four Cape Town high schools, described in Table 4.1. These were selected from a pool of 250 students who returned permission forms. Each school had two focus groups, making eight groups in total.

The intention was to disaggregate the groups into top performers and mixed achievers, according to school assessed mathematics performance. The reason for this disaggregation was based on the hypothesis that high achieving students would be more likely to have growth mindsets, which would have been congruent with previous mindset correlational studies (Blackwell, et al., 2007). Time tabling restrictions and lack of diversity in willing participants meant that we needed to have some flexibility in this planned structure.

Table 4.1

Profiles of Participant Schools[28]

School	2018 Bachelor Pass[29]	2019 Fee Band (per annum fee)
School 1	>80%	R7 500-R10 000
School 2	40-50%	>R3 000
School 3	>80%	R20 000 - R35 000
School 4	40-50%	>R3 000

[28]Information available in the public domain at https://wcedemis.westerncape.gov.za/wced/findaschool.html, http://matricresults.news24.com/2017/province/wc/school

[29] A Bachelor Pass is the highest final school matriculation pass in South Africa; technically allowing a student to go on to study for a bachelor's degree at university level. Students can pass matriculation at lower levels.

As discussed in Chaper 3, *Mathematics Education in South Africa*, poorer families in South Africa are less able to access high quality schooling due to the prohibitive cost (Christie, 2014). For the purposes of this study, cost of schooling will stand as a proxy for family income[30]. The current range of school fees for the province in 2019 was R0 (free) to R90 000 per year. The estimated provincial average cost of school was R6 000 per year. This was calculated based on 2014 data, with an annual 10% inflation on school fees applied (Christie, 2014). In this study, schools are defined as underprivileged if they charge less than R10 000 per year.

Most Cape Town schools are low performing, free schools They do not offer enough diversity to be statistically helpful in teasing out the relationship between mindsets and mathematics performance, though, so they were not included in the sampling.

School one consistently produces top matriculation results with a cost band of R7 500-R10 000. The language of instruction is English although many students speak Afrikaans or isiXhosa as their mother tongue. This school contained predominantly Black African and Coloured students at the time of my study. 13% of students were on scholarship with organisations that select based on inability to pay fees, and on academic strength. The school is a mathematics selective school and has special permission from the Western Cape Education Department to have students write an entrance exam. Most schools are not permitted to select students with entrance exams.

School three also produces strong matriculation results and has a high fee band of R20 000- R35 000, indicating the relative wealth of the attending families. The language of instruction is English although some students speak Afrikaans or isiXhosa as their mother tongue. At the time of study, the school was mixed racially with White, Coloured and other African students but very few Black South Africans. In comparison, the City of Cape Town consists of 39% Black South Africans, 42% Coloured,16% White, 1% Asian or Indian and 2% other (World Population Review, 2021).

Schools two and four are moderate performing, low fee, or free schools. Geographically, poorer areas tend to be racially homogenous, thus students who attend schools in these areas also tend to be racially homogenous. These two schools were included for the purpose of increasing racial diversity in the sample. At school two the language of

[30] Although it is noted that some low-income students attend at schools 1 or 3 with a bursary.

instruction is English and isiXhosa, with isiXhosa being the predominant mother tongue. At school four the language of instruction is English however the mother tongue of students is predominantly Afrikaans.

Design

The study gathered data through two sessions of semi-structured discussions. Most discussions were conducted in English but one had an isiXhosa translator. Eight focus groups met at schools for session 1 and seven for session 2. One group did not participate in session 2 due to school timetabling constraints. Participants were told that the research was about stress and mathematics achievement, and that participation was voluntary. The focus group discussions were up to 60 minutes long. The first session was audio-recorded on a Zoom Handy H2 recorder, then transcribed by the present author, and the co-researcher. The transcribers also took notes during the sessions. In the second session participants gave feedback on paper and this was collated quantitatively, counting incidents in which students reported not understanding a particular word or question

There are acknowledged difficulties with collecting reliable information via a group discussion. These include response bias and social desirability demands (Furnham, 1986). The problem of response-bias was reduced as far as possible by remaining aware of the issues both in the discussions and in the analysis of the discussions.

My own positionality in the research may have affected participant responses and my own interpretation of the responses (Usher, 2018). I am a White Australian. My participants are almost all young people of colour, born in South Africa. Being White in South Africa is deeply connected to both apartheid history and current privilege. As an Australian, I am somewhat able to position myself outside of the South African social system, likely avoiding some of the issues to do with the history of being White in South Africa. However, it is acknowledged that complete neutrality is impossible and although I am not a White South African, I am certainly privileged in my education and current income. Response-bias and social-desirability demands are not only dictated by my presence in the room, but also by the individuals in the group itself. The discussions were framed carefully as an exploration into what young people think about mathematics. We agreed at the beginning to value diverse opinions and speak respectfully, and we also assured students that the group discussion was confidential, particularly that we would not disclose content to any teachers mentioned in the group.

Session 1

In the first session the groups discussed explanations for mathematics achievement. The design of the discussion was developed by the researcher and unique to this piece of research. At the start of the session each participant was given a numbered "comment card" containing a contrived comment from another student about mathematics performance. The various cards represented both growth and fixed mathematics mindsets, stereotype threat and opportunity threat, as described in Chapter 2 (*Mathematics mindset and mathematics achievement*). The various numbered cards were read out by students as conversation prompts and as a way of deflecting from the possibility of individuals finding direct questioning to be threatening (Morgan, 2000). After the comments were read out, the facilitators asked the matched discussion question shown in Table 4.2. In conversations with students and teachers in Cape Town, the word "maths" is used instead of math or mathematics, in line with local language use conventions.

Table 4.2

Discussion 1 Questions and Comment Cards

Order	Comment Card 1	Comment Card 2	Discussion Question
1	Anyone can be good at maths, you just have to work hard.	Some people are just naturally good at maths.	When you think about someone who is achieving in maths, what explanations do you have for why that person is doing well?*
2	Doing maths makes me feel bad about myself so I avoid it as much as possible.	Maths isn't really important in my life right now and I am not planning a career that needs maths.	When you think about someone who is not achieving in maths, what explanations do you have for why that person is not doing well? *
3	My teacher expects me to do well in maths and is disappointed if I don't.	My maths teacher treats some groups of people differently to others, based on race, gender or family income.	Do maths teachers have the same expectations for all students, regardless of gender, race and social class?

4	Our school doesn't expect that everyone will take maths to matric.	I think that students at schools with more money probably get treated differently in maths class to students at my school.	Do you think that teachers at other schools have different expectations for their students' maths achievements?
5	I see a lot of unemployed people in my community. Even those that have jobs, they are not working in maths careers.	If you want to be a doctor, accountant, engineer or scientist then nothing is going to stop you.	Thinking about careers that need maths (science, medicine, engineering, accounting), do you think that everyone has equal opportunity to get into these careers?
6			How important is it for you to improve your maths grades (self-rate out of 10)?
7			What is it that stops your maths improving? *
8	People from poor families, like mine, don't end up with great maths grades.	I don't think we can make excuses about poverty stopping us from achieving.	What resources are available to you if you wanted to improve your maths? (prompt: school, community, family, friends, study strategies)
9			Which of the available resources are you using right now?

*Explore beliefs, actions, resources and environmental enablers and inhibitors.

Analysis: The transcriptions of session one discussions, and accompanying notes, were coded, and analysed thematically using the process described by Braun and Clarke (2006)[31]. The theme schedule and designation of data into those themes was developed and cross checked by both researchers to ensure that subtleties of language were not overlooked and to minimise the effect of personal biases in interpretation of the data.

Session 2

Based on discussion one results, 16 Likert-style self-rating mindset questions were developed. Dweck's set of eight, Implicit Theories of Intelligence questions (2000) were used as a basis and adapted to be "self-theories[32]" and mathematics-domain specific (see Table

[31] Braun and Clarke (2006) describe a six step process. Familiarization with the data; preliminary coding to describe the content; generating themes based on patterns; reviewing themes; defining and naming themes; writing up.

[32] Mindset theories can be self-focused or other focused. An example of self-focused – I believe that I can learn new things but I can't change my basic intelligence. An example of other-focused – I believe that people can learn new things but they can't change their basic intelligence. This is explained in more detail in Chapter 2.

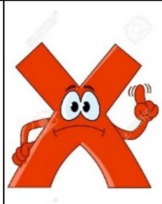
2.1). Mathematics domain was chosen as it is relevant to the specific aims of this study. Jo Boaler's (2015) book offered suggestions for mathematics-domain specific language. Negatively worded questions were avoided as they appeared to be confusing for English second language speakers (Weems, Onwuegbuzie & Collins, 2006). Counterbalance was achieved in the questions by representing both fixed and growth beliefs in positively worded statements. The questions were self-rating Likert style questions, consisting of statements that students agreed or disagreed with on a continuum of six points. This followed the trend for similar mindset assessments using self-rating scales of three or six points, allowing for a middle score of neutral.

An additional set of six questions was added to Dweck's original eight. Additional questions focused on preference for easy or hard mathematics questions and the strategies of asking questions and persevering.

To better facilitate understanding of the rating system, cartoon styled ticks and crosses were used to illustrate as shown in Figure 4.1:

Figure 4.1

Illustration of Rating Scale

Strongly agree	Agree	Mostly agree	Mostly disa-gree	Disagree	Strongly disa-gree
					

This followed the rating scale design used by Porter et al., (2020) in their Cape Town pilot study. Illustrated rating scales have been shown to be more accurate in gaining feedback from people in developing contexts (Laajaj & Macours, 2019).

Students were asked to complete the self-assessment questionnaire with pen and paper at the start of the group session. They were then invited to a participatory activity where they stood on an imagined continuum to show their rating[33]. Students were asked to discuss the

[33] My own practical experience of working in communities with language or literacy barriers led to my modification of

questions and their chosen rating to check that meaning was agreed upon. Students who misunderstood the question had the opportunity to change their rating and include a written comment about the word or concept that was confusing. In addition, I took thorough notes as to how the wording of the confusing question could be improved.

Analysis: Analysis was an iterative process. At the completion of each session, the number of understanding errors were counted per question. I adjusted wording of confusing questions based on recommendations made by students. The newly worded set of questions was presented to the next group and the same process continued through the seven participating groups. An additional two questions were added in iterations 5-7. The additional questions emerged out of participant comments and focused on interpretation of the experience of failure, a key piece of my model as described in Figure 3.1. The original questions, errors recorded and final changes to questions are reported in the results. Final recommendations from group seven were incorporated into the study 2 assessment tool.

Results

Session 1

66 students in 8 groups participated in session 1 discussions which lasted between 40 and 57 minutes. There were 44 females and 22 males (the sex imbalance is likely because many more males had left school 4 by Grade 9). Based on the discussions, five main themes with subthemes were identified, described in Table 4.3. School, achievement level and gender are reflected for individual respondents when reporting their comments. Gender was considered to be important as other studies have found relationships between mindset and performance to vary by gender (Degol, Wang, Zhang & Allerton, 2018; Heyder, Weidinger & Steinmayr, 2021; Huang, Zhang & Hudson, 2019).

rating scales. I learned directly from a community worker about how she gave out rocks and asked people to pick up the number of rocks that showed how important an idea was to them. I adapted this to a game that I often play with teenagers where they can stand on an imaginary rating line to show how much they agree or disagree with an idea. This allows for quick assessment or disaggregation of opinions leading to targeted discussions.

Table 4.3

Identification of Themes and Subthemes from Session 1 Discussions.

Theme	Sub-themes in both high and mixed achievement groups	Sub-themes in high achieving group only
Mathematics Intelligence Themes	Fixed theories Growth theories Stereotypes	Reactions to stereotypes
Expectation Themes	Academic reputation Parent expectation or pressure Social expectations Stress responses	
Future Goals	Relevance to life	
Teacher Themes[34]	Teacher/student demographic con-gruence Teacher communication Teacher qualities	Establishing a learning culture in the classroom
Resource Themes	School resources Poverty Violence	

Mathematics intelligence themes, expectation themes and teacher themes were discussed at length with other themes and ideas receiving less input from the participants.

Mathematics Intelligence Themes

Fixed intelligence (or entity) theories were often expressed with the accompanying ideas that mathematics ability is innate, that not everyone is fast at understanding mathematics, that students felt stupid if they had to ask a question and that they may give up if the question is hard. In the mixed achievement group students added that mathematics is hard, and they don't like it, even if they work hard, they don't achieve.

> "Some people they don't study but they still get high grades… they're just naturally smart." (Male in the mixed achievement group at school 1).

[34] Teacher themes were elicited by specific conversation cards and targeted questions. This formed the basis of research for my co-researcher, Layla Omar, and so I do not discuss these themes in detail.

Students were able to be content with the idea that some people were not good at mathematics by saying that everyone has different abilities.

> "Some people have their own talents… some people are not naturally good at some things. There is people like that so I do believe that some people just have different talents and it's find… you can work on it but you can't be as good as other people." (Female in the high achieving group at School 3).

Growth theories were evident when students discussed strategies for approaching hard questions, acknowledging that practice and hard work were required, and that passion is motivating.

> Researcher: "And when you get a question that you don't know how to do, what's that like then?"
> Student: "Um… I usually put a lot of thought into it and if I still don't get it on the day then I'll probably go and do some research on it." (Female in high achievement group at school 2.)

Practice and hard work were both noted as strategies to improve mathematics.

> "I just think if you practice more at mathematics, you'll be good there's no such thing as not good." (Female in high achievement group at school 4).

There was sufficient discussion of both fixed and growth mathematics mindsets for the researchers to be able to identity mathematics intelligence mindsets as being present in South African youth.

Race, gender and background stereotypes were also introduced as discussion points, however students had mixed beliefs about these, and the conversation was less informative than the conversation about intelligence beliefs. Whilst there was substantial discussion of reasons why people might struggle with mathematics, students did not reveal any new mathematics mindsets and did not confirm the idea that opportunity-threat (the lack of realistic opportunity) might be demotivating, as hypothesised in Chapters 2 and 3. This led to the identification of mathematics intelligence beliefs as being the most relevant to participants.

Expectation Themes

Young people listed expectations as one of the influencers on student performance. The academic reputation of the school feeds parent expectations of performance, leading to what some students experienced as unachievable performance targets.

> "My mother's really, like I go to an expensive school, and I must get high grades because she put me in a school to get high grades. I don't think it's right. Like it's the way I learn." (Male in mixed achievement group, School 3).

Students also talked about their own individual academic reputation and how difficult it can be when performance declines.

> "Maybe sometimes because you have achieved great in the past so they (parents) think ok that you are capable of achieving that again ma'am, you see ma'am, so now they expect you to be able to know, find out where you went wrong and be able to now bring that achievements back, Ma'am, but it's not as easy as they think it is... you doing bad now but you used to do good so you can do good again… but it isn't actually like that." (Male, School 1, mixed achievement group).

Parental expectations or pressure can be motivating but it can also be demotivating. Some students experienced that their parents could bring students down with criticism and expectations of failure. They particularly mentioned that they disliked comparisons to siblings or cousins.

> "Like some parents would be derogative about like you doing bad they would skel[35] you out, whereas other parents would motivate you like, like they would understand that you did bad and that like try to help you, I can do better. But that other parents would keep going on about the fact that you did bad and keeping bringing it up in even like the worst in like different scenarios they like bring up the fact that it is bad and it keeps breaking you down because now everything you think about is the fact that you did bad." (Male, School 1, mixed achievement group)

[35] Slang indicating that parents would shout, lecture or otherwise criticise.

Future Goals

Future career goals that require mathematics were motivating for student performance, although some students noted the problem of having a mismatched goal with high expectations but poor performance.

> "Like um um, um, I am thinking of being a doctor, becoming a doctor or a pharmacist but now I need pure math for it. Now I'm good in biology and science and… all that but then I see that you need to do maths to also pass matric but now, but now I'm also struggling; so that's kind of a downfall." (Male, School 3, mixed achievement group).

Female students, particularly, spoke about being motivated to achieve at mathematics, believing that mathematics is integral to life. They noted the association between mathematics achievement, university entrance and future jobs. Female students at School 2 saw mathematics as a pathway out of poverty. A female student at School 4 said "Everything has to do with maths".

When asked why someone might not be achieving at mathematics, students said:

> "Because they don't really care and how it make an influence in your future… it can, it can help you get more chances than other people that don't try…but I think math is very important because at the end of the day if you do it you get a lot of job opportunities… it's easier for you to get accepted into university". (Female, School 3, high achievement group).

> "Cos some of the children at this school are not focused on the future." (Female School 4, high achievement group).

Even some respondents with non-mathematics career goals acknowledged that career paths are uncertain and may shift to something requiring mathematics in the future. This kept them motivated to keep achieving at mathematics.

Students in the mixed-achievement group had mixed opinions about pursuing mathematics. "You don't need maths for everything in your life", female at School 1.

> "I feel like certain people have certain um strengths whereas me, I'm a practical person, I like doing stuff with my hands, I don't mean writing (group laughter) but drawing and stuff like that so when it comes to maths I feel like, why should I do this if I'm not going to use it?" (Female, School 3).

Other themes

Many students expressed confusion about algebra and seemed unable to grasp the reason why letters had turned up in mathematics.

Students talked with great energy about their views on what makes a good teacher. There was general agreement that a good teacher could convey passion for a subject. Good teachers would form a connection with their students and would be able to explain things so that students could understand. Good teachers allowed students to work together and ask questions. Students acknowledged that higher fee schools were in a better position to attract good teachers, leaving students at lower fee schools with less qualified, less experienced, and less able teachers. Additional family resources could also be used for after school tutoring, ensuring that any learning deficits could be remediated. At school 4, students reported that the mathematics textbooks were locked in a cabinet in the back of the classroom and never handed out in case the books became damaged or lost.

Poverty and violence were discussed at length, particularly at school 4. Students talked about problems at home and in their communities, and how this impacts ability to concentrate in the classroom or motivation to study at home.

> "Maybe some people are like being abused like you go home you do something wrong like you being abused like you don't have that time with that energy to just like just sit and open your books you just wanna[36] say that I just wanna go let's just tomorrow comes and then the next day you'll say the same thing, the next day because you're being abused every single day maybe verbally physically…" (Female, School 4, High achieving group)

Session 2

Seven groups of students, in four schools, completed the session 2 mathematics mindset questions and discussed their meanings. Fifty students participated in total. Students were invited to comment on words that they found hard to understand, words in multiple questions that had similar or different meanings, and questions that they had misunderstood. After each group, changes were made to the questions so that it became an iterative review process with a different group of students involved in each review. Table 4.4 shows the original question,

[36] Meaning "want to"

the final revised question, and the total number of errors of understanding made by students in the development of the final question.

The first eight questions come from Dweck's (2000) original mindset questions with a focus on theories about the self as opposed to theories about others. I developed the second set of eight questions based on Dweck's 'strategies of growth mindset theorists', which were also discussed by students in round one of discussions: hard work, perseverance, embracing failure and asking questions ("Two Mindsets" infographic[37]). A fifth strategy listed by Dweck (2000), 'being inspired by the success of others', was not discussed by students in the first session and so not included in second session questions as the intention was to select questions that were relevant to students in Cape Town.

Table 4:4

Presentation, Adaption and Errors of Understanding on Mindset Assessment Questions.

	Original question	Final Revised question	Total Errors (n=50)
1	I don't think I personally can do much to increase my maths[38] intelligence.	I can't do much to increase my maths performance.	12
2	I believe I can always make big improvements on my maths understanding.	I believe I can always make big improvements on my maths.	0
3	I can learn new things but I don't have the ability to change how smart I am at maths.	I can learn new things but I don't have the ability to change how smart I am at maths.	0
4	With enough time and effort I think I could significantly improve my maths intelligence level.	With enough time and effort I think I could significantly improve my maths.	5
5	To be honest, I don't really think I can change how clever I am at maths	I don't think I can change how clever I am at maths	9
6	I think I have the capacity to change my maths cleverness quite a bit, from where I am now.	I think I have the capacity to improve my maths cleverness quite a bit.	3

[37] https://fs.blog/carol-dweck-mindset/

[38] As noted above, the use of the word "maths" to denote math or mathematics is in line with local language-use conventions.

7	My maths understanding is something about me that I personally can't change very much.	I can't change my maths performance very much.	11
8	I believe I have the ability to change how maths smart I am, over time.	I believe I have the ability to increase how maths smart I am, over time.	1
9	I like doing easy maths questions because it makes me feel clever.	I like doing maths questions I easily understand because it makes me feel clever.	2
10	I don't like asking questions in maths class because it makes me feel stupid or slow.	I don't like asking others questions about maths because it makes me feel stupid or slow.	1
11	When I find something in maths that I don't understand, I work at it until I get it right.	When I find something in maths that I don't understand, I don't give up until I do understand.	1
12	I like hard maths questions because they challenge me and make me learn.	I like hard maths questions because they challenge me and make me learn.	0
13	I always like to ask my maths teacher questions.	When a maths teacher asks if anyone has questions I am willing to ask.	3
14	To be honest, I could work harder at maths but there are other things I'd rather do.	I could work harder at maths but there always are other things I'd rather do.	6
15	I am not discouraged by mistakes in maths.	I am discouraged by mistakes in maths.	3 *
16	When I get a bad mark on a maths test I find it hard to keep trying to achieve.	When I get a bad mark on a maths test I find it easy to keep trying to achieve.	1 *

*Questions15 and 16 were only presented to the last three discussion groups after the topic of interpretation of failure was raised in discussions by previous groups.

Many students viewed the word "understanding" as meaning something different to "intelligence", "mathematics cleverness" and "smart at mathematics". Understanding was described as something that was fluid for all students, even by participants who tended towards fixed mindset theories. Due to this ambiguity, "understanding" was replaced with "mathematics" or "mathematics performance" at the end of Study 1.

As predicted by local field work discussed above, problems emerged with the word "intelligence", with School 4 students generally feeling that they did not know what it meant.

It was replaced with mathematics or mathematics performance at the end of Study 1 and this language carried through to the mindset question set for Study 2.

There were problems with complex phrases such as “I don’t think I personally”, in the original version of question 1. These additional phrases were deleted during group iterations one to four.

There were problems with sentences that put a negative in the second phrase. These were adjusted so negatives appeared at the start of the sentence. There was also a problem with the double negative “not discouraged” in q15 and this was adjusted at the end of Study 1 with the new wording carrying through to Study 2.

Most wording adjustments were made between iterations one to four. In the final three groups the questions were not modified, however, questions 1, 4 and 15 were still misinterpreted by more than one student. The adjustments to these questions, in the table above, were made after the completion of Study 1 and carried through to Study 2.

The various iterations of the questions were answered on a six-point Likert-like scale. The per-student means for the question set ranged from 3.9 to 5.4, based on participants’ revised understandings if they indicated that there was an error in understanding, but not if the revision occurred after peer views were expressed. The standard deviations ranged from 0.8 to 1.7. Dweck’s original marking scale indicates that an average score of 1-2 is the fixed mindset range, 3-4 is the mixed mindset range and 5-6 is the growth mindset range (Dweck, 2000). It is clear from these preliminary findings that almost no students in this study would be classified with a fixed mindset according to the original classification. It should be noted, however, that this was an exploratory study, with a small number of participants and inconsistent questioning between groups. Additionally, the mindset continuum cannot be applied homogenously, and local interpretation of scale meaning is required.

There were five students in the study with mathematics grades under 6%. They are clearly outliers with the next lowest scores being 22, 28 and 34%. Even with an isiXhosa translator (in line with the students’ home language), understanding in this group was poor. Whilst they were happy to be in the group and welcoming of the researchers, they had little to contribute. The presence of extremely low performers would have had implications for data analysis in later studies. If some participants are unable to complete any of the grade level mathematics, then they are also unlikely to be able to reflect on their thoughts about mathematics. I therefore decided to exclude students with mathematics grades under 20% from all future research.

Discussion

The first aim of Study 1 was to establish whether mathematics mindsets existed in South Africa, and if so, if they were related to intelligence theories, stereotypes, or some other mindset construct, possibly opportunity-threat. This was achieved by discussing mindset theories with students and thematically coding their answers. Mathematics mindset themes emerged in the discussions on mathematics achievement, and I found that the construct did exist in South Africa. On the other hand, students had either not noticed mathematics stereotypes or had resisted them. Students mentioned other inhibiting or helping factors regarding mathematics performance. These included parent and school expectations, teacher interactions and the effect of poverty and violence on readiness to learn. All these factors may contribute to variation in academic achievement not explained by mathematics mindsets. No other mindset constructs were revealed. Female students talked about the importance of mathematics to everyday life and future goals.

The second aim of the study was to establish a shared understanding of potential mindset assessment questions. Discussion two presented statements expressing maths intelligence beliefs. The wording of the statements for discussion two was shaped by language used by students in discussion one, as well as existing mindset questions. Seven iterations of the mindset statements led to the development of a set of 16 statements that South African students generally agreed on the meaning of. Both understanding of particular words and overall syntax were considered. The final iteration of questions took into consideration that many participants are English second language speakers and considered local conventions in the use and understanding of language.

All statistical analysis in this exploratory study can only be taken as an indication of things to explore in future studies, due to the small sample size. I found higher-than-expected mindset scores, however, there may have been demand characteristics involved with discussions in a small group of students who were asked to disclose their understanding. The relative anonymity of an electronic questionnaire in a larger group may improve honesty (and hence one might see greater variation in responses), as was planned for Study 2. However, it can also be noted that other countries have also had different distribution patterns to the

United States (Boaler, 2013) and it may turn out that the distance from the overall mean is more important than the raw score. Yeager and Dweck (2020) state that mindset is best understood as a continuum, and as such, the actual scores obtained are less important than where individual scores fall in relationship to peers. For example, in a culture that expresses a strong narrative of hard work, the mindset mean might be further towards a growth mindset than another culture where there is a narrative of 'taking it easy'. In either culture, there will still be variation along the continuum.

The mindset questions generated included beliefs, goal orientation and engagement with the strategies of asking questions and persevering. In South Africa there is often a substantial gap between what students believe and what they do. This gap is generated by community narratives which value hard work and educational achievement as the pathway out of poverty (Morse, 2019). Students believe these narratives; however, they do not necessarily engage with the behaviours leading from these beliefs. Whilst the gap between belief and action is observable in other countries and contexts (see for example Grandin, Boon-Falleur, Chevallier on the failure of people to apply their environmental beliefs to congruent actions), it seems to be amplified in South Africa. This is rooted in apartheid history and the freedom struggle in which there was a social transition from legally mandated deprivation of access to opportunity to a removal of legal restrictions and a conscious social messaging of "you can be anything" (Morse, 2019). This message continues to be spoken and belief in this message is reinforced by the extreme Gini coefficient[39]. People who live in poverty see tantalizing wealth and opportunity close at hand.

This gap between belief and action may result in students expressing a growth mindset but not achieving the expected results due to a poor application of strategies. This is important information to consider analysing Study 2, the correlational study and in designing the intervention, Study 3. To be successful, the intervention must explain specific strategies and give students the impetus to attempt the actions that might lead to change in their mathematics performance.

[39] A measurement of income disparity used by the World Bank. South Africa ranks first as the most unequal country, last measured in 2014. https://worldpopulationreview.com/country-rankings/gini-coefficient-by-country

CHAPTER 5- STUDY 2, 2019

Introduction

Mathematics mindsets fall on a continuum between fixed and growth beliefs. At the fixed end of the continuum individuals tend to believe that poor mathematics results are due to inherited factors outside of their control. They believe that you are either born mathematics able or not. They interpret difficulty as a sign that they have reached the end of their abilities and should move their focus to something else. At the growth end of the continuum individuals tend to believe that poor mathematics results are due to factors within their control such as amount of effort and choice of strategies. They interpret difficulty as a sign that the problem is worth their increased effort, and they embrace the opportunity to learn.

The mathematics mindset continuum is not manifest in the same way across different countries or even between contexts within countries. Dweck argues that her research shows that in the United States 40% of students have a growth mindset, 40% have a fixed mindset, and 20% a mixed mindset (Dweck, 2006). In a study of students in China and Finland the majority of students were found to have a growth mindset (Zhang, 2020). These countries were selected for the study due to their success in the Programme for International Student Assessment (OECD, 2019) and are viewed as "effort-oriented" cultures (Dweck, 2000). Streaming classes based on ability contributes to fixed mindset beliefs (Boaler, 2013), however, most South African schools do not stream classes based on ability. Additionally, Study 1 showed that the concept of "intelligence" is not well developed in South Africa, indicating that South Africans may be less inclined to have had experiences of being categorised as intelligent or not intelligent. Mindset scores in Study 1 tended to be higher than those seen in the U.S. In Study 2, I therefore hypothesise that students in my studies i.e., South African students, will have beliefs more congruent with growth mindsets.

Similarly, whilst mathematics mindset does predict mathematics achievement in many studies, it is not homogenous. Claro, et al., (2016) reported a nationwide study of students in Chile. They found that a growth mindset was a strong predictor of achievement across all socio-economic groups and was particularly advantageous for students in the lowest 10^{th} income percentile, buffering the effect of poverty on achievement. Mindset predicted mathematics achievement in Chile at $r = 0.29$ (unconditional Pearson correlations between mindset and standardized mathematics test scores). In the United States, Blackwell, et al., (2007) followed 373 students across the transition from junior to middle school. At the time of transition students had comparable mathematics grades but diverse mindsets. As the year progressed, and students faced new challenges, grades declined for those with fixed mindsets whilst grades increased for those with growth mindsets. The correlation between mindset and mathematics achievement one year later was r = 0.2. In Kenya, a survey of 1000 high school students found that growth mindset correlated with grades at r = 0.2 (Kizilcec & Goldfarb, 2019). In China however, which I noted above as having a culture of growth mindset, the correlation between mindset and grades was non-significant in one study (Li & Bates, 2019). Li and Bates explain that in China extra classes are taken by most students and hard work is expected of all (2019). As such, the researchers hypothesise that change in mindset doesn't lead to any behaviour or strategy changes, as helpful strategies are already being employed.

Study 2 was a correlational study using the mindset assessment developed in Study 1. The primary aim was to establish face validity for the assessment tool by showing that it correlates with academic performance. Based on research discussed above, I hypothesised that mindset would correlate with mathematics performance at r = 0.2 (Blackwell et al., 2007; Claro et al., 2016; Kizilcec & Goldfarb, 2019). Whilst South Africa does have a culture of valuing hard work, which is consistent with the "effort-oriented" cultures cited above, lack of resources, a rigid and exam-based teaching system, and poor implementation of learning strategies mean that there will likely be disparity in achievement between those with fixed and growth mindsets.

It was not within the scope of our resources to draw a nationally representative random sample. The tool development and intended use of the tool is with disadvantaged students. This is the socio-economic group of students in South Africa most likely to struggle with mathematics performance and hence most likely to benefit from an intervention (Blackwell et al., 2007; Christie, 2014; Spaull & Kotze, 2015). Hence the study targets the intended user group.

A secondary aim was to refine the adjusted mindset assessment tool by removing poorly fitting and less powerful items using factor analysis and item analysis. The intention was to create the briefest scale possible to assist in rapid administration in future research and school-based application.

Finally, I aimed to explore the relationship between mathematics mindsets, mathematics performance, mathematics anxiety, mathematics study attitude and study milieu as measured on the Study Orientation to Mathematics (SOM) (Maree et al., 1998). The SOM was developed in South Africa and standardised on a population sample of Grade 8 -11 students in high school, including African-language speakers who answered the questionnaire in English, English speakers who answered in English, and Afrikaans speakers who answered in Afrikaans. Stratified sampling ensured that Education Departments, medium of instruction and urban/rural areas were represented. The mathematics anxiety scale consists of 14 items related to the physical and cognitive experience of anxiety, such as 'sweaty palms' or 'foggy thinking'. The mathematics study attitude scale consists of 14 items related to how important students believe mathematics to be and how likely they are to prioritise time spent on mathematics. The study milieu scale consists of 12 items related to home and school environment as well as physical and cognitive deficits that might be detrimental to learning, such as inability to see the board or unfamiliarity with mathematics terms. In effect, study milieu is a control variable for socio-economic-status.

I hypothesised that mathematics performance would be influenced by a combination of these variables- mathematics mindsets, mathematics anxiety, study attitude and study milieu. Additionally, I hypothesised that there would be a positive correlation between fixed mindsets and mathematics anxiety. When faced with a mathematics challenge, a person with a fixed mindset would believe that there is nothing they could do to change the outcome of the challenge, leading to increased anxiety. The increased anxiety would impair mathematics performance by reducing working memory capacity (Beilock, et al., 2017), thus fulfilling the belief that the person has reached the limit of their innate mathematics abilities.

Participants

Table 5.1

Participant gender by school

	School 1 Claremont	**School 2 Chris Hani**	**School 3 Bergvliet**	**School 4 Heathfield**	**Total**
Fee Band	R5 000-R10 000	>R3 000	R20 000-R30 000	>R3 000	
Male	22	3	32	20	77
Female	27	46	28	21	122
Total	49	49	60	41	199

Participants were Grade 9 students from four Cape Town high schools. Participants were recruited at the same time as Study 1 participants and all 250 students with completed permission forms were invited to participate. On the school test dates, 201 sets of data were collected; however, two students chose to withdraw, leaving a sample of 199. Of these a further three had missing data and could not be included in all the following analyses. The four school profiles are described fully in Chapter 4. Table 5.1 shows the distribution of participants across schools. As for Study 1, there are a low number of male participants at school 2 due to the overall low number of males in the grade.

Design

I completed this study with a co-researcher, Layla Omar. The research took place in mid-2019 with Grade 9 students. End of Grade 8 mathematics results were collected from the schools, as well as mid-Grade 9 results. The mathematics grades were based on internal school assessment. Collection of survey data occurred during the lead up to the Grade 9, mid-year exams. The set of 16 mindset assessment questions developed in Study 1 were used in Study 2 and analysed in two groups, 1-8 (closely based on previous mindset questions) and 9-16 (based on mindset traits identified by Dweck and also discussed by students in Study 1). These questions are listed in Table 4.4.

In addition, students completed the Study Orientation to Mathematics- SOM (full test[40]). The subscales measuring mathematics anxiety, study attitude and study milieu were included in the analysis. Study attitude relates primarily to subject interest and value and was included as a measure of relevance of mathematics to current or future identity. Figure 3.1 explains that viewing mathematics as relevant to the current or future self is theorised to be important to the process of changing mathematics interactions. SOM study milieu -the study environment at home and at school- was included as a control variable related to availability of resources in the physical and emotional study environment. Data was collected for two additional SOM scales but not included for analysis as they were not directly relevant to the model being tested[41].

Questions were completed online in a computer laboratory at school and during school time. The researchers explained the purpose of the research and reiterated that participation was voluntary. The researchers supervised the completion of surveys and assisted where needed. The mindset assessment questions, and the SOM were presented via

[40] Using the full SOM was a requirement of the SOM Publishers, JVR Psychometrics, who offered the use of the full test for free in exchange for sharing results. Even though the full scale was completed, only the selected subscales were analysed in this research. Including the full SOM undoubtedly contributed to survey fatigue and may explain why three students did not complete all the questions.
[41] This was also a requirement of JVR Psychometrics.

two separate links to an online survey. The two sets of questions took an average of 30 minutes to complete with the SOM 76 item test taking the longer amount of time.

In preparation for Study 2, Professor Maree (designer of the SOM) agreed to modify the wording of some items in recognition of the change in language use in the 20 years since it was first developed. The instructions, which were initially complex and wordy, were simplified to accommodate second language English speakers, at my recommendation. JVR Psychometrics designed an online version of the SOM which was previously only paper based. The survey was hosted online on the same platform referred to earlier.

Descriptive statistics and Pearson correlations were computed in STATA, initially with the full sets of questions. Factor loading and item analysis were used to consolidate the mindset scale into a shorter set of mindset questions. The same process was used to interrogate SOM mathematics anxiety items that students had expressed confusion about. The aim was to develop a shorter set of questions with acceptable reliability to expedite testing sessions. I removed items with low standard deviations in this sample (since that may indicate low inter-person differences), items that were not sufficiently different to other items, and items that did not properly fit into their scale subset. Correlation analysis was repeated with the adjusted question sets. Simple and multiple regression analysis was used to identify the respective contributions of variables to mathematics performance.

Results

Descriptive statistics

Table 5.2

Mathematics Results, Grade 9, Term 2 (g9_t2)

	School 1	School 2	School 3	School 4
Mean %	62.00	40.00	48.60	40.50
SD	15.86	16.96	48.68	12.70
Min	25	10	7	11
Max	91	82	90	82
n	49	49	60	41

Mathematics grades at the four schools were distributed differently. School 1 was clearly the strongest performing school, as expected based on historic performance data and the fact that this school selects students based on mathematics performance. Performance was weakest in schools 2 and 4. Weak performance was expected from these schools as they have historically poor performance and are free or low fee, which has historically correlated with poor performance (Christie, 2014). School 3 had a noticeably wide standard deviation of 23.4% in grades. Descriptive statistics for grades are shown in Table 5.2.

SOM results are reported for three of the five SOM subscales – study attitude, mathematics anxiety and study milieu. Based on Maree et al., (1998), study attitude has a possible range of 14 at the first percentile to 54 at the 99th percentile. A high score indicates a positive study attitude. Mean scores were higher in my sample by 14 points for females (SD=11.15), and 11 points for males (SD=9.6). This large difference may be due to my sample attending high performing schools, relative to the mathematics performance of schools with similar school fees, and relative to the performance of schools across the province (Christie, 2014). The differences may also reflect changing trends in attitudes towards the importance of education in general, and mathematics, as well as changes to the value of effort over the last 20 years. 20 years ago, it was only compulsory to study mathematics in South African schools until the end of Grade 9. In 2006 the syllabus changed, and mathematics became compulsory through to the end of Grade 12, although offered at two performance levels (Sidiropoulos, 2008). There was a distinct push from the Department of Education to promote mathematics as valuable, important and for everyone with specific interventions such as those in the so-called 'Dinaladi' schools, meant to boost profile and overall performance, (Parliamentary Monitoring Group, 2011). Change could also be due to gender specific efforts to counter gender stereotypes about math performance. In a concurrent study to this one, my colleague found that gender and mathematics stereotypes do not exist within the sampled population (Omar, 2019). However, as males and females had a similar +14 point difference between normative sample and study sample (Table 5.4), it seems more likely that the first explanation is correct.

Mathematics anxiety had a possible range of 13 at the 1st percentile to 54 at the 99th percentile. A high score indicates low maths anxiety. My sample data was very similar to the normative sample for maths anxiety for both genders. Indeed, it is interesting to note how stable this statistic is over time, refer to Table 5.3.

Study milieu has a possible score range of 15 at the 1st percentile to 50 at the 99th percentile. A high score indicates a good study environment. My sample mean for females and males was 4% higher than the normative sample. This could indicate a real, albeit small, difference between my sample and the normative sample. This would be expected as this sample is at a fee-paying school implying family income that is slightly above average[42]. It could also indicate an improvement in living standards and health since the original study was completed. Overall, the pattern of means between males and females is similar in the original population sample to that in this study, see Table 5.3.

Table 5.3

SOM study normative sample versus study sample, descriptive statistics by gender[43]

		Normative sample[44] n=667		**Study sample n= 122**	
SOM subset		Mean	SD	Mean	SD
Study Attitude	Female	34.22	9.32	48.49	11.15
	Male	35.19	9.32	46.27	9.60
Mathematics Anxiety	Female	35.40	9.52	36.45	9.60
	Male	36.40	9.52	36.42	9.03
Study Milieu	Female	33.86	8.85	37.55	6.72
	Male	33.86	8.85	37.76	7.38

The Mindset Assessment questions were scored on a Likert scale of 1-5. The sample average for the eight questions adapted from Dweck (2000) ranged from 2 to 5, with a mean of 3.9 and a standard deviation of 0.6. The distribution of grades was skewed towards 5, indicating a lean towards growth mindset. When the sample was split by gender the results were similar, see Appendix B, Table B1. The sample average for additional eight questions (9-16) ranged from 1-5 with a mean of 3.3 and a standard deviation of 0.64. The distribution was close to normal with a slight skew towards growth mindset.

Initial correlations on non-adjusted scales

Pearson correlations were computed in STATA. Although my intention was to use item analysis to reduce the scales, making them more usable in a time-constrained school setting, initial analysis on the full scales is important. In the case of the adjusted mindset assessment versions of these questions have a substantial test history and in respect to that,

[42] Most schools in the province are free to accommodate the very lowest (and majority) income earners, as explained in Chapter 4.
[43] The split into male and female follows the reporting offered in the original normative sample (Maree, et al., 1998)
[44] Grades 8 and 9 subsets

running some preliminary analysis seemed prudent. The SOM has been developed and normed in South Africa. Preliminary analysis using all questions in the targeted subsets allowed me to compare my subset to the normative sample. Given that over twenty years have passed since the scale was initially developed, I expected that the wording of some questions would be problematic, and this would result in some items not scaling together within each subset, as expected, and possibly not showing strength in item analysis.

The summed score for the full set of mindset questions correlated with mathematics grades collected in Grade 9, term 2 at $r = 0.22$ at $p < 0.01$, 95% CI [0.09, 0.34][45] in line with previous correlational studies. Additionally, the three SOM subsets, study attitude, mathematics anxiety[46], and study milieu, all correlated significantly with mathematics (see Table 5.3). The strong correlations between the average of mindset items 9-16 and the three SOM subsets indicates that these questions are likely not adding uniqueness to the test battery and this is explored later in the analysis. Mindset 9-16, as a set, does not correlate with mathematics performance, as would be expected from a mindset assessment, indicating that these additional questions likely do not belong to the same construct. The strongest correlation with current mathematics performance is previous mathematics performance, as indicated by the correlation of $r = 0.77$, $p < 0.01$, 95% CI [0.71, 0.83] with grades collected six months prior, in Grade 8, Term 4.

Table 5.3

Correlation of Mathematics, Mindset and SOM subsets before item selection

	Prior Math[47]	**Math**	**Mindset 1-8[48]**	**Mindset 9-16**	**Study Attitude**	**Math Anxiety**
Math	0.77**					
Mindset 1-8	0.26**	0.22*				
Mindset 9-16	0.17*	0.18	0.36**			
Study Attitude	0.22**	0.28**	0.33**	0.66**		
Math Anxiety	0.22**	0.21*	0.34**	0.46**	0.30**	
Study Milieu	0.29**	0.37**	0.29**	0.25**	0.22**	0.61**

[45] Normal distribution-based confidence intervals, with $\alpha = 5\%$
[46] The coding of math anxiety in the SOM attributed high scores as a measure of low anxiety and scoring poorly as a measure of high anxiety. This coding convention is followed throughout the thesis.
[47] Grades collected 6 months prior
[48] Based on the adaption of Dweck's original eight questions (2000)

*p < 0.05 **p < 0.01

Within schools, some correlations that were significant in the full sample were not significant at the level of individual schools. These are reported in Appendix B, Table B2. Most of this difference is likely due to smaller sample sizes within schools, however there may also be differences between schools. The correlation between maths grades in grade 8, term 4 and grade 9, term 2, reveals the consistency of scoring within the school. In other research, prior mathematics performance is the strongest predictor of future performance at around $r = 0.7$ (Hemmings, Grootenboer & Kay, 2011). This makes sense as Mathematics is a cumulative learning subject. At schools 2 and 4 the correlation between prior and current maths performance is lower than expected (school 2, $r = 0.54$, 95% CI [0.75, 0.91] and School 4, $r = 0.59$, CI 95% [0.37, 0.81]), but still significant at $p < 0.01$ with wider confidence intervals than schools 1 and 3 due to wider standard deviation (School 1, $r = 0.83$, 95% CI [0.75, 0.91] and School 3 and $r = 0.92$, 95% CI [0.88, 0.96]).

At school 1 (the high performing, selective school), patterns were similar except that mathematics anxiety did not correlate significantly with study attitude indicating that at this school, some but not all students with high mathematics anxiety have a positive attitude towards the relevance of mathematics. The correlation between growth mindset and mathematics was stronger at $r = 0.29$, $p < 0.05$, 95% CI [0.00, 0.58], $n = 49$. The wider confidence interval in this and the further within school correlations reported below is likely due to the relatively smaller sample size.

At School 2, the low-performing free school, growth mindset correlated non-significantly with mathematics performance at $r = 0.24$, $p = 0.09$, 95% CI [-0.04, 0.53], $n = 49$, however, all other correlations were statistically significant. I expect that the non-significant correlation between growth mindset and performance may have been due to a language barrier. Even though care was taken to construct mindset questions in locally sensitised language, the concept of beliefs about mathematics performance may have been too abstract for English second language speakers. In contrast, the other question sets which did have significant correlations with mathematics performance were focused on concrete actions or physical feelings and experiences which may have been more likely to be consistently understood.

School 3, the high fee, high performance school, had significant correlations between all variables. The correlation between mindset questions and mathematics was $r = 0.26$, $p < 0.05$, 95% CI [0.04, 0.48], $n = 60$.

At school 4, the low fee, low performance school, the pattern of positive correlations was similar but weak. The only significant predictor of mathematics performance was study milieu, and this did not correlate significantly with any other variable except mathematics anxiety, indicating that students with better learning conditions at home and school had less mathematics anxiety. Mindset questions correlated with mathematics at $r = 0.19$, $p = 0.2$, 95% CI [-0.13, 0.51], $n = 41$, which was not significant.

Factor analysis and item analysis

Factor analysis and item analysis were completed on the mindset variables with the purpose of reducing the number of items in the scale. Exploratory principal components factor analysis and a scree plot of eigen values indicated that the mindset items loaded on two factors (factor 1 eigenvalue =3.96, factor 2 eigenvalue = 1.6). The full set of results is reported in Appendix B, Table B3.

Table 5.3

Factor loadings (rotated), uniqueness, and standard deviations for mindset variables

Variable	SD	Factor 1	Factor 2	Uniqueness	Outcome
Mindset_1	0.73	0.55	0.15	0.68	Exclude-SD
Mindset_2	0.77	0.51	0.28	0.66	Exclude-SD
Mindset_3	1.2	0.35	0.49	0.64	Retain – factor 2
Mindset_4	1.3	-0.04	0.78	0.39	Retain – factor 2
Mindset_5	1.2	-0.01	0.75	0.44	Retain – factor 2
Mindset_6	0.6	0.61	0.23	0.57	Exclude-SD
Mindset_7	0.7	0.52	0.37	0.59	Exclude-SD
Mindset_8	1.1	0.29	0.69	0.44	Retain- factor 2
Mindset_9	1.0	0.58	0.07	0.65	Retain – factor 1
Mindset_10	1.1	-0.20	0.04	0.96	Exclude- weak loading
Mindset_11	0.8	0.61	0.03	0.63	Exclude- SD
Mindset_12	1.2	0.53	-0.16	0.69	Retain – factor 1
Mindset_13	1.1	0.39	0.10	0.84	Exclude – weak loading
Mindset_14	3.0	0.42	0.22	0.78	Exclude – weak loading
Mindset_15	1.2	0.64	0.03	0.59	Retain – factor 1
Mindset_16	1.3	0.36	0.10	0.90	Exclude– weak loading

Items were retained if the standard deviation (SD) of the item was >1 (suggesting reasonable variance in participant answers), the factor loading was >0.5 (indicating that it likely belonged to the set of questions). This is reported in Table 5.3. Additionally, I required the scale to have a reliability coefficient (Cronbach alpha) of at least 0.7, indicating good internal consistency, i.e., items are related as a group. Factor loadings are rotated. Full descriptions of items can be found in Table 4.4.

This process reduced the items to four loadings on factor 2 (items 3, 4, 5, & 8 from Dweck's original question set), and three loadings on a factor 1, from items I devised (9, 12, 15.). Whilst the original and additional mindset items are related, they do not belong to the same construct. The reduced mindset scale had a scale reliability coefficient of 0.67. Item analysis with Cronbach's alpha is shown in Table 5.4. Removing mindset_12 improved the scale alpha to 0.7 with five items.

Table 5.4.

Item analysis and Cronbach's alpha for reduced Mindset scale (n=199)

Item	Item-test correlation	Item-rest correlation	Average item correla-tion	Alpha	Outcome
Mindset_3	0.65	0.47	0.29	0.61	Retain
Mindset_4	0.59	0.37	0.30	0.63	Retain
Mindset_5	0.62	0.42	0.29	0.62	Retain
Mindset_8	0.71	0.57	0.28	0.59	Retain
Mindset_9	0.67	0.39	0.32	0.63	Retain
Mindset_12	0.37	0.13	0.39	0.7	Exclude
Mindset_15	0.57	0.34	0.31	0.64	Retain
Test Scale				0.67	

Finally, I checked the correlations between the selected items and the SOM – study attitude scale to ensure that items selected for the new mindset scale were not overly similar to items from the existing SOM scale. The items loading on factor one did correlate significantly with the SOM maths anxiety scale; mindset_9 correlated with SOM_SA at $r=0.46$, $p<0.46$ and mindset_15 correlated with SOM_SA at $r=0.64$, $p<0.01$. I retained only the factor 2 items – 3, 4, 5, 8 and the resulting scale had an alpha of 0.77. The final retained items are in Table 5.5.

Table 5.5

Final Mindset Scale

Item	Wording
Mindset_3	With enough time and effort I think I could significantly improve my maths.
Mindset_4	I can learn new things but I don't have the ability to change how smart I am at maths.
Mindset_5	I believe I have the ability to increase how maths smart I am, over time.
Mindset_8	I don't think I can change how clever I am at maths.

It is 20 years since the SOM was designed. It was possible that the wording was no longer relevant in 2020 or that it didn't make sense for the target population of disadvantaged youth. Factor analysis and screeplot analysis indicated that the SOM_MA subset loaded on one factor, which is consistent with the original analysis (Maree et al., 1998). During administration of the SOM, students asked questions about items 17, 44, 49 and 56. These items are listed in Table 5.6.

Item 17 – some students seemed confused about why they would cross out a right answer. Similarly, Item 44 drew confusion as to why a student would deliberately mismark their work. Item 56 caused the most confusion with many students not understanding the word "perspire". Even when the word "sweat" was given as an explanation, many could not imagine why they would sweat more in one class or another. They had a similar problem with item 49, not understanding why they would go to the toilet more in one class than another. Due to the questions raised on these four items, I investigated them more closely within the context of the full subset. The results are in Table 5.6.

The average interitem correlation was 0.34, and the alpha for the test scale was 0.78. I removed three of the four items that were questioned by students. Items 44, 49 and 56 had poor factor loadings and additionally, the scale alpha was improved by removing them. Item 17 was retained as it had a strong factor loading and the scale alpha would have decreased if it were removed. Scale alpha increased to 0.81 on the reduced set and the scale reliability coefficient and average interitem correlation increased from 0.35 to 0.5. This process resulted in retention of 11 of the 14 items for analysis with this particular sample and for use in future studies with a similar student sample. I planned to use this subset in Study 4.

Table 5.6

Item analysis and Cronbach's Alpha for SOM- Maths Anxiety subset

Variable	Item	SD	Factor 1 (f1)	Alpha
SOM_2	While answering tests or exams in mathematics, I panic.	1.3	0.71	0.75
SOM_7	When I do mathematics in class, I become anxious.	1.3	0.64	0.76
SOM_12	I cannot speak clearly when I suddenly have to answer a question in mathematics class.	1.3	0.64	0.75
SOM_17 (review)	I lose grades in Mathematics tests and exams because I cross out correct answers.	1.2	0.47	0.76
SOM_22	When my friends talk about a sum or way or solving a problem in the mathematics class, I chew on my fingernails, pencil or other object.	1.5	0.37	0.77
SOM_29	I play nervously with my pen, ruler or something else when I have to solve difficult mathematics problems.	1.4	0.58	0.75
SOM_34	I lose grades in mathematics tests or exams because I work too quickly or too slowly.	1.3	0.51	0.76
SOM_39	While writing mathematics tests or exams, I become worried when I see how quickly the other children work whilst I make slow progress because I battle.	1.5	0.62	0.75
SOM_44 (review)	Even though I know that certain sums are incorrect, I mark them correct.	1.2	0.11	0.79
SOM_49 (review)	In the mathematics class, I find that I have to visit the toilet.	0.9	0.27	0.78
SOM_56 (review)	In the mathematics class I find that I perspire more than in other classes.	1.3	-0.05	0.80
SOM_61	I struggle with certain sums because I have not read them carefully.	1.1	0.33	0.78
SOM_66	I move my feet when my mathematics teacher asks me a question.	1.3	0.63	0.76
SOM_71	I am afraid to discuss my personal problems with my mathematics teacher.	1.5	0.35	0.78

There were no questions asked by students regarding the study attitude (SOM_SA) questions. Factor analysis and a scree plot indicated that the SOM_SA subset loaded on one factor, which is consistent with the original analysis (Maree, et al., 1998). SOM_6 had a SD of 0.9 indicating relative conformity of answers which may indicate that this item needs to be reviewed. Some items did not load on the factor at loadings greater than 0.5 and these could possibly be excluded in the development of a shortened scale. These results are reported in

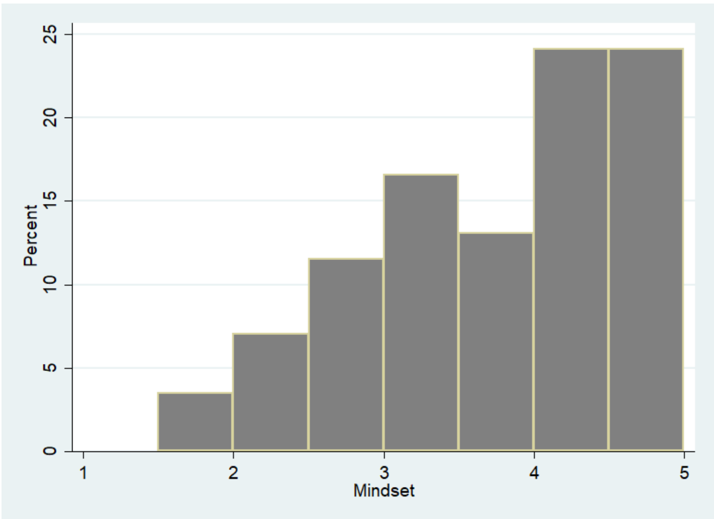
Appendix B, Table B4.

There were no questions asked by students regarding the study milieu (SOM_SM) questions. Factor analysis and a scree plot indicated that the SOM_SM subset loaded on one factor, which is consistent with the original analysis (Maree, et al*,* 1998). Some items had relatively low standard deviations, indicating relative conformity of answers. SOM_32 had a SD of 0.9, SOM_42 SD= 0.8, SOM_47 SD=0.88. All items had uniqueness scores of <0.5 indicating duplication of concepts between items. Most items did not load on the factor at greater than 0.5. These results are reported in Appendix B, Table B5.

Mindset scores range

Figure 5.1

Distribution of mindset scores.



Mindset scores on the adjusted scale ranged from 1.5 – 5 with a clear skew toward 5, which represents the growth mindset end of the continuum, see Figure 5.1. The mean score was 3.6, sd = 0.9. 96/199, 48% of scores were 4 or greater, clearly in the growth range. 44/199, 22% of scores were less than 3, at the fixed end of the continuum. 30% were mixed, between 3 and 4, showing traits of both.

Correlations between adjusted scales

Table 5.7

Correlation of variables after factor analysis and item selection

	Math	Prior Math	Mindset	Study Attitude	Math Anxiety
Prior Math	0.77**				
Mindset	0.30**	0.23*			
Study Attitude	0.22**	0.28**	0.33**		
Math Anxiety[49]	0.15*	0.15*	0.28**	0.32**	
Study Milieu	0.29**	0.37**	0.29**	0.22**	0.61**

Significance: **p < 0.01 *p<0.05

Males and females showed very different distribution patterns. There was a very low correlation between mindset and performance for males, r = 0.11, p = 0.3, 95% CI [-0.12, 0.33]. However, mathematics anxiety, r = 0.41, 95% CI [0.24, 0.57] and study milieu, r = 0.43, 95% CI [0.27, 0.59], both correlated significantly with performance at p < 0.01, indicating that males' performance is adversely affected by anxiety and study environment. For males, mathematics anxiety and study milieu correlated strongly at r = 0.73, p < 0.01, 95% CI [0.58, 0.87]. A poor study environment appears to be anxiety-inducing for males. As for the full sample, prior performance was the strongest predictor of current performance at r = 0.81, p < 0.01, 95% CI [0.71, 0.91].

Table 5.8.

Correlations between math performance, mindset, anxiety, study attitude, by gender.

	Math		**Mindset**		**Anxiety**		**Study Attitude**	
	Male	Female	Male	Female	Male	Female	Male	Female
Mindset	0.11	0.27**						
Anxiety	0.41**	0.03	0.43**	0.22**				
Study Attitude	0.19	0.35**	0.22	0.20*	0.28*	0.34**		
Study Milieu	0.43**	0.33**	0.27*	0.36**	0.73**	0.40**	0.15	0.27**

Significance: **p < 0.01 *p < 0.05

[49] Low math anxiety is coded as a higher score.

For females, mindset did correlate with performance at r = 0.27, $p < 0.01$, 95% CI [0.12, 0.43]. Additionally, all other variables correlated significantly with performance except for mathematics anxiety at r = 0.03, p = 0.7, 95% CI [-0.16, 0.21] indicating that high anxiety does not impair performance for many females. Gender differences in the relationships between performance, mindset, anxiety, study attitude and study milieu are summarized in Table 5.8.

I had expected an interaction effect between mathematics anxiety and mathematics mindsets. A linear regression analysis showed that the interaction effect was significant, indicating that mathematics mindsets and mathematics anxiety are related and interacting together in their relationship with mathematics performance. This interaction held for males only but not for females only. Results are in Table 5.9.

Table 5.9

Interaction between mathematics mindset and mathematics anxiety

Math Model	All participants		Females		Males	
	b	p=	b	p=	b	p=
Mindset x Anxiety	0.11 SE=0.03	0.001**	0.08 SE=0.04	0.07	0.15 SE=0.05	0.004**
	N=196		N=121		N=75	

Significance: **p < 0.01 *p < 0.05

Multiple Regression Analysis

Multiple regression analysis was used to identify the relative contribution of the SOM and Mindset scales to performance. Variance in the full sample was best explained by a combination of all the predictors, which together accounted for 20% of variance in the full sample (Table 5.10). Due to the observed differences in correlation patterns between genders, I also ran gender specific models. The summary of the regression analysis on mathematics performance and all the dependent variables is in Table 5.10. Full regression tables are included in Appendix B, Table B6. Both unstandardised beta (b) and standardized beta (β) are reported.

In the full sample, model 1, the mindset contribution to performance is small but significant, b = 5.05, SE(b) = 1.52, t = 3.31, $p < 0.01$.

Mathematics anxiety is added in model 2 and is significant at b = 3.62, SE(b) = 1.60, t = 1.37, $p < 0.01$. Mindset continues to be significant but now at $p < 0.05$. A likelihood ratio test was used to indicate whether each model differed significantly from the model proceeding it. One observation from model 1 was dropped as the data was incomplete. There was no significant difference indicated between models 1 and 2 indicating that the addition of math anxiety, even though significant in the regression model, does not account significantly in explaining performance variance beyond that accounted for by mindset. However β in the model does reveal the which of the independent variables is more important. In this model, it is mindset, β = 0.23.

Table 5.10

Regression Analysis for Mathematics Performance, full sample

Math Model	**1: Mindset**		**2: Mindset + Math Anxiety**		**3: Mindset + Math Anxiety + Study Attitude**		**4: Mindset + Math Anxiety _ Study Attitude + Study Milieu**	
	b/SE/ β	p =	b/SE/ β	p =	b/SE/ β	p =	b/SE/ β	p =
Mindset	b=5.05 (SE= 1.52) β =0.23	0.001**	b=3.62 (SE = 1.60) β =0.20	0.02*	b=3.19 (SE = 1.56) β =0.18	0.04*	b=2.09 (SE = 1.52) β =0.11	0.17
Anxiety[50]			b=4.33 (SE = 0.17) β =0.10	0.003*	3.12 (SE = 0.17) β =0.03	0.03*	0.55 (SE = 0.18) β =-0.13	0.74
Study Attitude					b=0.39 (SE = 0.14) β =0.24	0.004**	0.37 (SE = 0.13) β =0.23	0.005**
Study Milieu							0.81 (SE = 0.23) β =0.35	0.001**
	N = 197	R^2 = 0.05	N = 196	R^2 = 0.10	N = 196	R^2 = 0.13	N = 196	R^2 = 0.19

Significance: **p < 0.01 *p < 0.05

Study attitude is added to model 3 and is significant at b = 0.39, SE(b) = 0.15, t = 3.38, p < 0.01. Mindset and anxiety both continue to be significant. The likelihood ratio test showed that there was a significant difference between models 2 and 3; χ^2 (1) =11.33, p = 0.001 indicating that study attitude did improve the model and explain further performance variance. In this model β is highest for study attitude, β = =0.24.

Study milieu is the control variable proxy for SES and is added in model 4. Study milieu is significant at p < b = 0.81, SE(b) = 0.23, t = 4.52, p < 0.01. Once study environment (home and school resources) is accounted for, mindset and anxiety are no longer significant, but study attitude continues to be highly significant. R^2 indicates that 19% of variation is explained by this last model. The likelihood ratio test showed that there was a significant

[50] Low math anxiety is coded as a higher score.

difference between models 3 and 4 which added the control variable – study milieu; χ^2 (1) = 19.88, p = 0.001. In the final model, β is highest for study milieu, β = 0.32 however it is interesting that β for study attitude is almost unaffected by the addition of study milieu, β = 0.23.

Inclusion of the mathematics anxiety x mathematics mindset interaction in the model did not add to model strength, see Table B6, in the appendix.

There were unique correlation patterns between the variables for males and females, indicating possible gender differences in explaining mathematics performance. Hence, I repeated the analysis described above for males and females separately. The models for males are in Table 5.11

Table 5.11

Regression Analysis for Mathematics Performance, Males only

Math Model	1: Mindset		2: Mindset + Math Anxiety		3: Mindset + Math Anxiety + Study Attitude		4: Mindset + Math Anxiety _ Study Attitude + Study Milieu	
	b/SE/ β	p =	b/SE/ β	p =	b/SE/ β	p =	b/SE/ β	p =
Mind-set	b =2.48 SE=2.65 β =0.11	0.352	b =-1.71 SE=2.74 β =-0.07	0.54	b =-1.98 SE=2.76 β =-0.09	0.48	b =-1.85 SE=2.71 β =-0.08	0.50
Anxi-ety			b =1.04 SE=0.28 β =0.44	0.001**	b =0.98 SE=0.28 β =0.42	0.001**	b =0.47 SE=0.39 β =0.20	0.24
Study Atti-tude					b =0.21 SE= 0.37 β =0.10	0.37	b =0.23 SE=0.22 β =0.11	0.32
Study Milieu							0.76 SE=0.41 β =0.29	0.07
	N = 76	$R^2 = 0.01$	N = 76	$R^2 = 0.17$	N = 76	$R^2 = 0.18$	N = 76	$R^2 = 0.17$

**p < 0.01 *p < 0.05

Mindset is not significant in model 1, as expected from the low correlation between mindset and grades. R^2 indicates that the addition of mathematics anxiety in model 2 accounts for 17% of variation for males. The likelihood ratio tests shows that the addition of mathematics anxiety to the model is significant; χ^2 (1) = 13.06, p = 0.0001. Adding study attitude in model 3 does not change the variation accounted for and is not significant in the likelihood ratio test. Finally, model 4 controls for study milieu adding a small amount of strength to the model and rendering all other variables not significant. The likelihood ratio test shows study milieu to be marginally significant; χ^2 (1) = 3.67, p = 0.055. This underscores the apparently detrimental effect of study milieu on performance for boys likely due to its strong relationship with mathematics anxiety[51] with poor study environment leading to higher anxiety for males, which is detrimental to their mathematics performance.

Variation for females is explained by a different model, as described in Table 5.12. In model 1, mindset is significant at b = 6.03, SE(b) = 1.94, t = 3.12, $p < 0.01$, as expected from the correlations above, and explains 8% of the variance. In model 2, anxiety is not significant, also as expected from the correlations above. Females do not appear to be adversely affected by mathematics anxiety. The likelihood ratio test shows that mathematics anxiety does not significantly add to the model to explain performance variance. R^2 indicates that adding study attitude in model 3 improves the variation accounted for to 18%. The likelihood ratio test shows that this is a significant improvement to the model; χ^2 (1) = 14.82, p = 0.001.

Table 5.12

Regression Analysis for Mathematics Performance, Females only

Math Model	1: Mindset		2: Mindset + Math Anxiety		3: Mindset + Math Anxiety + Study Attitude		4: Mindset + Math Anxiety _ Study Attitude + Study Milieu	
	b/SE/ β	p =	b/SE/ β	p =	b/SE/ β	p =	b/SE/ β	p =
Mindset	b =6.03 SE=1.94 β =0.27	0.001**	b =6.08 SE=1.99 β =0.28	0.001**	b =5.15 SE=1.90 β =0.23	0.01**	b =3.44 SE=1.92 β = 0.16	0.08
Anxiety			b =-0.09 SE=0.21 β =-0.36	0.69	b =-0.34 SE=0.21 β =-0.15	0.11	b =-0.53 SE=0.21 β =-0.23	0.01**
Study Attitude					b =0.65 SE=0.17 β =0.35	0.00**	b =0.59 SE=0.16 β =0.32	0.001**
Study Milieu							b =0.87 SE=0.28 β =0.29	0.001**
	N=121	R^2=0.08	N=121	R^2=0.08	N=121	R^2=0.18	N=121	R^2=0.24

**$p < 0.01$ *$p < 0.05$

Adding study milieu in model 4 has an interesting effect. The combined variables account for R^2= 24% of variation in mathematics performance. The association strength of Mindset is reduced and no longer significant at b = 3.44, SE(b) = 1.92, t = 1.80, $p < 0.05$. Study attitude continues to be significant at b=0.59, SE(b) = 0.16, t = 3.69, $p < 0.01$ however mathematics anxiety, previously not significant is now significant at b = -0.53, SE(b) = -0.21,

[51] These variables have an acceptable level of collinearity for use in the regression analysis, VIF = 1.96.

$t = -2.55$, $p < 0.05$ with a negative coefficient. The likelihood ratio test shows that the control variable study milieu is significant for females, χ^2 (1) = 9.43, p = 0.002. With study milieu controlled for, low mathematics anxiety (high scores) corresponds with worse performance and high mathematics anxiety (low scores) corresponds with better performance. The test becomes more sensitive as extra variables are added and residual variance decreases.

Finally, I created a variable to split study milieu at the 50^{th} percentile. This was exploratory analysis following the same method as Dweck's large scale study in Chile (Claro et al., 2016) which found that mindset boosted performance for the lowest income earners. Although the variable, study milieu, is not directly an income variable, study environment is influenced by income, and I expected the results to be similar. Indeed, I found that in simple regression for the 89 students in the poorer study milieu group, mindset was a significant contributor to performance at b = 5.1, SE(b) = 1.81, t = 2.81, $p < 0.01$. For 108 students in the better equipped study milieu group, mindset was not significant, b = -0.13, SE(b) = 2.30, t =-0.05, p = 0.96. The interaction effect for mindset x milieu in the full model was significant at $p < 0.001$, b = 0.14, SE = 0.03.

Discussion

South African Mindset Assessment Scale

The primary aim of this study was to establish validity for a South African Mindset Assessment scale for use with young people from disadvantaged backgrounds. I completed a correlational study with 199 Grade 9 students in four Cape Town high schools during 2020. The test scale was based on Dweck's (2000) eight adjusted questions and included an additional eight questions that I devised. The wording of the 16 mindset questions was refined for use with South African students from disadvantaged backgrounds during Study 1.

The mindset questions based on Dweck's work (2000) correlated with mathematics performance at r = 0.22, p<0.01, 95% CI [0.09, 0.34], n=199. This was in line with the hypothesis prediction of a correlation of r=0.2, and in line with previous research (Blackwell et al., 2007; Claro et al., 2016; Kizilcec & Goldfarb, 2019). The set of eight additional mindset questions I added did not correlate with math performance. Exploratory factor analysis and item analysis reduced the staring total of 16 items to four. The adjusted mindset scale correlated with mathematics performance at r=0.3, p<0.01, 95% CI [0.10, 0.35]. Hence validity was established for the scale which was named "Thinking About Maths". The scale has construct validity – it measures the concept it is intended to measure, as established in

Study 1 discussion groups. The scale has face validity – it appears to be suitable to its aims. The scale has criterion validity – the results correspond to the correlations between mindset and achievement in previous research. The scale has content validity.

When additional items (mindset 9-16) were added to the scale which seemed to be in line with the construct and the language used by students, they did not add significantly to the strength of the scale. Hence the reduced scale seems to be a good representation of the mindset construct for students in South Africa. The final selected items are in Table 5.13.

The mindset score range was skewed towards growth mindset, as hypothesised, based on Study 1 results and speculated differences between South Africa and the United States' school systems. South Africa does not stream based on ability and intelligence testing and discourse about intelligence is uncommon. This was expected to have a positive effect on mindsets (Boaler, 2013).

Table 5.13

Final items selected for "Thinking About Maths" mindset assessment

Item	
1	I can learn new things but I don't have the ability to change how smart I am at maths.
2	With enough time and effort I could significantly improve my maths.
3	I don't think I can change how clever I am at maths.
4	I believe I have the ability to increase how maths smart I am, over time.

A secondary aim of this study was to refine the adjusted mindset assessment tool by removing poorly fitting and less powerful items, rendering the tool to be as short and effective as possible, for quick administration. The Mindset questions selected are in Table 5.13. The final scale had an alpha or internal reliability of 0.77 indicating that the construct is consistent and reliable. Each item had a +1 standard deviation indicating reasonable diversity of responses to show that the item was discriminating differences between individuals.

Three SOM subsets were analysed: mathematics anxiety, study attitude and study milieu. The average means and standard deviations by gender, for mathematics anxiety were compared to those in the original sample. My sample had slightly higher study milieu scores, possibly due to improvements in living conditions since the original study or due to most of my participants being at fee paying schools, associated with higher income. My sample had much higher study attitude scores likely indicating that there may have been a substantive change in attitude towards the usefulness of math and willingness to work hard at it since the test was developed. Alternatively, the better study attitude in my sample may be due to the better study milieu of my students, as study attitude correlates significantly with study milieu.

Students raised questions about four items on the SOM, mathematics anxiety subset. I analysed the scale using exploratory factor analysis and item analysis and decided to remove three of the four questions for the purpose of this analysis. The SOM was developed 20 years ago, and it is unsurprising that there have been changes in language use and even student behaviour over this time. I recommend that the developer and publishers review these three items with a broader population sample with the view to adjusting or removing them.

My final study aim was to explore the relationship between mathematics performance. mindsets, anxiety, study attitude and study milieu. The correlational analysis revealed an initial gender difference in the pattern of relationships between mindset, anxiety, study attitude and performance. It was not part of my initial analysis plan to examine relationships based on gender, however, previous researchers have also found unique gender patterns between variables influencing mathematics performance and mathematics career orientation (Degol et al., 2018; Heyder, Weidinger & Steinmayr, 2021; Huang, et al., 2019). Wills & Hofmeyr (2019) noted that in South African rural and township schools, being female promoted academic resilience, even after controlling for other variables.

For females, there was a strong correlation between math performance and mindset however maths anxiety did not correlate significantly with performance. Females performed well despite being anxious. For males, mindset did not correlate significantly with performance, however math anxiety did. Males who were anxious generally did not perform well. As this is a correlation the direction of the relationship is unclear. Poor performance may be anxiety inducing for males or anxiety may cause poor performance, or both. There is some additional clarity revealed in the very strong correlation between study milieu and math anxiety. A poor study environment appears to be anxiety-inducing for males. There was a significant interaction effect between mathematics mindset and mathematics anxiety for males and this relationship is worthy of further research.

I used simple and multiple regression modelling to explain variance in maths performance in the whole sample, and by gender. 20% of variance in the full sample was explained by a combination of the three SOM subsets plus the mindset assessment. Mindset made a small but significant contribution in the simple regression model explaining 4% of variance but was not significant in the full model. Study attitude and study milieu were both significant in the full model. Study attitude encompasses both general attitudes about the usefulness or importance of math as well as effort and time spent on the subject. Study milieu (environment) is not something that can be targeted by psychosocial interventions; however, study attitude is. Previous research has found that roughly 60% of the learning gap between poorer and wealthier South African students is explained by differences in home background (Shepherd, 2016). These results indicate that an intervention targeting study attitude may be appropriate for young people from disadvantaged backgrounds, assuming that cost and ease of delivery are appropriate to school settings.

Modelling for females showed that anxiety is not significant in a simple regression, however, it was significant in the full model. Interestingly, for females the coefficient was negative, meaning that highly anxious females are performing well. Anxiety becomes significant only once study milieu is controlled for. This indicates the relatively strong influence of study milieu on performance however still captures the relationship between high mathematics anxiety and strong mathematics performance for females. Mindset was significant in the simple regression and explained 8% of variance, however it is not significant once study milieu is controlled for. A combination of the variables accounted for 24% of variance for females. It appears that females in impoverished study environments place a higher value on mathematics and its relevance to their lives; possibly drawing associations between mathematics skills, future employment, and escape from poverty.

In the simple regression models for males, mindset was not a significant contributor to performance, however math anxiety was significant. Once study milieu was controlled for, mindset continued to be non-significant. Study attitude was not significant in any multiple regression model for males. The best model explaining performance for males included mindset and anxiety explaining 17% of variance. It seems important to target math anxiety in designing psychosocial interventions for males.

Finally, I followed the lead of the nationwide study in Chile (Claro et al., 2016) and investigated the prevalence of growth mindset in students with poorer study milieus. I found that mindset was a significant contributor to performance for this lower scoring subset whilst it was not significant for the higher scoring subset. This resonates with research in the United States where Yeager and colleagues have also found that those most at risk benefit the most from growth mindsets (Yeager et al., 2019). This was a helpful find in directing where to best focus future mindset intervention efforts in South Africa.

In conclusion, the adjusted mindset scale is appropriate for use amongst South African disadvantaged youth. It does correlate significantly with mathematics performance. Gender differences do exist in the pattern of variables studied and these should be considered when developing interventions. Mindset accounts for a small amount of performance variance in females but not in males, and in students with poorer study milieus rather than those with more supportive study environments. Overall, in this South African sample, variation in performance was better explained by study attitude, mathematics anxiety and study milieu, than by mathematics mindsets.

CHAPTER 6- STUDY 3, 2019

Introduction

Mindset assessments and interventions have been primarily developed in the USA. Often these have been generic, not considering specific target groups' perceptions and preferences. Yeager introduced the idea of applying design thinking to the adaption and improvement of psychological interventions, particularly to mindset interventions, (Yeager, et al., 2016). Design thinking seeks to solve a problem for a particular user group. The user groups' perspective is privileged in the design process and development involves iterative cycles which progressively apply recommendations for improvement from the user group. Yeager et al., recommend that mindset interventions are specific to the problem or domain; that language and delivery methods are appropriate to the target group and that arguments used are persuasive to the target group. An additional consideration in developing interventions with teenagers is to take into consideration the adolescent desire for respect and status (Yeager, Dahl & Dweck, 2018).

Yeager et al., (2016) adapted an online intervention developed by Paunesku, Walton, Romero, Smith, Yeager & Dweck (2015) and published as PERTS. Yeager's 2016 adaption was further modified for use in Norway by Bettinger et al., (2018). The modifications were achieved via interviews with focus groups in Norwegian high schools, adapting the materials to consider language, culture and context. They do not describe the process of adapting the mindset. Although the PERTS program is available online to all schools in the USA, I was declined permission to view it and therefore could not use it in developing the South African intervention.

In South Africa, Porter et al., (2020) piloted an intervention in low resourced high schools in the Western Cape, using content from Class Dojo, available free and online. They did not use the word "intelligence" in their assessment questions but rather used "smart". Rebecca Ross said, in personal discussion, that they had found that the word "intelligence" was poorly understood (R.Ross, personal communication, 11 February, 2019). The use of the word "smart" is also consistent with Class Dojo content. Class Dojo animations were thought to be appropriate as they avoid racial assumptions that might have been made with a real-person video (R.Ross, personal communication, 11 February, 2019) however, Class Dojo is developed for use with primary school students and that may have been a detractor for the teenagers in the study. Porter et al., used a pictorial Likert-type scale as agree-disagree scales have shown low reliability in developing countries.

In Study 1 I developed a mindset assessment tool that was appropriate for use with Cape Town youth. Participants expressed maths intelligence beliefs consistent with those found in studies in other countries. In Study 2 I tested this tool in a correlational study exploring the relationship between mathematics performance and mindset. I established validity for the tool, finding the expected relationship between growth mindset and stronger mathematics performance. The aim of the Intervention Development in Study 3 was to adapt a USA-based mindset interventions for use in South Africa using a design process. The aim of the Intervention Pilot was to trial this intervention with a group of Grade 8 students who were invited to give feedback. The intervention drew on existing mindset interventions and local cultural and teaching knowledge garnered from teachers and high school students in informal settings. The intervention combines both mindset messages and learning strategies. The intervention incorporates the recommendations of design thinking as listed by Yeager et al., 2016. It is specific to math mindsets. It uses language that is generally understood and comfortable for the target group (as established in Study 1). It takes into consideration recommendations for delivery through consultation with teachers in the development phase of this study. It positions students as the "experts" in developing a program to help new high school students. This confers respect on them, as recommended by Yeager *et al.,* 2018. The pre and post mindset assessment uses the mindset scale developed in consultation with students in Study 1 and established as a valid measure of mindset in Study 2.

The description of the design process and the decisions made in shaping the intervention rely heavily on field notes along with small amounts of quantitative data, for example voting on which possible mindset messages are most relevant. Whilst the work described in this chapter does not comply to a scientific paradigm, the description of the design process is important and may provide some signposts to future researchers wishing to adapt interventions developed in a different cultural context.

Intervention Development

Participants

Teachers from the four selected Cape Town schools (Table 5.1) were invited to participate in a focus group discussion to assist with the development of the intervention tool. Teachers were consulted both as general experts in the field of Education and as experts in their knowledge of engaging teaching methods for South African students. Invited teachers were mentioned by students in Study 1 as being skilled at making teaching content relevant. Due to problems with communication and timeline constrictions imposed by the Western

Cape Education Department (WCED)[52], School 4 did not participate in the teachers' focus group discussions. At school 1, six teachers were invited and four were able to participate. At school 2 six teachers were invited and all six were able to participate. At school 3 five teachers were invited and two were able to participate, bringing the total participants to n=12.

Thirty-two Grade 10 and 11 students were selected via opportunity sampling. These students were consulted as experienced, older, mathematics students with peer knowledge of helpful mathematics beliefs and strategies. They were all on maths scholarships with the NGO, SAILI[53], and I had access to them as an employee at SAILI. The students lived in similar communities to the students in the study, were from the same racial categories, and some attended the same schools as those in the study. They were recruited to give end-user expert input into the development of the intervention.

Design.

Teachers met in small, school-based groups for 30-70 minutes, depending on their availability. The discussions were semi-structured around the following questions:

- Why do you think students identified you as teachers who can make content relevant?
- What methods do you use to make content relevant?
- If you had to get an important life message across to a young person, what do you think is the best way to do that?

Notes were taken during the discussions and teacher advice was extracted anecdotally on two key themes relevant to developing the intervention: connecting with young people to deliver an important message and learning strategies teachers are trying to develop in young people. Formal thematic analysis was not completed. Field notes were taken and are included in Appendix C.

Following these discussions, I made a list of learning strategies mentioned by teachers and also those mentioned by Jo Boaler in her You Cubed online resource or by Mindset Works in the online Brainology resource (Boaler, 2015, 2016; Dweck, 2013).

I presented this list of strategies to the Grade 10 and 11 maths scholarship students. I told them I was developing a program to encourage younger (Grade 8 and 9) students with

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[52] Research permission excludes researchers from schools during Term 4 as this term is busy with assessments and exams.

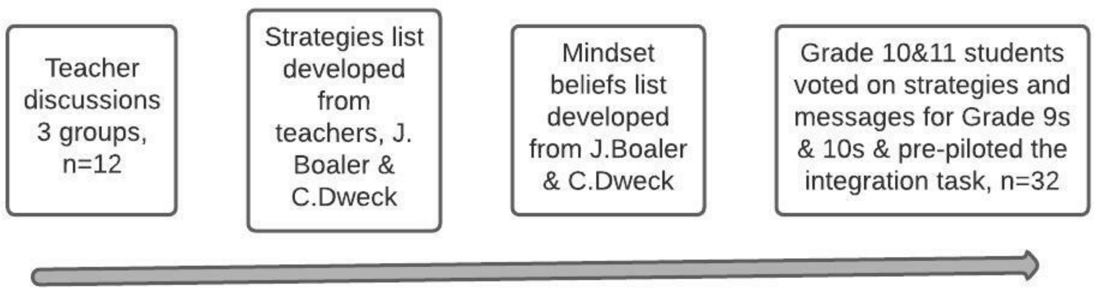
[53] www.saili.org SAILI awards high school scholarships to low-income students from disadvantaged backgrounds who demonstrate solid mathematics attainment at the end of primary school.

their maths. I asked them to vote on which strategies they felt were the most important to them. I also made a list of growth mindset messages present in Jo Boaler and Carol Dweck's materials and asked the scholarship students to select the message that was most important to them.

Students then broke into small groups and made a 60 second film sharing one message or strategy with a younger (Grade 8) maths learner. I was considering using this film-making integration activity in session 2 of the piloted intervention. The intervention integration activity used in session 2 of the Intervention Pilot. I observed that the students both enjoyed the activity and took the production of their clip seriously. Hence, it seemed to be an appropriate integration task for my target group. The design of the Intervention Development is summarised in Figure 6.1.

Figure 6.1

Process to develop intervention key mindset messages and learning strategies



Results, Intervention Development.

Twelve teachers participated in focus group discussions from three schools to assist with developing the intervention. Discussion themes were of two main types: connection with students, and strategies for learning. These are summarised in Tables 6.1 and 6.2 below. All examples mentioned by teachers are listed in the tables. Teachers at all three schools spoke at length about the ways they engage students. At school 1 they were particularly excited about this conversation and listened to each other with interest. At the conclusion they remarked that they wished they could take more time to learn from each other's methods. Teachers at school 1 met with me for 45 minutes. Teachers at school 3 had the most time available for the discussion group, 70 minutes. As there were only two teachers present the comments were detailed. One of the school 3 teachers was familiar with Growth Mindset theory and reported using Jo Boaler's "YouCubed" resources in her classroom (Boaler, 2016). Teachers at school

2 had only a short time available to them, 30 minutes, and their group was larger than the others. Hence, their comments were less detailed, and it was harder to steer the conversation to relevant content.

In addition to the two key themes that I introduced (promoting a learning environment and strategies teachers hope students will develop), teachers at school 2 spoke at length about problems they faced, including class size, lack of intrinsic motivation in the students, students not using available resources (Wi-Fi), students only engaging in learning when supervised to do so. Whilst these comments were clearly pertinent to the teaching environment at school 2, they were not relevant to the development of the intervention.

Table 6.1

Theme 1- Connection with students to promote a learning environment

	School 1	School 2	School 3
Build relationship	x		x
Connect to everyday life and stories	x	x	x
Be passionate about your material	x		
Make it fun/ use humour	x	x	x
Involve parents			x
Use video/PowerPoint	x	x	x
Prepare well		x	
Promote learner-led learning environments		x	
Ask students questions	x	x	

Table 6.1 summarises subthemes mentioned at each participating school regarding connecting with students.

Teachers spoke anecdotally about the ways they engaged students and helped them be receptive to learning. Although it was clear that teachers with different personalities had different techniques, all teachers were able to speak confidently on this topic. A teacher at School 1 described making a visual connection with students, as being like establishing "an invisible thread[54]". A teacher at School 3 said "we have a bond". The Life Orientation teacher at School 1 said "what is incredible is to connect with them out of the classroom. If they feel connected with, they want to learn with you." In terms of teaching style, a teacher at

[54] Quotes were taken down in field notes, included in Appendix III.

School 1 remarked “it really is like putting on a show” and a teacher at School 3 said “passion counts”.

Teachers used creative and varied methods to gain class engagement. A maths teacher at school 1 had made up a song to help students remember Pythagoras’ theorem. Another teacher described a supply of children’s stories in his class that he gets students to read aloud from “with the voices”. This gets the class laughing and helps them relax and the teacher believes it improves their test scores. At school 3 a maths teacher described playing “Battleships” using grid paper to teach co-ordinates. At all schools, teachers noted that students enjoy PowerPoint and YouTube. At school 2 a teacher remarked “they get used to our teaching style and they get bored. Different styles are important.”

Teachers at school 3 spoke about the importance of finding out how students are feeling and what’s going on in their lives. They said that they make sure students know that they (the teachers) are always available to talk about life issues. Students need to be able to deal with these things before they are ready for learning. Learning content also needs to be connected back to everyday life. Teachers also described telling relevant stories from their own lives. The maths teacher at school 2 tells students about his maths learning journey saying, “I was not born knowing maths”. At School 1 a teacher said “I always tell them about my background, my story. I didn’t have it easy so they can see that they can still achieve.”

A teacher at school 2 said “if you are well prepared, you will be able to market your lessons”. Teachers there also spoke about how to start a lesson. Many teachers mentioned using humour- “I always start with a joke relevant to what is happening today.” School 2 teachers also spoke about checking in with students for how much they understand on the topic before starting teaching. They referred often to “learner-centred” practices. This included peer-lead tuition and group work. They said “Students like learning from other students. They come up with their own way of explaining”.

Teachers spoke about using questions as a way of promoting personal change, noting that careful questions can help students break down the steps needed to reach a goal. At school 1 the geography teacher said, “Don’t target students who need to be changed, open a class discussion and ask their input”. This resonates with the recommended stealthy approach for growth mindset interventions (Yeager & Walton, 2011).

In consideration of the teacher recommendations for connecting with students I decided to prioritise the following in developing the intervention: connecting content to the lives of the students, delivering content with “passion” including being prepared for questions and use of YouTube videos as all teachers had noted that students enjoy this.

Teachers at school 2 spoke enthusiastically about peer-lead tuition which included ideas like getting students to work in groups both to cover content and formulate questions and asking one learner to present information to the class. In response to this I decided that the integration session (session 2) would include students working in small groups to make their own 60 second film explaining a key learning point to encourage a new Grade 8 learner.

In response to the indirect approach to inviting change, discussed by teachers at school 1 and the advice given by Yeager et al., (2018) in showing teenagers respect, I decided that students selected for the intervention would be told that they were going to help me develop an intervention for new Grade 8s at their school. They would not be told that they were selected because they had low growth mindset scores and average or below average maths grades.

Teachers at schools 1 and 3 spoke about learning strategies they tried to develop in students, listed in Table 6.2. Teachers at school 2 did not have time to discuss strategies.

Table 6.2

Theme 2 - Strategies teachers hope students will develop

	School 1	School 3
Try hard things		x
Attempt so the teacher can see the problem		x
Take notes in class	x	x
Don't be afraid of mistakes		x
Recap, revise, remember	x	x
Look for connections between learning content		x
Set personal learning goals		x
Develop self-belief	x	x
Move away from distracting students	x	

Teachers talked about building self-belief as a starting point to getting students to try challenging things. A science teacher at School 3 said "the biggest issue is self-belief. They think that science is hard. I'm always encouraging them to just try it. Look how far you got!" She also said that when students refer to themselves as "stupid" she tells them she doesn't have time for stupid people and walks away. At school 3 the mathematics teacher spoke about the “power of suggestion”, that when you tell a learner that he or she can do it then they find that they can. Teachers said they were conscious of what they say to students all the time so that they can build them up.

Teachers at both schools talked about the strategy of “recap, revise, remember”. This is included in their classroom delivery as well as promoted to students for their own study time. At school 1 a teacher said, “I think I have to repeat a few times, recap.” At School 3 the Science teacher said “kids need to find what works for them in revising and remembering. Different subjects might require different methods.”

The mathematics teacher at school 3 who uses Growth Mindset in her classroom talked extensively about the importance of trying challenging things and attempting questions before asking for help. She said, “They must try the work and not be afraid of mistakes.” This teacher gives students questions on various difficulty levels and encourages them to try some of the questions they are comfortable with and some that they are challenged by. The Science teacher said “They say, ‘please help me’ but they just want you to give the answer. They must attempt it so I can see what they don’t understand.”

Teachers at both schools talked about the importance of taking notes in class. They said that students mustn’t try to write down everything they hear or only copy from the board. They need to write things in their own words, to process the information. They can also use mind maps or pictures as notes. A teacher at school 3 says she rewards students with good handouts if they write in their books. In this way she can promote students processing material through note taking whilst assuring them that they won’t miss key content by writing things in their own words.

In response to the teachers’ input on strategies I considered how I could integrate strategy messaging and practice into my intervention. In session one, I decided to pause after each key growth mindset message and give students time to write down their own notes on what they had heard and also to ask questions.

In response to the “recap and revise” strategy I decided to send students WhatsApp messages over the two weeks between sessions reminding them of the mindset messages and introducing learning strategies for them to try out. From the connection with students’ discussions above, I noted that telling stories and connecting to students’ lives was important. Hence, I decided that some of the WhatsApp messages would be stories or quotes from famous or locally relevant people.

I made a list of strategies teachers had mentioned and added strategies listed by Jo Boaler on her maths online resource You Cubed and also those mentioned by Mindset Works in Brainology (Boaler, 2016, Dweck, 2013). I also made a list of Growth Mindset Messages in the same resources. 32 Grade 10 and 11 Mathematics Scholarship students voted on the messages and strategies they felt were most important for Grade 8 and 9 students. The list and votes are shown in Table 6.3.

Table 6.3

Votes on Growth mindset messages and strategies

Messages	**Vote**
Maths problems can be solved with many different insights and methods.	6
There is no such thing as smart or not smart at maths. Everyone can learn maths at high levels.	6
Your brain is like a muscle. The more you work it by practicing maths, the more it grows.	5
A mindset that embraces learning leads to success at school.	5
Your history with learning maths does not determine your future potential with maths.	5
Maths mistakes grow your brain. Struggle and challenge are good for you.	3
When you believe in yourself and your ability to learn maths, your brain works better.	0
Having a stronger brain equips you to make a difference to your community.	0
Every maths learning experience will improve your maths ability.	0
Maths will help in life because maths teaches you to think creatively, ask question and solve problems.	0
Strategies:	
Be curious and ask questions – ask your teacher, ask your friend, look things up on the internet.	7
When you can't get an answer in maths, step back and try a new approach.	5
Take great notes in maths class. Summarise with point, pictures or mindmaps.	5
Practice maths outside of class time.	4
Try maths questions that look hard, embrace the challenge.	3
Tell yourself – it's OK to make mistakes in maths, that's part of learning.	3
It's not important to be fast in maths, step back and try a new approach.	2
Recap your maths work at the end of the day.	1
Work on maths tasks that can be solved in different ways and/ or with different solutions.	1
When you come to a new question, try and make connections to work you've done before.	0
Spend time thinking about your learning progress and set yourself learning goals.	0

There were five Mindset messages that students strongly identified with, gaining at least 5 votes each. Based on previous experience of delivering mindset lessons, ten minutes seemed an appropriate length of time to teach a mindset concept. School class periods range from 40-60 minutes. I decided that the intervention should be 35 minutes to ensure that all classes could complete the lesson. This allowed for the presentation of three messages, and I chose the following:

1. Your brain is like a muscle. The more you work it by practicing maths, the more it grows.
2. There is no such thing as smart or not smart at maths. Everyone can learn maths at high levels.
3. Your history with learning maths does not determine your future potential with maths.

These are three of the four key messages presented by Jo Boaler (2016) and were three of the messages with the strongest support from the Grade 10 & 11 students consulted.

There were four strategies that Grade 10 & 11 students identified as being useful for younger students, and these concepts were included in the WhatsApp group messages:

1. When you can't get an answer in maths, step back and try a new approach.
2. Be curious and ask questions – ask your teacher, ask your friend, look things up on the internet.
3. Take great notes in maths class. Summarise with points, pictures or mind maps.
4. Practice maths outside of class time.

Intervention Pilot

Participants

Grade 9 students from each of the four schools were invited to participate in a pilot intervention and to give feedback to assist with the refinement of the program. 40 students were selected from the full research sample of n= 198 (10 students from each of the 4 participating schools). Invitations were sent to parents and students. I selected students with the lowest mind-set assessment scores in the school sample, as these had the greatest potential to benefit from the pilot if it was successful in promoting a mind-set change. Students who participated in any Study 1 discussions were excluded from the intervention. Students with math scores of less than 20 were eliminated from the selection pool as these students gave very little input about maths learning in Study 1, even when the discussion was facilitated in their home language. Selected students had maths scores that were at school average or below as prior research has shown that these students are most likely to benefit from a mindset intervention (Yeager et al., 2016). Table 6.4 compares the maths grades, mindset scores and number of participants from the full sample to Study 3.

Table 6.4

Profile of participants in Study 3

	Math % mean	Math % range	Math % SD	Mindset Mean*	Mindset Range	Mindset SD	n
Full Sample	47.8	7-91	20.15	3.6	1.50-5.00	0.91	198
Pilot Study	39	21-62	11.88	2.7	1.50-3.75	0.68	32

*Score /5

At schools 1 and 2, the full complement of 10 students participated in the first session of the pilot. At school 3, two students were absent. At school 4, four students withdrew in the first 10 minutes of the intervention and two students were absent. The school replaced one of these absent leaners with a learner who did not comply with the sample selection, but who participated anyway. This left a sample of n=33 participants in the first session but only 32 for comparison of maths grades (due to the non- compliance with selection parameters of one learner).

The second session of the pilot ran close to the end of term and clashed with scheduled school assessments, following which students stopped attending school. Student absenteeism in the last week of term one was unexpected. Only 10/32 students completed the second session. The second session gave students an opportunity to give written feedback on the first session and to complete an integration task – making a short film about a mindset message. A further seven feedback forms were collected by teachers (n=17), however, no forms were completed from school 2.

As there were only 17 feedback forms submitted, I decided to present the session to a new group of Grade 8 students and collect their feedback. 12 Grade 8 students were recruited through opportunity sampling from the NGO, SAILI Scholarships, where I worked. The group were demographically similar to the students in the core study and is described in the Intervention Development participants. The feedback form is shown in Appendix C. This brought the learner sample for feedback on session 1 to n=29.

Design

The Intervention Pilot was an experimental design with a passive control group. Term 2 maths grades and mindset assessment scores were collected prior to the intervention. Mindset assessments were collected again after the intervention and term 4 maths grades were also collected. Students attended a 35-minute Growth Mindset lesson. They were told that they would be helping to develop an intervention for new Grade 8 students coming to their school the following year, conferring respect to them as recommended by Yeager, Dahl and Dweck (2018). I delivered the intervention on my own. I took field notes during the program and made further notes afterwards. The sessions were not recorded.

The program started with inviting students to remember their own transition to high school, particularly how they felt about maths then, and their journey with maths until now. This followed the advice of teachers, collected during field work in the development phase, who pointed out the importance of helping students connect new content to their own lives. The program delivered the following key messages:

1. Your brain is like a muscle. The more you work it, the more it grows.
2. There's no such thing as smart or not smart at maths. Everyone can learn maths at a high level.
3. Your history with learning maths does not determine your future potential with maths.

The messages and strategies were selected in the development phase, as described above. The lessons were supported with short YouTube videos, as teachers in the development phase recommended this as an appropriate means of engaging young South Africans in learning content.

During the program, students were invited to take notes on what they had heard at the end of each key section. This was a strategy recommended by teachers in the development phase to keep students engaged and important to the learning process. It is also a strategy taught as part of existing Growth Mindset Interventions (Dweck, 2013). Students were also regularly invited to ask questions, a Growth Mindset strategy listed by Boaler (2016).

Following the face-to-face program, I formed students into school-based WhatsApp groups and delivered follow-up mindset messages and study strategies over the next two weeks. The messages and strategies supported those delivered during the face-to-face intervention with the addition of some strategies suggested by the students themselves during the face-to-face class and strategies recommended by the Grade 10 & 11 maths students and teachers consulted in the development of the program. A total of 8 messages were sent and these are listed in the table 4 in the results with links to the mindset message or strategy noted.

Two weeks later students were invited to return to give feedback on the films, the WhatsApp messages, to reassess their mindsets, and to integrate their learning through two activities. The first integration activity was a written question to students: “If the research team came back in a year from now to see how I’m going with maths, one thing that would be different is…” The second integration activity was a film making activity. Students selected a message from the program that they felt that they personally connected to and would be an important message for new grade 8s to hear. They then worked in groups to construct a short script and make a 60 second film delivering that message.

The full program is in Appendix C.

APPENDIX C– STUDY 3

Field Notes

Teacher Discussion Groups

I explained the purpose of the research in general and the purpose of the discussion. Teachers were asked to complete permission forms. All notes are quotes unless otherwise marked in italics in which case they are a paraphrase. ”Q” designates a question asked by the researcher

Date: 1/8/19

Venue: School 1

Length: 45 min

Present: 4 teachers

Description: Teacher discussion group

Introduction: I had invited six teachers to the discussion, based on the recommendation of students in study 1 however one teacher was absent from school on the day and the other forgot to attend the meeting. They teachers were enthusiastic about the research but also about the opportunity to share ideas with each other. They listened to one another with interest and commented that they would like to have more discussions with each other like this one. We met in a classroom during a class period.

Q: What methods do you use to make content relevant?

- Humor
- Share a story from personal life

- Discussions
- Relate to stuff they use every day, the more recent and trendy, the better.
- Make it visual. I like to connect with each pupil and make sure they are looking at me – like an invisible thread between us.
- *The maths teacher described how she had made up a silly song about Pythagoras theorem to help students remember the rule*
- *A second maths teacher described how she gives students choice and asks* Is this too much information for you? Do you want to stop? *She also described giving frequent two minute brain breaks and said* Talk about something random, yester-day it was ants.
- It really is a like putting on a show.
- You've got to enthusiastic about whatever you're teaching. If you're dead boring it's dead boring for you and them.
- Give them some leeway.
- *The geography teacher described how he gets a learner to read a picture book for the class, with voices and showing the pictures. Everyone ends up laughing. This is how he gets them to relax before a test and believes it improves their grades.*
- They must write something down, not copy off the board, but make their own spi-der diagram.
- Repetition, I think I have to repeat a few times, recap.
- *A teacher described how environmental changes can help- sometimes moving a child can get them to work.*
- They like to feel special.
- *A teacher described the importance of suggestion – telling a learner they can do something then they find* – Oh I can! I know that's happened to me in my own life.

Q: What learning strategies do you try to teach students?

- Ask questions as a strategy to develop concrete steps to life goals.
- I always tell them about my background, my story. I didn't have it easy so they can see that they can still achieve.
- Don't target students who need to be changed, open a door, start a discussion and ask their input.

- What is incredible is to connect with them out of the classroom. If they feel connected with you they want to learn with you.
- Write a contract and they have to come up with their own punishment – for example, if late do 20 jumping jacks.

Date: 2/8/19

Venue: School 3

Length: 75 min

Present: 2 teachers

Description: Teacher discussion group

Introduction: I had invited five teachers to the discussion, based on the recommendation of students in study 1. However, one teacher had left the school, one was on maternity leave and one was at mosque. The two teachers who attended were a maths teacher and a physics teacher. They attended during the school assembly period. They seemed excited to be invited to participate and discussed the issues in depth.

Q: What methods do you use to make content relevant?

- *Teachers described relationship with students as being important.* Gauge how they are feeling.
- We have a bond
- Give them warning of things coming up to reduce stress
- Use lots of colour on a black background
- Connect to everyday life
- The biggest issue is self-belief. They think that science is hard. I'm encouraging them to just try it. Then I say – Look how far you got!
- I like an interactive class. I can't handle it when no one is talking to me.
- Passion counts
- I don't praise kids always getting things right. I praise hard work. It's not about speed. I slow them down.
- *Maths teacher described using Jo Boaler's YouCubed videos with her maths classes.*
- They must be adventurous enough to choose a difficult question. *Maths teacher described offering students questions at different levels and letting them choose 3/6 to answer.*
- I never scream at my kids.

- *Maths teacher said that the maths department has done growth mindset training. They also go away together for weekends and swap idea.s*
- *Maths teacher mentioned an app called Plekkers. (I can't find this though so I must have misheard)*
- *Maths teacher expressing frustration* - Because we put a time limit on exams, I wish we could give them unlimited time, we put pressure on but we're trying to teach them to take their time.
- Sometimes it's connection to the teacher
- They say please help me but they just want you to give the answer. They must attempt so I can see what they don't understand.
- May be because the syllabus is so broad, you can just touch the surface you don't go to any depth.

Q: What learning strategies do you try and teach to students?

- They must take notes in class, they must try the work and not be afraid of mistakes.
- *Teachers described pairing teachers and students by learning style. Their school did an experiment with testing learning styles and putting kids into classes with teachers that like to teach that way.*
- *Teachers said that the lessons must be fun. The maths teacher described using the game – Battleships - to teach co-ordinates.*
- *Teachers described that students must be able to interact with the lesson content, it must be concrete.*
- I bribe then with good handouts if they write notes in their books. *This teacher said that this means they can write down their thoughts without worrying about if everything is right. This enhances their learning process. They know they will get thorough notes from her if they have made their own effort at taking notes.*
- If parents are involved and invested then that gets them moving.
- When kids tell you stuff that happens at home it becomes really taxing on you as a teacher.
- *Teachers described Revise, Recap methods. They said that kids need to find what works for them in revising and remembering. Different subjects might require different study methods.* Maths is practice.
- They need to do many questions on the same topic.

- They don't have reflective mindsets. They don't connect the question to the things they did before. When they get the exam back, they can't find where they went wrong. *Teachers described trying to get students to use their exam as a learning tool but said that students resist this.* I tell them to write down where they need to improve but I can see only two kids are writing out of a class of 19.
- Sometimes people put kids down for failing, even though they are improving. *Teachers said you have to look to see how the learner was performing previously and not just look at the current mark.*
- *Physics teacher said she hears students say these things:* Mam, can you help me? I'm stupid. *She replies:* I don't have time for stupid people. I walk away. If they are saying that, they don't know me yet.
- You must be conscious of what you say to the child the whole time.
- Sometimes the only place they look for love is here at school.
- When bad things are happening for kids, they don't want to work.

Date: 7/8/19

Venue: School 2

Length: 35 minutes

Present: 5 teachers.

Description: Teacher discussion group

Introduction: I made several attempts to meet with the teachers prior to this day including one appointment that I arrived for but teachers were unavailable. Today I arrived at the time of the appointment (2pm) and students were already leaving the school as there was a teacher training meeting scheduled for that afternoon. As it was my second attempt to meet with the teachers they excused themselves from their training to join my discussion. We met in a head teacher's office starting the meeting with three teachers and three other teachers joined in the first 10 minutes. The teacher took the meeting seriously and offered considered reflections. However, they were also anxious about how long the meeting might take and indicated that they needed to get back to their training. Hence the length of the discussion was shorter than I would have liked. The teachers who attended included some that I had specifically invited and others who felt that their contribution was important.

Q: What methods do you use to make content relevant?

- If you are well prepared, you will be able to market your lessons

- I always start with a joke, relevant to what is happening today
- You must get them involved
- Give them a chance to work it in their own way
- They like to take a lead in their learning, they want to find out themselves. *Teachers discussed learner-centered classrooms, techniques of grouping students and giving each group a chance to report back. They mentioned co-operative learning and said that students love working together.*
- They get so excited if they are the peer-tutor *example given of the homework class after school.* Students like learning from other students. They come up with their own ways of explaining.
- They get used to our teaching style and they get bored. Different styles is important.
- They like it we use PowerPoint or watch videos. But they are only interested if you are with them. They won't watch if you are not there with them. *The teachers said that the students could watch additional educational videos using school wi-fi but they won't do it.*
- *Class size is a challenge.* By the time you get to the last class you are exhausted. *There was extensive discussion about the challenges faced by teachers at this school.*

Q: What learning strategies do you try and teach to students?

- We try to build skills for life. *Teachers described these as using technology and Harvard in-text referencing.*
- They don't have intrinsic motivation, as much as we give it externally, they are not able to have it for themselves.
- You can read a case study or watch a video then discuss the stories. *Heartline was mentioned as a resource.*
- I tell stories from my own life. I say – I was not born knowing maths. *Teacher then described her struggle with maths and how she overcame it.*

Learner Intervention

Date: 2/9/19

Venue: School 4

Length: 50 min

Present: 8 students, 4 male, 4 female.

Description: Learner Intervention, session 1

Observations: Students attended during the school maths period. They participated in all discussion activities. They only asked questions at the end, asking about neurology and how learning happens. Students took substantial notes of ½-1 page each. As notes are taken after each section of the lesson, they were not writing down my words verbatim. I was impressed with how much effort they put into note taking.

Students listed the following strategies as ones that would help a new grade 8 students: focus in class, develop passion for maths/ relationship with maths, work harder and practice at home.

Date: 30/08/19

Venue: School 3

Length: 35 min

Present: 9 students (but 4 withdrew), 4 female, 3 male

Description: Learner Intervention, session 1

Observations: Students attended during the assembly period. One learner had indicated that he would be absent due to mosque and the school replaced him a different learner who would ordinarily be excluded due to her participation in Study 1. However, I did allow her to stay. Students had not been notified of the invitation to participate and objected to being directed into the research conversation. One learner was anxious about missing assembly. When she found out that participation was not compulsory, she opted to leave. Three other students left with her. It seemed that they were motivated by not wanting to write notes and work when they could sit in assembly and do nothing. I checked later and all four students did return to the assembly. It was unsurprising really as I had targeted students with fixed mindsets. Why would they want to learn and work? The remaining students had moderate participation. They wrote short notes (maximum 6 lines total) and one learner asked on question – so how do we learn? They participated in discussion and feedback when required. They seemed disappointed when we finished before the assembly was concluded and asked if they could stay in the classroom. We spent some time talking about their career plans which has nothing to do with this research but is a personal interest of mine.

Students listed the following strategies as ones that would help new Grade 8 students with math: focus on class, have a positive relationship with maths, practice maths at home.

Date: 2/9/19

Venue: School 1

Length: 45 min

Present: 10 students, 2 male, 9 female.

Description: Learner Intervention, session 1

Observations: Students attended after school during the afterschool tutoring program. The classroom was very noisy outside and made the session challenging. The group participated in answering questions. Confidence in speaking English appeared to be a challenge and I ran the session slowly to make sure that students would have maximum opportunity to understand the content. Students took 1/3 to ½ page of notes, in total.

Students listed the following strategies as ones that would help a new grade 8 students: focus in class, develop passion for math/ relationship with maths work harder and practice at home.

Date: 3/9/19

Venue: School 2

Length: 40 min

Description: Learner Intervention, session 1

Present: 10 students, 7 female, 3 male.

Observations: Students attended during a school life orientation period. This group had many questions about learning, brain function and their own schoolwork. Students took ½ page of notes. They also asked for technical terms for brain structure and asked for these words to be written on the board so that they could copy them. They were genuinely excited about the idea that they could be helping Grade 8 students and participated with enthusiasm. At the end of the session they asked about my own relationship with math.

Students listed the following strategies as ones that would help a new grade 8 students: listen up in class, have a positive attitude to math, work faster, struggle but don't give up and grades will improve.

Date: 11/9/19

Venue: School 1

Length: 40 min

Description: Learner Intervention, session 2

Present: Six students, three male, three female.

Observations: This session was scheduled during the sports period and some students did not attend because they did not want to give up sports. Those who did attend were enthusiastic about the feedback session and willingly participated in making videos. They divided themselves into two groups according to the message that they felt was most important. The first group chose practice at home and take notes in class (based on the WhatsApp messages). The second group chose building neural pathways and neuroplasticity (based on the videos in the first session). The students generally showed a good understanding of Growth Mindset. Some students could not remember the second film without prompting.

Date: 13/9/19

Venue: School 3

Length: 40 min

Description: Learner Intervention, session 2

Present: Two students, one male, one female.

Observations: Students were invited to attend session 2 during an exam study period. They completed the feedback form. One learner couldn't remember any of the films without prompting. The male learner liked the WhatsApp story about the woman from the US, however, did not express a clear understanding of mindset theory or strategy. The female learner liked the WhatsApp message about math anxiety and the neuroplasticity film. She could not remember the second film without prompting. Both students said that the videos plus the WhatsApp follow-up messages were important and that they felt encouraged by the messages. Neither learner wanted to make a video.

Date: 16/9/19

Venue: School 4

Length: 40 min

Description: Learner Intervention, session 2

Present: Two students, one male, one female.

Observations: This session had to be scheduled a number of times due to clashes with end of term exams. The male learner had provided his mom's cell phone number and the WhatsApp messages had been sent to her by SMS however he had not read them. The female learner liked the WhatsApp messages and said that they had really encouraged her in the lead up to exams. Her favorite WhatsApp message was the Nelson Mandela quote. They noted that the messages that would be important to Grade 8s were not necessarily the ones important to them. The female learner talked about the importance of studying and home and the male learner valued the message about asking questions, even though he doesn't personally ask questions. The students made an attempt at videos but were unsatisfied with their efforts.

Intervention Facilitator Instructions

Introduction:

5 minutes

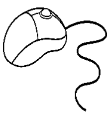
Thank the group for volunteering for the research. Ask them to think back to when they started high school maths. Explain that most young people start high school maths thinking that they will be able to do it. However, things change, algebra comes along, confusion sets in and many people give up trying. This giving up often happens because people don't really understand how their brain works and how learning happens.

Explain that the purpose of this session is to introduce them to some fun fact about the brain and learning that could really help Grade 8s to keep trying with maths. The task of the group is to understand the messages. Tell them it will help if they take some notes during the class. Give them a pen and paper to do this. Tell them to just write down what they understand from each section – they can write a few words or draw a quick picture.

Explain that when the group meets again in two weeks, they will be using the information about the brain and learning to make short video messages. These messages will encourage new grade 8s at their school next year.

Message 1: Your brain is like a muscle. The more you work it, the more it grows.

10 minutes



Khan Academy "Growing Your Mind" (3 min)

https://www.youtube.com/watch?v=WtKJrB5rOKs

Watch the video through. Then take the video back to the picture at 1 minute and freeze there. You should see three key pictures: on the left are pictures of neurons of a baby at birth, then at age 6; and a picture of neurons of animals raised alone in a bare cage, compared to animals raised with toys and other animals. On the right is a picture of a weight lifter. Ask for a volunteer to come up the front and teach the class the meaning of the first picture. A second volunteer teaches the second picture and a third volunteer teaches the third picture. Be prepared to prompt for the word "neuron". You might like to write it up where everyone can see it.

Get everyone to write down a sentence or a quick drawing to help them remember this message.

Ask if anyone has questions? Tell the group that noticing when you don't understand something and asking a question is a great strategy for building your brain.

Message 2: There's no such thing as smart or not smart at maths. Everyone can learn maths at a high level.

10 minutes

Content: Seeker "You're Not Bad At Maths, You're Just Lazy" (3 min)
https://www.youtube.com/watch?v=tg0Z--pmPog

Watch the video through. Say: Some people really believe that they are just not smart at maths and there is nothing they can do about it. If you could convince Grade 8s that there's no such thing as smart or not smart at maths, what do you think would change for them? How would they respond when maths feels hard?

Prompt: they would try harder, they wouldn't give up, they would ask questions when they don't understand, they would look for different ways to solve problems, they wouldn't panic when it feels hard.

Invite everyone to write down a sentence or a quick drawing to help them remember this message.

Ask if anyone has questions? Remind the group that asking questions shows that you are thinking things through.

Message 3: Your history with learning maths does not determine your future potential with maths.

10 minutes

Content: Sentis "Neuroplasticity" (2 min)
https://www.youtube.com/watch?v=ELpfYCZa87g

Watch the video through. Write the word "neuroplasticity" up. Ask for someone to explain, what is neuroplasticity? A simple explanation is: the ability of the brain to make new connections in response to learning or after an injury.

Ask the group if anyone knows someone who had a stroke and couldn't walk or talk, but later they got better? Ask that person to tell the story of what happened. Explain that when a person has a stroke an area of the brain is damaged and the connections there are broken. Over time though, the person is able to build new connections to restore some of the lost body movements and speech. This is a good example of neuroplasticity – our brains are able to grow!

Content: Leigh Needleman (42 sec)

https://www.youtube.com/watch?v=A9zLKmt2nHo

Watch the video. Whilst it is playing, explain that the video shows neurons making synapses or connections. This is what happens when we learn. The most connections get built when we are trying something new, when it is a little hard and when we are making mistakes. Challenge and making mistakes are part of learning. The pathways get stronger when we repeat the activity, when we make notes in class and when we practice maths at home. Hard work builds stronger pathways so that when we have to remember how to do something in an maths exam the information is easily available on a super highway of smooth strong connections. If we don't make notes and practice then it's more like trying to get information from a potholed bumpy road.

Invite everyone to write down a sentence or a quick drawing to help them remember this message.

Ask if anyone has final questions.

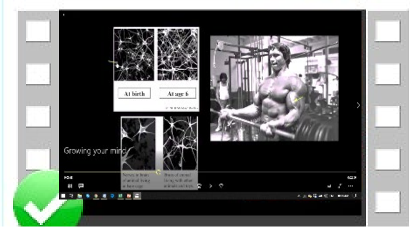
Conclusion:

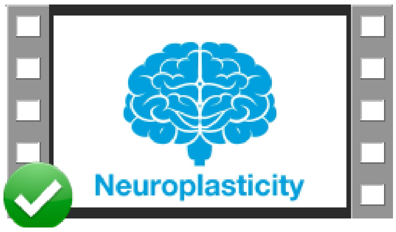
Remind the students that you will be meeting again in 2 weeks. You will be sending them a short WhatsApp message each day to remind them of the messages from this lesson and strategies they might like to try to build their own brains.

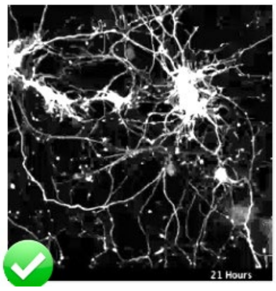
Video Session Feedback

Name:

School:







1. Write one short sentence to explain what happened in this film.	*2. How useful was this film for you personally? Circle one.*
	1 Not useful *2 A little useful* *3 Useful* *4 Quite useful* *5 Very useful*
	1 Not useful *2 A little useful* *3 Useful* *4 Quite useful* *5 Very useful*
	1 Not useful *2 A little useful* *3 Useful* *4 Quite useful* *5 Very useful*
	1 Not useful *2 A little useful* *3 Useful* *4 Quite useful* *5 Very useful*

3. Do you have any ideas about how this session could be better for Grade 8s next year?

Whatsapp Feedback

	Did you receive this message? Circle one	Please rate how useful the message is to you personally.
a. Hope you have a great day of learning. Remember every time something is challenging and you have to work at it, your amazing brain is growing stronger.	Yes/ No	1 Not useful 2 A little useful 3 Useful 4 Quite useful 5 Very useful
b. Sometimes when a maths problem is hard, we panic and can't think straight. If you get a challenging problem, try this instead: take a breath, step back and look for a different way to solve it. Your brain is amazingly creative.	Yes/ No	1 Not useful 2 A little useful 3 Useful 4 Quite useful 5 Very useful
c. Here's a learning strategy from Barack Obama, former president of the US. Don't be afraid to ask questions. Don't be afraid to ask for help when you need it. I do that every day. Asking for help isn't a sign of weakness, it's a sign of strength. If shows you have the courage to admit when you don't know something, and to learn something new.	Yes/ No	1 Not useful 2 A little useful 3 Useful 4 Quite useful 5 Very useful
d. Practice maths at home. It gives your brain a chance to build stronger neural pathways so that when you get a similar problem in an exam, you can quickly remember how to solve it.	Yes/No	1 Not useful 2 A little useful 3 Useful 4 Quite useful 5 Very useful

e. Here's an inspiring story in the US news this week. It shows that your history with learning does not determine your future. A woman from the US has served as an example of strength and inspiration after climbing the ranks at her workplace. Pam Talbert who once worked as a school janitor mixed hard work and perseverance to give rise to a booming career as an assistant principal. According to WBRZ, the mother of three had a learning disability that had not been diagnosed but this did not stop her from achieving her dreams. For someone who could not read or write, becoming an educator was nothing short of a miracle. Pam admitted her kids pushed her to greatness and forced her out of her comfort zone. The dedicated assistant principal learned and read what her kids were learning and started to pick up a few things from their books. Most times, when the kids returned from school they would tutor their mum. Eventually, she managed to go back to school and earn both her bachelor's and master's degrees at Southern University. ''It was very hard, but I persevered because I knew that it was important that I did that," Pam added. Even more inspiring, Pam and her son are headed to school to earn their PhDs from Southern University. "Despite where you are coming from, or your background, your history or where you live... It is going to be alright if you persevere. If you try," Talbert said.	Yes/No	1 Not useful 2 A little useful 3 Useful 4 Quite useful 5 Very useful

f. You get a lot of information through your senses and classrooms can be noisy and distracting. Turning on your focus is like turning on a spotlight. Deliberately paying attention in class will help your brain hold on to learning. When you notice you are getting tired, take a brain break. Turn off the spotlight and draw a picture, fiddle with something, close your eyes and breathe, move your eyes in figures of 8 or squeeze your fingers and toes. Then turn the spotlight back on.	Yes/No	1 Not useful 2 A little useful 3 Useful 4 Quite useful 5 Very useful
g. Take great notes in maths class. Even when the teacher isn't saying to write – WRITE ANYWAY! It helps you brain to process the information and form memory pathways.	Yes/No	1 Not useful 2 A little useful 3 Useful 4 Quite useful 5 Very useful
h. Nelson Mandela: Do not judge me by my successes. Judge me by how many times I fell down and got back up again.	Yes/No	1 Not useful 2 A little useful 3 Useful 4 Quite useful 5 Very useful

1. Do you have any suggestions about the messages for Grade 8s next year?

2. One new Brain Trick for Learning Maths that I'm going to start using for myself is:

Maths Beliefs Feedback

1. Chose one answer for each question and put a circle around the answer that shows how much you agree with the statement. Be honest. You know what I think now but you don't have to agree with me!

a. I believe I can always make big improvements on my maths understanding.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disa-gree

b. With enough time and effort I think I could really improve my maths intelligence level.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree

c. I think I can improve my maths cleverness quite a bit.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree

d. I believe I have the ability to increase how maths smart I am, over time.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree

2. If the research team came back in a year from now to see how I'm going with maths, one thing that would be different is:

Results, Intervention Pilot.

32 Grade 9 students from four schools participated in the first session of the intervention pilot, with 36 students in a control group.

Students at School 1 were observed to be excited to participate and liked the idea that they would be helping new Grade 8s. The session lasted 40 minutes, including set up and pack up stages. I observed the students taking half an A4 page of notes each and asked many questions about learning, brains and about my work. As this is a maths and science focused school it was not surprising that they wanted to know the names of various parts of the nervous system. The students spoke about their own relationship with maths and asked about my relationship with maths. I asked them which strategies they would expect to see in Grade 8s who really believed anyone could learn maths. They said: listen up in class, have a positive attitude towards maths, work faster, struggle but don't give up and they also noted that they would expect maths grades to improve.

At School 2 the session lasted 45 minutes. It ran a little slower than at other schools as the students were second language English speakers. I observed that the group took between a third and a half a page of notes each. They asked some questions about learning - however they did not seem confident in speaking English. When asked about learning strategies, they listed the following: focus in class, develop a passion for maths and a positive relationship with it, work harder and practice at home.

At School 3, the session ran during assembly and although students were excused from it, one learner was particularly anxious about missing assembly and chose to withdraw after ten minutes. Three other students then decided to leave with her, as they seemed unwilling to participate in note taking and asking questions, resulting in a group of five. The students had not been given the invitation to participate that I had asked the school to distribute, and they did not know why they were being sent to me. This did not give us a good start. The remaining students had moderate willingness to participate, writing notes of six lines or less in total. One learner asked one question only. They participated in discussion and feedback only when required. They listed the following strategies: focus in class, have a positive relationship with maths, practice maths at home.

At School 4 the session ran for 50 minutes due to the deep interest of the students in the subject matter. Students took between half a page and a full page of notes, more than at any other school. They asked question focused on neurobiology and learning, including asking for names of various parts of the nervous system. As this school is chronically under-resourced and under-performing, the level of interest and participation from students was surprising. They listed the following strategies for learning: work harder, focus in class, ask questions, when faced with a challenge try to get the answer another way, don't give up.

My field notes taken during and after the session indicate that students were generally responsive. Students demonstrated with questions and discussions that they understood the content. In terms of content chosen there were two sections that needed to be reviewed before Study 4. Firstly, the illustration of stroke recovery as an example of neuroplasticity was inappropriate. Many students had not experience of stroke and those who did may have had traumatic memories of affected family members. Secondly, the presenter in one of the videos spoke faster than content presented in other videos, possibly impacting learner ability to absorb the content.

The questions asked clustered around requests for additional details on neurobiology and the question "so how do we learn?" was asked at every school. The facilitator guide could be improved by the addition of a frequently asked questions (FAQ) page.

The strategies listed by Grade 9 students in session 1 differed slightly to those shortlisted in the development phase based on feedback from Grade 10 & 11 students. I added the strategies: "focus in class" and "step back and look for another way to get the answer" to the WhatsApp follow-up messages.

The final list of WhatsApp messages is listed in Table 6.5 showing the mindset message or strategy each WhatsApp message links to and the research base supporting its inclusion.

Table 6.5

WhatsApp messages Used in Intervention

WhatsApp Message	Links to	Source
a. Hope you have a great day of learning. Remember every time something is challenging and you have to work at it, your amazing brain is growing stronger.	Mindset message: Your brain is like a muscle. The more you work it by practicing maths, the more it grows.	Boaler (2016) Dweck (2013) Grade 10 & 11 students

b. Sometimes when a maths problem is hard, we panic and can't think straight. If you get a challenging problem, try this instead: take a breath, step back and look for a different way to solve it. Your brain is amazingly creative.	Strategy: When you can't get an answer in maths, step back and try a new approach.	Grade 9 students
c. Here's a learning strategy from Barack Obama, former president of the US. Don't be afraid to ask questions. Don't be afraid to ask for help when you need it. I do that every day. Asking for help isn't a sign of weakness, it's a sign of strength. If shows you have the courage to admit when you don't know something, and to learn something new.	Strategy: Ask questions	Grade 10 & 11 maths students
d. Practice maths at home. It gives your brain a chance to build stronger neural pathways so that when you get a similar problem in an exam, you can quickly remember how to solve it.	Strategy: Practice maths at home.	Grade 10 & 11 maths students
e. Here's an inspiring story in the US news this week. It shows that your history with learning does not determine your future. A woman from the US has served as an example of strength and inspiration after climbing the ranks at her workplace. Pam Talbert who once worked as a school janitor mixed hard work and perseverance to give rise to a booming career as an assistant principal. According to WBRZ, the mother of three had a learning disability that had not been diagnosed but this did not stop her from achieving her dreams. For someone who could not read or write, becoming an educator was nothing short of a miracle. Pam admitted her kids pushed her to greatness and forced her out of her comfort zone. The dedicated assistant principal learned and read what her kids were learning and started to pick up a few things from their books. Most times, when the kids returned from school they would tutor their mum. Eventually, she managed to go back to school and earn both her bachelor's and master's degrees at Southern University. ''It was very hard, but I persevered because I knew that it was important that I did that," Pam added. Even more inspiring, Pam and her son are headed to school to earn their PhDs from Southern University. "Despite where you are coming from, or your background, your history or where you live... It is going to be alright if you persevere. If you try," Talbert said.	Mindset message: Your history with learning maths does not determine your future potential with maths.	Boaler (2016) Dweck (2013) Grade 10 & 11 Maths Students

f. You get a lot of information through your senses and classrooms can be noisy and distracting. Turning on your focus is like turning on a spotlight. Deliberately paying attention in class will help your brain hold on to learning. When you notice you are getting tired, take a brain break. Turn off the spotlight and draw a picture, fiddle with something, close your eyes and breathe, move your eyes in figures of 8 or squeeze your fingers and toes. Then turn the spotlight back on.	Strategy: Focus in class	Grade 9 Students
g. Take great notes in maths class. Even when the teacher isn't saying to write – WRITE ANYWAY! It helps **you**r brain to process the information and form memory pathways.	Strategy: Take great notes in maths class	Teachers at School 1 & 3 Grade 10 & 11 maths students
h. Nelson Mandela: Do not judge me by my successes. Judge me by how many times I fell down and got back up again.	Strategy: Don't give up.	Teachers at School 1 & 3 Grade 10 & 11 maths students

I struggled initially to get a reliable format for the WhatsApp group message. The original format – broadcast – did not send to all students. I then formed a WhatsApp group with a setting that allowed students to message me but not each other. This successfully sent messages to all group members. I sent SMSs to one student's mother as he did not have WhatsApp. Unfortunately, I found out in the second session that none of the messages were passed on to him. This illustrated the importance for students to have direct access to the group to ensure that they received all content. The WhatsApp group format allowed me to see who had received the message and who had opened it. The messages were received 100% of the time and read 96% of the time. At School 2 one mother did not read or pass on the WhatsApp messages. At school 1, one learner missed one message. Otherwise it was a successful mode of delivery.

Students were invited to a feedback and integration session two weeks later. The feedback form is in Appendix C. Unfortunatley the timing of this session clashed with school assessments following which, students did not return to school. Teachers were busy with reports and were less willing to assist me in ensuring that students arrived at the session. Hence attendance was poor with only a total of ten students at session 2 across all schools. I was able to get schools to collect a further seven feedback forms however none were collected from School 2. School holidays immediately followed and then term 4, during which I did not have departmental permission to do research. For this reason it was not possible to engage further with the students in the intervention group.

Table 6.6

Student ratings of films

Film	Related message	Typical learner content note	Mean Rating	SD	n
1	Your brain is like a musle.	"You can train your brain like a muscle."	3.6	0.9	28
2	There's no such thing as bad at maths.	"The man told that there is no such thing as not smart at maths, but they are just lazy."	3.8	1.0	24
3	Your history with maths does not determine your future potential.	"They showed us how pathways in our brain worked."	3.8	0.8	28
4	Your history with maths does not determine your future potential.	"This picture showed neurons over an extended period of time."	3.7	1.2	29

As I felt that feedback from only 17 students was insufficient, I drew once again on my pool of Mathematics Scholarship students to gain session feedback on the video content from a further 12 students giving me a n=29 for YouTube video feedback. Students rated the usefulness of the film on a 5 point likert-like scale from "1", not useful, to "5", very useful. Students at session 2 were prompted if they did not remember a particular film however some students did not rate films they did not remember, hence the varying n totals. The ratings are described in Table 6.6.

All the films had mean ratings of useful (3) to quite useful (4) and there is no indication that any should be excluded. Film 2 was most likely to be forgotten and this is likely due to speed of presentation and the introduction of multiple arguments. The other films had slower presentation and fewer arguments. The last film was short and was played twice, clearly enhancing learner recall of content. Some students rated the films but noted that they couldn't remember the content. I am unable to say whether this is true or whether they were unwilling to engage in further feedback effort as these students were the ones canvassed by teachers following their absenteeism at the second session.

As part of the iterative design process, students were asked on their feedback form for ideas to make the session better and generally responded that the session was good as it was or didn't respond at all. For example, "It is already better this way, I don't see anything wrong with it." Others were positive about the potential for Grade 8s, for example "This could benefit Grade 8s next year … to have a positive mindset about maths." Some students at School 1 complained that the session was held during sport (which they didn't want to miss). School 3 students noted that they were not properly told what the session would be about, and this detracted from their experience. Two students noted that reinforcement was important and indicated that further sessions could be helpful.

Students were positive about the WhatsApp messaging saying that they felt encouraged by it and that it helped them remember and apply the content from the first session. One learner from School 4 reported verbally that the WhatsApp messages spurred her to study more than usual for her recent exams and she felt confident when she wrote her papers.

Students were asked verbally to select their favourite Growth Mindset message or strategy from the films and WhatsApp messages. Field notes were made of their answers. Favourite messages at School 1 were: practice maths at home, take notes in class and the neuroplasticity films which showed that your past with maths doesn't determine your future. No students attended the follow-up session from School 2 or completed feedback forms distributed by teachers. The School 3 students liked the news story about the woman from the United States (US) who showed that your history with learning does not determine your future. They also liked the YouTube film from session one which matched this message. At School 4 students liked the Nelson Mandela quote about not giving up and the WhatsApp message "focus in class". However, when asked to make a film they chose different messages that they thought were more relevant to Grade 8s – practice maths at home and ask questions. This was an interesting learning point for me about how to word the lesson integration task for best personal results. This feedback should be interpreted with caution as only 10 students attended the second session.

The WhatsApp messages were rated by 17 students on a Likert-type five-point scale from "not useful", 1, to "very useful", 5. All messages were rated on average between 3, "useful" and 4, "quite useful", mean = 3.7, SD = 1.2. The favourite message was the last one which was a quote from Nelson Mandela about not giving up, resonating with the design thinking recommendation of relevance, (Yeager et al., 2016). Most students did not have suggestions to improve the messages however two students suggested that the messages should be individually shorter and three suggested that there should be more messages. One learner particularly asked for more quotes and more facts. It seems like it could be useful to extend the WhatsApp messaging section of the intervention. Possibly it could include links to resources where students could research growth mindset on their own.

Almost all students wrote on their feedback form that they intended to practice more and / or take notes in maths class. Strategies listed included "taking notes in maths class and listening", "practice math at home and take a break when I become tired" and "practice, practice, practice!"   Most students noted that if the research team were to come back in a year, they would see that their maths grades had improved. Comments included "My grades would likely go up because of the researcher's amazing inspiration." Another learner wrote "My maths mark would be different because I found this program very useful, and I would be practicing math harder."

Students completed the revised Growth Mindset Assessment, as developed in Study 2. The mean mindset rating for students prior to intervention was 2.8, SD=0.68, on a 5-point Likert-type scale where higher scores indicate a growth mindset, and lower scores indicate a fixed mindset. The range of scores was 1.5-3.75. After the intervention the average mindset score was 4 with a range of 2.25-5, SD= 0.63. This improvement should be interpreted with caution. Firstly, the sample size was small, with only 17 students returning feedback forms. Secondly there was a clear demand bias in the second set of results, as students had just completed the intervention. To try and moderate the demand bias the instructions said, "You know what I think now but you don't have to agree with me!"

Discussion

The aim of this study was to develop a Growth Mindset intervention that was targeted to South African students and to pilot this. A design thinking framework was used focusing on the end user; in this case high school math students in Cape town. Recommendations followed included specificity of the intervention, use of appropriate language and mode of delivery, consideration of what arguments that would be persuasive to the target group and treating the target group as experts, thus conferring respect.

In the first stage, 12 teachers from three schools were consulted on engaging ways of delivering content. They also informed on useful study strategies. Teacher input was combined with existing strategies and mindset messages, particularly from the work of Carol Dweck and Jo Boaler. Grade 10 and 11 Mathematics scholarship students voted on which messages and strategies they felt were most important for Grade 8 maths students and these were incorporated into the intervention. Teacher and learner input was valuable in developing the key content and style of delivery.

32 students from four Cape Town school participated in the intervention. The intervention developed contains a 35 minute session, delivering three key growth mindset messages supported by YouTube videos. It is unfortunate that none of the videos are made in South Africa however students are used to watching You Tube teaching videos from non-South African sites, and this is unlikely to have impacted their learning. The first video specifically mentions "intelligence" and the students in Study 1 clearly said that they do not understand this word. The teaching illustration of neuroplasticity which refers to stroke victims needs to be revised due to the potentially traumatic reference for students who have had family members experience stroke. The facilitator guide could be improved by the addition of an FAQ page to assist with training of other facilitators. Despite these limitations, students were positive about the session as a whole and about each individual film.

In the two weeks following the session learner were sent eight WhatsApp messages to reinforce the messages and introduce new learning strategies. Students reported feeling encouraged by these messages and the messages were generally found to be useful. Some students suggested that more messages would be welcome. Extending the dosage of this phase of the intervention is something to be considered.

The post-intervention mindset scores improved by an average of 1.2 points on a 5-point Likert scale however only 17 post-scores were collected and there were clear demand characteristics in collecting these answers as part of the growth mindset intervention.

In conclusion, Study 3 developed a mindset intervention that was specific to high school mathematics students in Cape Town from disadvantage backgrounds. The intervention design considered recommendations from design thinking which emphasise an iterative process of development incorporating feedback from the end-user.

CHAPTER 7- STUDY 4, 2020-2021

Introduction

A mindset assessment tool called Thinking About Maths[55]was developed and tested during 2019, for use in South Africa. Mindset statements used in previous mindset research were tested with South African students in four, diverse, Cape Town high schools. Student

[55] The word "maths" in the name of the tool and in the items in the tool, is used in line with local convention and means mathematics.

feedback and adjustments followed an iterative cycle until wording appeared to be clear and meanings agreed upon for most students. Thinking About Maths was tested in a correlational study (Study 2) and mindset was found to correlate with mathematics performance within expected parameters. Item analysis and scale analysis reduced the scale from 16 to four questions, considered more suitable for rapid, classroom testing. Mathematics mindsets correlated with performance at $r=0.3$, $p<0.01$, 95% CI (0.01;0.35). Construct, content, and face validity were established.

Teachers and high school students consulted on the development of a mathematics mindset intervention. The resulting intervention was piloted at four Cape Town high schools with Grade 9 students. The intervention consisted of one face-to-face lesson introducing three mindset messages and some supporting strategies. This was followed by 2 weeks of WhatsApp messages, 4 messages per week, reinforcing the mindset messages and strategies using short lessons, quotes, and stories. The intervention concluded with a face-to-face integration session where students were asked to assist new Grade 8 students by making a short video about their favourite message or strategy.

The original intention for Study 4 was to reproduce the pilot study in a field-based quasi-experiment with an intervention school and a control school during 2020. However, in the week following the baseline data collection, schools closed due to COVID-19 and remained closed or only partly functioning for the following year. Even when open, visitors were not allowed on the premises. As lockdown continued into 2021, I redesigned the intervention to be fully delivered on WhatsApp with minimal support from classroom teachers and an interactive chat with trained mentors to assist with integration of the mindset messages and strategies.

In this redesign I drew on previous studies describing interventions delivered on social networking sites. Social Networking services (SNS) have been used to promote health behaviour, targeting issues such as diet compliance for diabetes, heart disease and food allergies, and supporting participants to quit smoking (Phua, 2013), lose weight (Turner-McGrievy & Tate, 2013), and promote sexual health (Bull, Levine, Black, Schmiege & Santelli, 2012), as a few examples. As best as I am aware, this study is the first to try to deliver a mindset intervention via SNS.

With the challenge of COVID-19 face-to-face restrictions, the roll-out and upscaling of SNS interventions, campaigns, and support is critical. SNS interventions have excellent potential to scale so even a very small effect at a local level will have a noticeable impact when scaled up. One informal equation that is sometimes used is *Impact = reach x efficacy,* where efficacy is the ability to produce a desired result (Glanz, Rimer, & Viswanath, 2008). SNS interventions also have the advantage of being accessible anywhere where internet is available, thereby offering services to people living in remote places who may ordinarily miss out.

There are good early indicators that SNS can be effective in changing behaviour, particularly health. A meta-analysis[1] completed by Yang (2017) found that whether the interventions were conducted on SNS alone or incorporated other platforms did not make a difference in the effectiveness of the intervention. The following mediating factors did impact the effectiveness of health interventions on SNS: topic of the intervention, study design, participant engagement level, and length of follow-up (Yang, 2017). Discussion on these four points follows.

The topic of the intervention must be relevant to the participants. Healthy groups of people were less likely to participate in a health intervention than groups who recognised that they were at risk (Yang, 2017). In Study 1, I established that high school students in South Africa are interested in discussing mathematics achievement, factors that boost achievement and those that create barriers to achievement. Additionally, I established that South African students do have mathematics mindset beliefs. Students showed varying degrees of belief that mathematics was relevant to their current or future identity, and they seemed inclined to believe that mathematics achievement was important to everyday life. For this reason, I expected my Study 4 intervention participants to be motivated about participation.

The design of an intervention is critical in effecting behaviour change. A gap exists between intentions and actions (Wendel, 2020). Good intentions and the sincere desire to change a behaviour are not enough. They need to be followed through with application of specific strategies that will lead to a change in outcomes. In the case of this study, improving growth mindset beliefs alone should be followed through with learning and studying strategies for mathematics as well as assistance in re-interpreting difficulty as a positive sign of growth. Yang (2017) found that longer follow-up is needed when using SNS to deliver the intervention.

Engagement is a key component to the success of such interventions. Engagement can be understood through various theoretical frameworks. Social support theory postulates that social support prompts participants to encourage one another (Cohen & Wills, 1985). Social comparison theory postulates that comparison of self against others prompts participation

(Livingston, Tugwell, Korf-Uzan, Cianfrone & Coniglio, 2013). A friendly competitive environment offering token achievement awards or leader boards is another way to frame engagements (Zhang, Brackbill, Yang & Centola, 2015). Programmes built on SNSs that encouraged engagement and personalised messaging were far more successful than broadscale messaging with no interactions (Yang, 2017). Hence this study allowed for group discussion and interaction with a trained mentor. Although including human interaction makes the intervention more difficult to scale, it is still significantly cheaper than individual, face-to-face support meetings, (Yang, 2017).

Regarding length of follow-up, Yang (2017) draws attention to the natural unfolding of conversations over time. SNS interventions typically try to support the development of new daily habits (Wendel, 2020). This is better achieved longitudinally. Whilst a longitudinal study, particularly during COVID-19, was beyond the scope of this study, the intervention period was extended from the original two-week WhatsApp contact in the pilot investigation to four weeks in the final study.

I pre-registered this study on OSF[56]. The aim of the study was to test the mindset intervention on students in a controlled, field-based intervention, and assess changes in mathematics anxiety, mathematics mindsets and mathematics achievement between an intervention and a control group. A secondary aim was to repeat the correlational study described in Chapter 5 to validate the previous findings.

Hypotheses

1. Mindset interventions have found to be effective in changing both mindset and mathematics performance (Aronson et al., 2002; Bettinger et al., 2018; Blackwell et al., 2007; Paunesku et al., 2015). Hence, I hypothesise that participants will show greater change in mindset scores in the experimental group than the control group, with intervention participants showing greater movement toward a growth mindset (directional hypothesis).

2. Interventions delivered via SNS are more effective if participants interact (Yang, 2017). In the mindset intervention delivered via SNS I expect that participants will show positive significant correlations between change in growth mindset scores and participation in the intervention WhatsApp chat group, per WhatsApp group

[56] Open Science Framework: www.osf.io; Registration link: https://osf.io/a9gw2/

3. Growth mindset, mathematics anxiety and mathematics performance have been shown to correlate in several previous studies (Blackwell et al., 2007; Claro et al., 2016; Kizilcec & Goldfarb, 2019; Lee et al., 2019). In Study 2, described in Chapter 5, performance correlated with mindset at $r = 0.30$, $p < 0.01$, 95% CI [0.10, 0.35] and mathematic anxiety correlated with mindset at $r = 0.28$, $p<0.01$, 95% CI [0.15-0.42]. Study 4 will repeat the study 2 analysis with a different sample, and I expect the results will be similar, that is; participants will show positive, significant correlations between growth mindset scores, mathematics anxiety and mathematics grades.
4. Following from hypothesis 3, I expect that positive correlations between growth mindset scores, mathematics anxiety and mathematics grades would be observable at pre and post-test.
5. Following from hypothesis 1, I expect that participants will show greater change in mathematics grades in the experimental group than the control group: this is a directional hypothesis with a prediction that intervention participants will show greater improvement.
6. Mathematics anxiety is associated with performance goals and fixed mindsets (Lee et al., 2014). Additionally, Oyserman (2015) explains that the way that performance anxiety is interpreted will impact on achievement. The intervention tested here assists with reframing the interpretation of the experience of anxiety and also with encouraging growth mindset strategies such as embracing challenge, and growth mindset messages including the idea that mistakes help you learn. Hence, I expect that intervention participants will show greater reduction in mathematics anxiety in the experimental group than the control group - this is a directional hypothesis that intervention participants will show greater reductions.

Participants

Students from Grades 8 and 9 in two schools were invited to participate in the study. At the intervention school 164 students agreed to participate. At the control school 141 students agreed to participate, resulting in a total sample of 305. Four Grade 9 students left the intervention school before the intervention, and they were removed from the data set for analysis of the intervention. It was challenging to get permission forms returned at the control school as the timing of the research coincided with the start of the COVID-19 pandemic in March 2020 and this reduced the number of learners who completed the study.

At the intervention school, there were nine classes and the four class teachers also participated. The nine classes were divided amongst four mentors who were volunteers and self-selected to assist with the research. The intervention school was involved in the previous three studies and is designated as School 1 in studies 1-3. The control school was selected for study 4 on the basis of having a similar geographical, demographic, socio-economic and performance profile to the intervention school. Study 2 revealed that school differences may influence the pattern of relationships between variables. The intention in selecting two similar schools was to attempt to reduce the effect of variation between schools. The two schools are situated 6km from each other in the Southern Suburbs of Cape Town. School performance and fees are shown in Table 7.1. Both schools are racially mixed but neither has any White students.

Whilst SES (socio-economic status) impacts on schooling outcomes, this is primarily through determining which school students attend. Families with more disposable income are able to send children to better resourced schools which also have better outcomes (Christie, 2014). Hence individual differences in SES cease to explain variation in performance outcomes once school differences are accounted for (Morse, 2019; Taylor & Yu, 2009)

Table 7.1

Participant school profiles.

	Intervention (School 1)	**Control**
Fees per annum (2021)	R10 000	R10 600
Matriculation Bachelor Pass (2020)	86%	80.8%

Design

This study was a field-based quasi-experiment with a passive control group, and used mixed-methods, integrating quantitative and qualitative data to promote a multi-dimensional understanding of the impact of a mathematics mindset intervention. A passive control was chosen as Sisk et al., (2018) found that there was no difference in mindset intervention effects between active and passive controls and a passive control was more feasible for a sing researcher to manage. Students from Grades 8 and 9 in two schools, were invited to participate. School 1, from previous studies was designated the intervention school as I had worked with the staff at this school in previous studies and the already working relationship best facilitated the research demands. The other school was designated the control school. This method was chosen as I could not reasonably apply a Randomised Controlled Trial within a school setting. The chosen design has the advantage of minimising intervention leakage, where students in the intervention condition within a school may have shared content with students in the control condition at the same school. Additionally, it allowed the intervention to make use of existing whole class WhatsApp groups. The disadvantage of this design became particularly evident with Covid-19 teaching restrictions. It could not account for differences between the schools in the way that they modified teaching time, curriculum coverage or assessment timing and standards. The field-based setting gave rise to multiple uncontrolled and unexpected variables.

Quantitative data collected included student mathematics grades at three time points over approximately 18 months – baseline, midline, and end line The timeline is described in Table 7.2. Baseline psychometric testing including the adjusted mindset scale developed in study 1 and 2 – Thinking About Mathematics (TAM) and the Study Orientation to Mathematics (SOM) subscale – Mathematics Anxiety (MA). End line psychometric testing repeated the TAM to assess changes in mindset.

SOM-MA was not repeated at end line as the test publisher, JVR Pscyhometrics, had changed their research policy and declined to make the subscale available for this final study. This affected my analysis plan as I had intended to observe whether the change in mathematics mindsets correlated with a change in mathematics anxiety; hence I was unable to test hypothesis 6 and needed to adjust hypothesis 4.

Collection points for baseline and post-intervention were not consistent due to variations between school assessment calendars and methods. Grade 8 is the start of high school in South Africa. Grade 8 mathematics baselines were taken from term 1 report results. Grade 9 mathematics baselines were taken from the term 4 report results, generally considered to be more reliable than term 1 results. End line mathematics results were drawn from the term 2 (mid-year) report at the intervention school and from a mid-year exam at the control school. Due to COVID-19 related school attendance complications, School 1 (intervention) decided to forfeit the mid-year exam which would have otherwise been used for end line performance data. The quantitative data collection timetable is summarised in Table 7.2.

Table 7.2

Quantitative data collection

School + Grade	Baseline math	Baseline TAM + SOM_MA	Midline math	Interven-tion	Endline TAM	Endline math
Intervention Grade 8*	March 2020 (Grade 8, term 1, report)	May-June 2020	Nov 2020	May 2021	June 2021	June 2021
Intervention Grade 9	December 2019 (End Grade 8 exam)	May-June 2020	Nov 2020	May 2021	June 2021	June 2021
Control Grade 8	March 2020 (Grade 8, term 1 report)	May-June 2020	Nov 2020		June 2021	August 2021
Control Grade 9	December 2019 (End Grade 8 exam)	May-June 2020	Nov 2020		June 2021	August 2021

Notes: TAM = Thinking About Math; SOM_MA= Study Orientation to Mathematics, Mathematics Anxiety

*In this table and the report following, school grades refer to the school grade the students were in at the start of the study. The study was completed over two school years.

The school grades were divided into 9 WhatsApp chat groups, one group per mathematics classes. The class teacher was also a member of the group, as was I. Membership in the group was not voluntary as the group was pre-existing, also serving to deliver curriculum information from the class teacher. Participation in the group discussions was voluntary. Each group had a volunteer group mentor who was trained and supported by me (outlined in more detailed below). I was blind to the identity of the group participants, as were the group mentors. We did not save each members' name and number to our phones. Participants, parents, and teachers were all sent information about the group before it commenced. Students who could no longer remember whether they gave consent to their qualitative data being collected were invited to request confirmation, and some students did so.

As detailed in the introduction, I had to deviate from the intervention format, piloted in Study 3, due to COVID-19-related restrictions on student face-to-face contact. I extended the popular WhatsApp section of the piloted intervention to become the main vehicle of delivery for the program.

The intervention followed the theory of change process outlined in Figure 3.2, in Chapter 3. The mechanisms of change were information delivered via WhatsApp and

YouTube. Integration of the information occurred via WhatsApp chats. Social support was provided through group mentors who initiated regular topic-based conversations. Finally social currency was generated through chats both in the WhatsApp group and outside the group, as observed by teachers.

The intervention was delivered via WhatsApp group chats and short YouTube video clips over a period of four weeks in May 2021. The program was called "Maths Brain Tricks[57]". On four mornings per week, Monday to Thursday, a short message was delivered in the morning. In the evenings students were invited to discuss the message. Each week followed this pattern:

Day 1 – A short story or poem introducing the key message for the week.

Day 2 – A YouTube clip link and introduction to the clip.

Day 3- A learning strategy related to the key message for the week.

Day 4 – An integration challenge or task that students were invited to participate in.

The focus for each week was:

Week 1: Your brain is like a muscle. The more you work it, the stronger it gets.

Week 2: There's no such thing as smart or not smart at mathematics.

Week 3: Your history with maths does not determine your future with maths.

Week 4: Maths anxiety doesn't mean you're bad at maths.

These topic choices and the accompanying YouTube clips were piloted in Study 3 except for week 4 - mathematics anxiety. The extended WhatsApp delivery allowed for an additional focus. Mathematics anxiety was an appropriate choice as it forms a central place in my theoretical model and I was able to establish a correlation between mathematics anxiety and mindsets in Study 2, particularly for boys. The intervention structure follows in Table 7.3. The mentor conversation prompts are reported in the Appendix D.

As process indicators, student WhatsApp interactions were collected along with initial survey feedback about their experience of the group. Drawing on the Theory of Change framework outlined in Chapter 3, process indicators gave information about engagement and uptake of the ideas introduced in the WhatsApp lesson. They were important in understanding barriers and incentives to change. Students additionally reported in the feedback surveys which of the YouTube clips they had watched.

[57] The word "maths" is used in South Africa to denote "mathematics". When there is reference to the mindset tool or intervention delivered in South Africa, the local use of language is deferred to.

Table 7.3

Maths Brain Tricks – WhatsApp delivery plan

Week Focus	Monday - Story	Tuesday – Lesson & link	Wednesday – Strategy	Thursday -Challenge	References
Week 1: Your brain is like a muscle. The more you work it, the stronger it gets.	**An inspiring story for Belhar, Cape Town:** Cleaner-turned-teacher, Natasha Dietrich, says you're never too old to learn. The 47-year-old mother of two who will receive her Bachelor of Education from the University of the Western Cape on 5 May is proof that **learning is a life-long journey.** (Edited for ease of reading: full story in Appendix D). Manie Regal, at UWC, said Dietrich's remarkable achievement is a testament to her determination. "**It takes commitment and grit to work and finish** such a demanding degree."	Brains are like muscles. The more you work them, the stronger they get. Every time maths feels hard, even when you make mistakes, your amazing brain is building new neural pathways and growing stronger. https://www.youtube.com/watch?v=WtKJrB5rOKs	Practice maths at home. Repetition helps your brain build stronger neural pathways. Lots of practice forms connections like superhighways – fast and accurate. So, when you get to a problem, you can quickly remember how to solve it. Not much practice is more like a bumpy dirt track. It takes lots of time to get to the answer and you might fall over on the way!	Nelson Mandela said, "Do not judge me by my successes. Judge me by how many times I fell down and got back up again." Challenge: What message can you cheer yourself on with when your maths work is hard? Post your message on this group.	Monday: uwc.ac.za/news-and-announcements/news/uwc-cleaner-swaps-scrubbing-floors-for-social-science-and-calculations-becoming-a-primary-school-teacher Tuesday: Aronson et al., (2002) Khan Academy (2014) Wednesday: Boaler (2016) Dweck (2013) Grade 10 & 11 maths students (study 3) Thursday https://www.inc.com/peter-economy/17-wise-nelson-mandela-quotes-that-will-inspire-your-success.html
Week 2: There's no	Slow Jo didn't know how;	Sometimes we say we are bad at maths when	Take great notes in maths class. Even when	Some people really believe that they are just	Monday My own original poem.

such thing as smart or not smart at maths.	Did the numbers go up? Did the numbers go down? Slow Jo said, with a frown on her head; I'm not really smart I've known from the start. And Slow Jo gave up. Hard thinking Lephelo Chewed on her pen She read through the problem, then read through again. I don't have it yet, But I will in the end. I will just keep trying until Maths is my friend. *Lephelo means the end in Xhosa	really we mean that we are lazy at maths. There's no such thing as having or not having a maths brain. We are hardwired for maths, just like we are hard wired for talking. So, unless a brain surgeon has chopped up your brain, stop saying you can't do maths. Find out more at: https://www.youtube.com/watch?v=tg0Z--pmPog	the teacher isn't saying to write – WRITE ANYWAY! It helps your brain to process the information and form memory pathways that will become superhighways and help you (dramatic voice) take over the world (evil laugh)!	not smart at maths and there is nothing they can do about it. Challenge: If you could convince Grade 8s that there's no such thing as smart or not smart at maths, what do you think would change for them? How would they respond when maths feels hard? Post your answers to the group.	Tuesday DNews (2013) Wednesday Teachers at School 1 & 3 (Study 3) Grade 10 & 11 maths students (Study 3)

Week 3: Your history with maths does not determine your future with maths.	**Brains can change!** London taxi drivers have to give their brains a workout when they navigate the complicated streets of London. Research suggests this has an impact on the brain. The part of the brain responsible for spatial awareness is bigger in taxi drivers compared to other Londoners. And the longer a person has been a taxi driver, the bigger that part of the brain. And you know what the really interesting part is? When they quit their job their hippocampus goes back to normal size!	The brain changes and develops throughout life – a process called **neuroplasticity**. Certain experiences cause new connections in the brain to form or strengthen, making the brain smarter by literally rewiring it. Watch how neuroplasticity works: https://www.youtube.com/watch?v=ELpfYCZa87g (https://www.mindsetkit.org/growth-mindset-parents/learn-about-growth-mindset/which-mindset-is-right)	**Don't be your history, be your future.** Barack Obama, former president of the US. Don't be afraid to ask questions. Don't be afraid to ask for help when you need it. I do that every day. Asking for help isn't a sign of weakness, it's a sign of strength. If shows you have the courage to admit when you don't know something, and to learn something new.	**Challenge:** How could you change your relationship with maths in a way that would surprise your teacher? (Good surprise – no nasties)! Post your answer here.	Monday https://www.mindsetkit.org/growth-mindset-parents/learn-about-growth-mindset/which-mindset-is-right Tuesday Sentis (2012) Wednesday https://www.azquotes.com/quote/670266 Thursday Grade 10 & 11 maths students (study 3)

Week 4: Maths anxiety doesn’t mean you’re bad at maths.	**Use your strain to boost your brain!** Experiencing anxiety when you come across a maths challenge could be your body’s way of getting you ready to push through, just like the moments before a big race. The increased heart and breathing rates give your brain the extra oxygen and blood it needs to boost you all the way through to the finish line.	If you experience maths anxiety you are not alone. But **maths anxiety doesn’t mean you’re bad at maths**. Whilst maths might come a little easier to some than others, pretty much everyone, with the right instruction and the right mindset, can learn maths. https://www.youtube.com/watch?v=xzNabs4-0fc&ab_channel=CBCNews	**Anxiety Dump** Negative anxiety thoughts can quickly get us into a bad headspace, closing down memory and creativity at just the wrong moments. Try this: notice your harmful anxious thoughts and write them down, then just leave them there in the “dump”. Research shows that doing this right before a test or challenge, frees up headspace and boosts performance.	**Challenge** Please go to this link and complete the end of group survey. It will take 5 minutes to complete and will help us to help other young people to improve their maths.	Monday: Jamieson, et al., (2010) Tuesday: CBC news (2018) Wednesday: Park, et al., (2014)

Group mentors were four young men[58] who had written their own program for high school students to support them in career decisions. They volunteered to participate in the research seeing it as a way for them to gain experience. Two 2-hour training sessions were provided on Zoom, one before the intervention commenced and one midway. I was the trainer. Additionally, daily support and feedback was provided to the mentors via WhatsApp. At the end line, mentors participated in a one-hour debriefing session and completed a survey about their experiences.

Four teachers were responsible for the nine classes. Teachers were asked to show the YouTube clip to each of their classes weekly. Teachers were also asked to complete a survey about their experiences at the end line and to report on which clips were shown to their classes. A summary of data collection about the intervention is in Table 7.4.

Table 7.4

Intervention delivery data collected

Teachers	Students	Mentors	WhatsApp Groups
Post-intervention survey – participation experi-ences, number of clips shown per class, help-fulness rating	Post-intervention survey – participation experi-ences, number of clips watched, helpfulness ratings, favorite mes-sages	Post-intervention survey – participation experi-ence, helpfulness rating	Number of participants who read messages, per day Number of interactions and students interacting on challenge days. Conversation content

Data Analysis Plan

The data analysis plan for the quantitative data was registered on Open Science Framework[59] before the intervention commenced. All statistical analysis was completed in STATA. A linear mixed model approach was use: the model regressed maths performance on two fixed effects (intervention: control versus experimental school, and time: pre-test and post-test), and treated participants within conditions as a random effect, by-participant intercepts. Mathematics mindset, mathematics anxiety, and gender were entered as covariates in the model.

There were several measures of participation, by WhatsApp group. These included: number of video clips watched in class, teacher reported class discussion on intervention content, number of individuals in each class who contributed to WhatsApp conversations and the length of these conversations.

[58] The volunteers approached me looking for opportunities to be involved in any research I was doing. Their participation was unsolicited.
[59] https://osf.io/a9gw2/

Correlations between mathematics grades, mindset and mathematics anxiety were calculated using Pearson's R. Correlations between WhatsApp group participation and change in mathematics mindset were calculated using Pearson's R. Alpha was set at 0.05 for significance tests, and for computing confidence intervals (CI) and correlations should not cross from negative to positive.

Where a student missed an exam, and their data were missing, estimates of their data were arrived at through multiple imputation. Missing values for mathematics performance and mindset were imputed in STATA using multivariate normal regression and predictive mean matching. Anomalous grades were identified by checking for within unit mark discrepancies>20, followed up with verbal confirmation from the school. Participants with mathematics grades <25 at pre and post-test were excluded as preliminary qualitative research (Study 1) showed that these students were unable to express coherent beliefs about mathematics achievement due to their general lack of participation in the subject. Where psychometric data was only available at pre or post-test, data missing in the observed dataset were imputed. There were enough complete, or near complete sets of variable data to feel confident that the imputations were good predictive models.

Results

Context

The intervention took place during a term that was disrupted by continuing COVID-19 school restrictions. The intervention school implemented a rotational attendance system in the period in question. Classes were split in two and learners attended 50% of the time, completing work at home on other days. This put an extraordinary burden on teachers to try and deliver content with shortened teaching time. Additionally, the intervention overlapped with a school holiday and Eid during week 2, both of which disrupted delivery.

The term finished earlier than anticipated due to a peak in COVID-19 infections. The early school closure fell during the end of term exam/assessment period. For this reason, the intervention school did not write an end of term mathematics paper, which was to be used for end line results. Their term mathematics mark consists of two class tests which teachers feel is not as reliable as a mid-year exam paper. The control school wrote their mathematics paper at the start of the following school term.

One of the four tutors, Anathi[60], contracted COVID-19 during the intervention and was unable to attend to his group over week two and part of week three. I covered the group during his absence, however, the disruption may have impacted interactions.

Due to the ongoing school disruptions over the 16 months of this study, the unpredictability of future COVID-19 infections and government restrictions on school delivery and the unknown impact of previous school disruptions on mathematics trajectories, it did not seem feasible to try and repeat this study at a later date in the hope of better conditions. Hence, the impact of the intervention on mathematics performance and mathematics trajectories must be interpreted with caution. However, there is a significant amount of data about the unique intervention vehicles of delivery – WhatsApp groups and YouTube clips.

YouTube Clips

Table 7.5

YouTube Clips shown in class.

Class	Clip 1 -Your brain is like a muscle	Clip 2 – You're not bad at mathematics	Clip 3 - Neuro-plasticity	Clip 4 – Mathe-matics anxiety	Total
9D AA	No	No	No	Yes	1
9E BB	Yes	Yes	Yes	Yes	4
9F AA	No	No	No	Yes	1
9G BL	Yes	Yes	Yes	Yes	4
9H BB	Yes	Yes	Yes	Yes	4
10AL/1	Yes	Yes	Yes	Yes	4
10AL/2	Yes	Yes	No	No	2
10AA	No	No	No	No	0
10BL	Yes	Yes	Yes	Yes	4

Teachers were asked to show one YouTube clip to each class each week. The range of compliance was between zero to four clips shown with AA being the teacher least likely to show

[60] All names for mentors and class groups have been changed to preserve anonymity, however, gender and race are reflected accurately in the mentor names.

clips. The number of clips shown to each class is reported in Table 7.5. Students were also given the link via their WhatsApp groups, and some watched the clips out of class time.

All students were invited to give feedback on the intervention and 37 students did so. These students watched an average of three video clips each. Four of the students were in 10AA whose teacher showed no clips in class, however the students had watched between two and four clips each, indicating that there was uptake outside of class time. The clip content dovetailed with the WhatsApp group messages. All four themes were mentioned by students when questioned about favorite messages from the intervention. There was no correlation between number of video clips watched in class and change in mathematics performance or change in mindset scores. However, students who watched videos in class engaged less frequently on the WhatsApp chat, $r = -0.35$, $p<0.01$, 95% CI: [-0.50, -0.20]. This suggests that students regulated their own intervention dose.

WhatsApp Group Engagement

Overall, most daily messages were read by most students with a slight decline in week 2 due to holiday disruptions. A very small number of students did not have access to WhatsApp and did not read the messages. Generally, this was not the case as students needed WhatsApp to keep in touch with their teachers and classes during work from home school days. Percentage of messages read is shown in Table 7.6.

Table 7.6

Percentage of WhatsApp messages read by students.[61]

n=210	**Week 1**	**Week 2**	**Week 3**	**Week 4**
% messages that were read	92%	86%	92%	92%

Each week, on day four of the message cycle, students were directly invited to interact with a challenge activity that was designed to stimulate integration of the week's teaching and discussions. Unfortunately, the end of the week was the day when mentors were least likely to elicit student interest. Table 7.7 shows number of students engaging on that day, indicating uptake of the challenge. Table 7.8 shows to-and-fro engagements and indicates breadth of conversation – how many people were involved.

[61] Messages with two ticks indicated that the message was delivered and read.

Table 7.7

Number of unique students engaging on challenge day

Class	Tutor	Week 1	Week 2	Week 3	Week 4	Total
9D N=23	Bongi	3	4	2	3	12
9E N=23	Anathi	0	1	0	0	1
9F N=22	Bongi	3	1	4	3	11
9G N=23	Olwethu	2	0	2	0	4
9H N=20	Anathi	9	1	0	3	13
10A N=25	Sipho	8	0	2	2	12
10B N=24	Sipho	7	0	2	2	11
10C n=26	Bongi	5	1	3	3	12
10D N=24	Olwethu	3	0	0	0	6
Total		46	8	15	16	71

It is evident from the results that in some classes many students engaged and in others very few or even no students engaged. The 9E class stands out as almost no students engaged on challenge days over the four weeks. This cannot be attributed to the tutor, Anathi, as the same tutor also had the most engagements over four weeks in 9H and is more likely due to the activity of the teacher who showed all 4 video clips and reported engaging her class in conversation about the content. However, Olwethu does seem to have struggled more with engaging his classes than other tutors. Overall, more students engaged in week one – 22% and the conversation had more breadth than in other weeks. Week 2 engagements suffered due to school closures, as mentioned in context, above. 7% of students engaged in the remaining weeks. However, even when students didn't actively engage in conversation, most students did read the messages.

Table 7.8

Breadth of engagements on Challenge Day

Class	Tutor	Week 1	Week 2	Week 3	Week 4	Total
9D N=23	Bongi	6	6	4	6	22
9E N=23	Anathi	1	8	1	1	11
9F N=22	Bongi	14	4	8	7	33
9G N=23	Olwethu	4	1	4	1	10
9H N=20	Anathi	14	4	1	1	20
10A N=25	Sipho	13	0	4	5	22
10B N=24	Sipho	11	0	4	7	22
10C n=26	Bongi	11	5	5	6	27
10D N=24	Olwethu	7	1	1	1	10
Total		81	29	32	35	177

There does not appear to be a relationship between mathematics performance and the number of unique engagements, the breadth of engagements, or the combination of both engagement measures and the number of video clips watched in class. See Table D5 in the appendix, for details.

There were too many uncontrolled variables to gain clear feedback about dosage. For example, some students who missed the video clip in class watched it in their own time. Some students may have read all the messages and thought about them, others might have clicked on the messages but not read them. Additionally, there is uncertainty about the strength of dose created by social currency. Social currency of mindset ideas refers to how often the promoted ideas were mentioned. As an indicator of social currency, students were asked on the feedback form to rate how often their class talked about Maths Brain Tricks during maths classes and outside of maths classes. On average, students said that the ideas were talked about sometimes, both in class and outside class, indicating some social currency. Students who were engaged in more conversations about mindset effectively increased their own intervention dose but there was no way to identify who those students were.

Mentor Engagement

When asked about mentor support via the feedback form, 96% of students said that they felt supported by their mentor (n=37). For instance, two comments from students were: "Our group mentor was a really nice guy. He was understanding and supportive." (Student from 10D) "I've enjoyed talking to Olwethu and getting his view on things." (Student from 9G).

Mentors developed strategies to engage students, including planning a time for WhatsApp conversation, using emoticons, having a good starter question, summarizing at the end, not making right or wrong judgements on student ideas, using language that the students relate to, and sharing from their own experience. These strategies were identified collaboratively during our daily check-in sessions, mid intervention training and final training debriefing.

This extract from Sipho illustrates setting a time to talk, setting the agenda, and using emoticons. The importance of good beginnings was also discussed by teachers in Study 3, Chapter 6.

> Uhm, okay guys and females, I hope you all have arrived safely back at home(s) 🙂
>
> So I am going to give y'all a 30-45 minutes head start to read over the story about Natasha Dietrich again and settle down, that's if you were busy with something else... 😉
>
> So we will start engaging with it +/- @17:30

Bongi demonstrates opening a conversation using emoticons.

> Bongi: So what did you learn from the video?
>
> The 🎤 is yours 😄
>
> Hints:
>
> ✅ growing your mind
>
> ✅ intelligence
>
> ✅ neurons

Anathi demonstrates using an opening question that many students could relate to.

> Anathi: Who knows that feeling when you thought you understood something in mathematics class, but it comes up on the test and you can't remember how to do it?

Here Bongi gives an example of summarising to bring a conversation to a close.

Bongi: Okay guys I think this enough for today. Remember that the more you practice mathematics or any other subject, the better you are able to remember it, even under the pressure of a test ☑️. Have a good evening

Engaging with students was a learning process for the mentors. Anathi uses making right or wrong judgements in one of the first sessions which is then modelled by a class participant. This was a practice that all mentors avoided going forward.

Student 1: I've learnt that your brain grows not only when you get an answer right but actually when you get it wrong

Anathi: Correct ✅

Student 2: = 💯

Anathi: Anyone else? 🎤

Student 3: That our brains r like muscles and the most effective way to grow is doing things that challenge us.

Anathi: Another Top Scorer ✅

Here Bongi used an example from his own life when he talked to his Grade 10 classes about ways to improve recall.

I once had a female in class (she was in the Idols top 16) who said she would sing the formula so that she remembers them better. Her name was Josslyn Hlenti.

Whilst there were many examples of engagements with mentors, there were also days where students didn’t engage. Apart from individual day differences, particular classes also had stronger engagement patterns than others, as illustrated above in Tables 7.7 and 7.8. Of the nine classes, there were two instances of mentors disagreeing that the group engaged in conversation with them, however in all other classes mentors agreed or strongly agreed that the group had engaged.

Student engagement with intervention themes.

Students offered diverse opinions on the themes and debated ideas. On the theme of how hard work leads to improvement, some students did not agree with the idea that people were not born smart or that hard work would always pay off. They were allowed to disagree.

I believe that working hard gives you a better chance of achieving success however it doesn't guarantee that you will be successful... Hard work is a risk and without any risks it is impossible to get what you want so wouldn't it be better if a person works hard and gets closer to what he or she wants rather than not taking a risk and achieving very little in life (Grade 10 student)

Sir we just have to accept that some people are born smart. They don't even try. Its natural but i think if you're lazy it does actually effect you. Even if "you're born smart" I still believe you should be trying harder to improve yourself. They should look at such things they might be a downfall. (Grade 9 Student)

Other students supported the YouTube clip "Your brain is like a muscle".

I find this video really interesting as someone who really struggles with mathematics when we learn a new concept as I make many mistakes and It's always satisfying when you start getting the sums right. It's always nice to learn new things and especially learn about the brain and its functions. (Grade 9 student)

It's like riding a bicycle, the more you fall the more you learn ..same as the brain the more you fail your brain tries to build itself to become stronger and to not suffer from the same mistake (Grade 9 student)

I believe everyone is born with intelligence and it can certainly be groomed. I believe that challenging your brain will improve your intelligence. I agree with the fact that it is better for the brain if you get something wrong then work and then get it right. I agree because it is easier to re-member, and therefore, appreciate something you have struggled and worked hard to get correct than something that was easy to get correct. As time goes on, we are challenged more, and that it why the neurons connect over time. That is why challenges and practice will better memory and skill. (Grade 10 Student)

During week two the students read a short research summary about the hippocampus of London taxi drivers. The hippocampus of London taxi drivers increases in size when they memorize all the streets but returns to normal size when they retire. This was an example of neuroplasticity. Olwethu's grade 10 group engaged on this topic.

Student 1: It was strange that it reduced in size again

Sipho: How does it make you feel to know it shrinks and expands 🤣

Katherine Morse: If anyone on this group knows an older person, it should give perspective. I used to be able to do grade 12 algebra and now I can only do grade 7. Lack of practice. 🙃 Kath

Student 2: I totally agree. That's y when u get older ur brain doesn't work as well

Student 2: Uncomfortable. Something that controls my body keeps changing its size😶

Student 3: True😅

On some days, classes engaged with the content on a deeper level. I provided support to the mentors when the questions became detailed, as in this engagement which followed a discussion on neuroplasticity.

> Student 1: But if someone loses memory and they are a dancer for example wouldn't they have to rely on muscle memory because they have practice it repetitively in the past but now have loss the memory of it

> Bongi: Oh that is super interesting. There are different types of memory. The more we've practiced something, muscle or problem solving, the better that connection is. So, if we get sick or have an accident the really strong connections have the best chance of sticking together. But the good news is that even if the connection breaks completely, we can build again and we can work around the damaged areas.

This grade 9 learner is thinking through the role of the school system in creating mathematics mindsets and contributing to student failure.

> Because of the systems schools and society have put in place kids that need more time to really understand things get left behind because the "syllabus needs to continue" but unless you go to a school with 20 students in a class where the teacher gives you sufficient induvial attention but the reality in SA is those schools are private and expensive so you just have to go to a regular school where if you don't get in one go, hard luck and then kids find themselves in a classroom not understanding anything because mathematics needs you to understand what was taught before so you can understand what is being taught in the present then they end up being made to feel dumb and that's one of the reasons a lot of kids drop out of school. (9F)

Apart from student engagement on the group, occasionally students would ask to directly contact the mentor or myself, interestingly, often to explain about problems with clinical anxiety and depression and how those were affecting them in the classroom. We tried to keep private interactions to a minimum for the safety of the students and where appropriate directed private queries or comments back to the main group.

It was evident from some of the student engagements that students did not understand and sometimes did not agree with the content taught in the intervention. Of the nine classes, mentors disagreed that the group understood the content in two classes. In all other classes mentors agreed or strongly agreed that the group understood the content.

Overall mentors said they agreed or strongly agreed that they put in effort and had enough training and backup support although one mentor still did not feel confident as a group leader, at the end of the intervention.

Student engagement with strategies.

Reflections on strategy emerged from the content of each week, sometimes directly related to the intervention content but more often spontaneously generated. In week one there were discussions about mistakes caused by seeing mathematics symbols in a different context or seeing problems in a new format. Part of the mindset problem demonstrated here is the idea that mathematics is about formula and procedure and not realizing that it is also about creativity and problem solving.

A student in Anathi’s Grade 9 group made a mistake with a dot.

> Anathi: 😩 Oh no! What caused you to make that mistake you think?
>
> Student 1: I thought it was a decimal
>
> Anathi: Mistakes like that are costly 🙆, so what did you learn from that?

A learner in Bongi’s Grade 9 group also commented on unexpected formats.

> Student1: I think something else that makes us "panic" is the type of equation, expression, shape etc. we are given. Cause when I was practicing I was used to working with one exponent and BOOM in the test we get 2 exponents

In Bongi’s Grade 9 group – strategy of practice and linking to prior knowledge

> Algebraic equations of exponents I practiced several times and finally got the hang of it and when the test came I just looked different to what I was practicing so I just stuck to what I knew

Here another Grade 9 student discusses the strategy of skipping hard questions and coming back to them and also the strategy of slowing down and thinking deeply

> Well because i did not remember i skipped the question and answered the other questions and as time went by eventually i remembered ..I was so relieved

Sometimes students try strategies like avoidance or giving up. These are still strategies. Olwethu explored this with a student in his Grade 10 group, without making a judgement on them.

> Olwethu: Giving up, what kind of impact did it have on your math grades??
>
> Student 1: Not a very good one, my Math grades were mediocre.

Olwethu: What lesson could one learn from giving up??

Student 2: It doesnt get rid of the problem

Students sometimes disagreed with suggested strategies, saying that they did not work. In week 4 there was a technique introduced called “Anxiety dump” – encouraging students to write down their negative thoughts before an exam. In this case, a grade 10 student responded that he didn’t like this idea and the group mentor asked for my assistance.

> Hi sir, if I'm being 100% honest that technique of writing down your negative feelings and dumping them away, doesn't really work for me... I have tried that technique in the past and it didn't work because by "physically" throwing your emotions away, it just makes me feel guilty...
>
> It makes me feel guilty in the sense that I'm throwing a part of me away. Don't get me wrong... I'm not saying that those negative emotions should overpower your positive or neutral emotions, I am saying that they should still be with you because those emotions are part of you, they are part of who you become in the future so by writing them down and throwing them away just doesn't seem right to me
>
> Kath: Thanks for this feedback and deep thinking. I think I should have called it Anxiety box. The technique is supposed to help you leave mathematics anxiety thoughts to the side so you can focus on the task at hand. There is no throwing away involved. I agree that it's important to acknowledge and accept all parts of yourself, even the uncomfortable parts. Not all techniques work for everyone. When we say research shows... It makes it sound like everyone, but it never is.

It is evident from the engagements that students did not always understand the strategies, and as above, may not have agreed with them. Of the nine classes, two mentors disagreed that their class understood the strategies. For the other seven classes mentors agreed or strongly agreed that the class understood.

There were many other examples of engagement with strategy - however, referring again to Table 7.7 and 7.8, engagement was not uniform. There were also many examples of silence[62].

Overall, mentors agreed or strongly agreed that the groups enjoyed the intervention. There was only one class where the mentor disagreed and in this class the group also had not engaged and had not shown signs of understanding the content or strategies taught.

Teacher Participation

[62] The WhatsApp chat downloads are not presented in the Appendices as they contain personal information including phone numbers and occasionally names.

Four teachers covered the nine classes in the intervention. In general, teachers were not supportive of the program. They reported that it was difficult to show the YouTube clips as equipment was not always available and set up. Teaching time was already compromised by COVID-19 timetabling restrictions, and they resented further interruptions to their class. Three of the four did not think the program was helpful for their classes and would not recommend the program to another school.

Table 7.9

Teacher feedback on the program

Class Teacher	**I talked with my classes about Mathematics Brain Tricks**	**I kept up with the WhatsApp chats.**	**I think the program was helpful for my classes.**	**Comment**
10D/ 9G	Strongly agree	Disagree	Agree	COVID-19 made this very difficult with all the setbacks. In person I think it will have a better impact. However, I really appreciate anything that tries to uplift the kids. Thank you
10C/9D/9F	Strongly disagree	Agree	Strongly disagree	This is not normal times…and we are pressed for teaching time and extra pressure of completing the syllabus... And then on top of this, taking extra time out of my lesson, to set up to watch a video. It took longer to set up ALL the equipment than to watch the video... Maybe being more adaptable to the times would be better.
10A/10B	Disagree	Agree	Disagree	It was really difficult to keep up with showing videos and teaching content. Our time is so limited with each class now during COVID-19 and it takes away from teaching time. It is not only about showing a video but takes lots of time to actually set everything up .... Would have been helpful if kids had to watch the video by themselves.
9E/9H	Agree	Agree	Disagree	This is a good initiative, and the videos were really good.

Hypothesis 1 & 2 - Change in Mindset Scores

In the intervention school, mindset scores shifted towards growth mindset from a mean of 3.85, SD = 0.79, to a mean of 4.26, SD = 0.57 between baseline and end line. However, mindset scores similarly shifted in the control school to a higher mean and lower standard deviation. Whilst passive controls can introduce the potential for placebo effects, this did not eventuate in this study. A paired t-test showed that the change in scores at both schools was significant at $p < 0.01$, see Table 7.10.

Table 7.10

Change in mindset scores from baseline to end line.

		Intervention n = 81		**Control n = 55**	
	Mean	Standard deviation	95% CI	Mean	Standard deviation
Baseline	3.89	0.78	3.67-4.02	2.14	0.66
Endline	4.24	0.55	3.67-4.02	4.37	0.50
paired t (endline – baseline)	t (79) = 2.56*			t (54) = 16.79*	

* p < .01

A one-way ANOVA was conducted between schools for base line and end line mindset means. Whilst there was a significant difference between schools at baseline, $F(1, 1) = 362.25$, $p = 0.001$, there was no significant difference between the two schools at endline $F(1, 1) = 2.05$, $p = 0.15$; contrary to my first hypothesis. As the control school had a lower baseline mindset, it is unsurprising that he improvement in the control school was significantly different to the intervention school in a one-way ANCOVA, $F(1, 1) = 24.37$, $p = 0.001$.

One-way ANOVA for change in mindset scores between classes also shows no significant difference, contrary to my second hypothesis. This was true even when class interactions were taken into account. Class interaction measures included teacher report of number of video clips watched, teacher report of class discussions on intervention content, number of individual students who participated in WhatsApp conversation and the length of those conversations. As noted above, it seems that students self-regulated intervention dose by engaging less on the group if they had more engagement in class and by watching YouTube clips in their own time if they missed them in class.

Hypothesis 3 & 4 – Change in Mathematics Performance

Mathematics scores for the baseline, midline, and end line measurement points are shown in Table 7.11. In both schools there was a significant decline in average scores between baseline and end line, 18 months later. At the intervention school, Grade 8 and 9, the large drop in mathematics grades occurred from baseline (pre-COVID-19) to midline (3 months into school closure). After that, Grade 8 grades appeared to stabilize at the new, lower mean although standard deviations continued to increase. In Grade 9, there was mark recovery at the end line. Anecdotally, teachers at the intervention school said that they tried to modify the syllabus and subsequent testing so that a smaller amount of work was taught effectively and tested rather than trying to teach and test the whole syllabus with reduced student contact. This may explain the initial decline prior to syllabus adjustment and subsequent improvement after syllabus adjustment.

Table 7.11

Change in mathematics grades by school and grade, over three time points.

	Time	n	Mean	SD	Range
Intervention Grade 8	T1	88	76.95	10.89	47-98
	T2	88	69.57	11.27	43-93
	T3	88	70.13	14.04	32-96
Intervention Grade 9	T1	75	66.29	13.54	39-90
	T2	75	55.81	18.41	11-93
	T3	72	63.42	19.79	18-96
Control Grade 8	T1	83	56.67	24.42	16-100
	T2	84	57.33	23.13	0-98
	T3	84	60.69	20.48	24-98
Control Grade 9	T1	57	61	20.65	20-96
	T2	55	45.36	23.84	10-90
	T3	51	32.58	27.78	0-88

Note: T1 = baseline, T2 = midline, T3 = end line.

At the control school, Grade 8s stands out as there is no decline in grades, rather there is a slight upward trajectory and decreasing standard deviation. Grade 9 however, shows the same pattern seen at the intervention school with a drop in grades and increased standard deviation. The intervention school has decreased standard deviations across both grades, likely due to them being able to utilize a mathematics entrance selection test, not available to the control school. Results are show in Table 7.11.

Mathematics scores declined for both males and females alike with very little difference between baseline and end line means or standard deviation by gender. These results are included in Appendix D, Table D1.

Study 2 was a correlational study to establish the validity of the mindset assessment tool developed in Study 1 by examining the correlation between mindset and mathematics performance. Study 4 offered an opportunity to repeat this study with a different sample and potentially establish reliability for the mindset tool. Study 2 included students from 4 schools chosen for income diversity. Study 4 included students from two schools with similar income profiles. The mean study milieu score for Study 2 participants was 37.6, SD = 6.96 and for Study 4 participants was 40.8, SD = 6.26, slightly higher, but as expected from the school selection. Study 4 baseline correlations were compared to Study 2, to establish reliability for the assessment tool and to re-examine the correlation patterns between mindset, anxiety and mathematics achievement, by gender, as Study 2 revealed an interesting gender difference.

Table 7.13

Comparison correlations between Study 2 and Study 4

	Male		**Female**	
	Study 2	Study 4	Study 2	Study 4
Math & Anxiety	r=0.40**	r= 0.28**	0.03 n.s.	0.24**
Math & Mindset	r=0.11 n.s.	r=0.23*	0.38**	0.27**
Mindset & Anxiety	r=0.40**	r=0.19 n.s.	0.22*	0.16*
n	77	144	122	163

*p<0.05, **p<0.01 n.s = not-significant

In Study 2 there were distinct gender-based correlation patterns. There was no significant correlation between mindset and mathematics performance for males and there was no significant correlation between anxiety and mathematics performance for females. These patterns are not repeated in Study 4.

The correlation between mathematics performance and mindset is significant and within the expected range based on previous studies, as described in Chapter 5. In this study mindset correlates with performance at $r = 0.25$, $p < 0.01$, 95% CI [0.13, 0.37] for the full sample. Mindset correlates with anxiety at $r = 0.24$, $p<0.01$, 95% CI [0.14, 0.34]. This establishes reliability for the mindset assessment tool within South Africa and supports the third hypothesis regarding the relationships between mathematics performance and mindset and performance and anxiety.

The expected correlation between change in mathematics performance and change in mindset from baseline to end line is non-significant, likely due to mindset scores increasing uniformly across both schools, thus failing to provide corroborative evidence for hypothesis 4.

Hypothesis 5 – Intervention versus Control Group

Collecting end line scores was complex due to COVID-19 related school closedowns. Whilst baseline scores were collected in-person, on school computers, during class-time, end line scores were collected via a WhatsApp link to an online questionnaire distributed after school.

Missing mathematics performance and mindset values were imputed in STATA using multivariate normal regression and predictive mean matching. Five imputation data sets were generated. The number of imputations per variable is shown in Table 7.14. Very little mathematics performance data was missing which is likely to have improved accuracy for imputation of missing mindset scores. 30/307 mindset scores were missing at baseline. The end line mindset scores had many missing values with only 140/307 complete, however, an effort was made to ensure that both schools and all grades were reasonably represented and the fact that other data sets were nearly complete improves the accuracy of the imputations. The missing scores were assumed to be missing at random. I suspected that students who had poorer mathematics grades would be less likely to submit their endline data. However, there was no significant difference between students' mathematics scores at midline and whether they submitted end line psychometric data, in a one-way ANOVA. Also, there was no significant difference in mathematics trajectories and submission of end line psychometric data, in one-way ANOVA.

Table 7.14

Imputed values for mathematics performance and mindset

Variable	Complete	Imputed	Total
Math0	303	4	307
Math1	302	5	307
Math2	295	12	307
Mindset0	277	30	307
Mindset2	140	167	307

Notes: math0 = math at baseline; math1 = math at midline; math 2 = math at endline;

mindset0 = mindset at baseline, mindset2 = mindset at endline.

The imputed models had very similar means and standard deviations to the original data. The original data and model 1 are shown in Table 7.15. All models are shown in Appendix D, Table D2.

Table 7.15

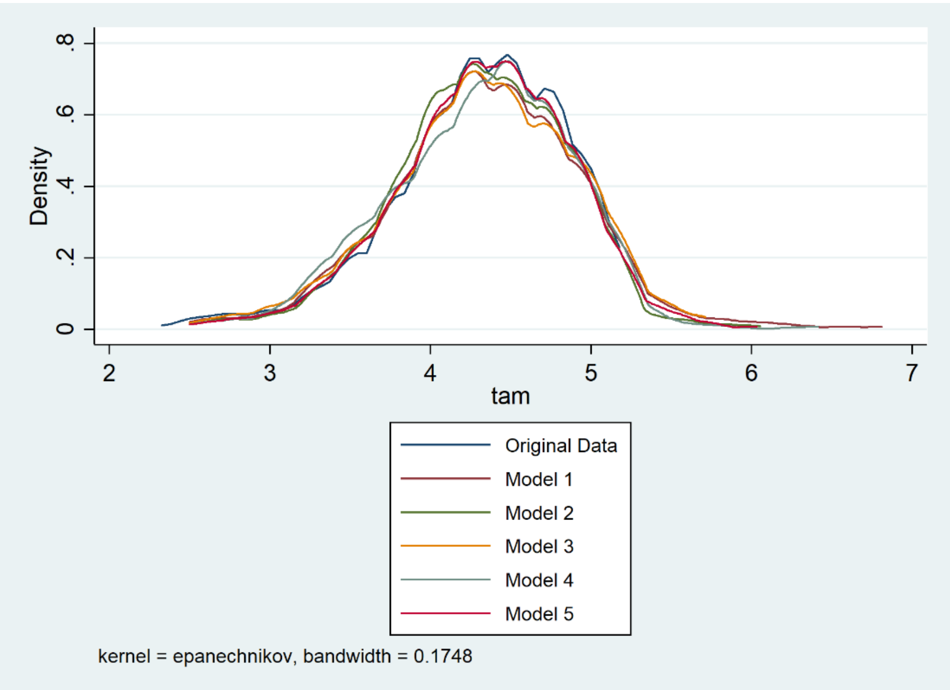
Comparison between original data and imputed data used in model 1.

	Original Data				Model 1			
Variable	n	Mean	SD	Range	n	Mean	SD	Range
Math0	303	65.76	19.59	16-100	307	65.86	19.53	16-100
Math1	302	58.05	20.80	0-98	307	57.95	20.79	0-98
Math2	295	59.32	23.60	0-98	307	58.87	23.76	0-104.9
Mindset0	277	3.18	1.10	0-5	307	3.17	1.10	0-5.52
Mindset1	140	4.31	0.52	2.5-5	307	4.37	0.57	2.5-5.84

Over 50% of end line mindset scores were missing. To confirm that the mindset imputations were a good fit, the distribution of scores in the original dataset was plotted against the imputed data. This is shown below in Figure 7.1. The density graph shows that there is minimal variation between the original data and the imputed data. The imputed models have small amounts of data generated beyond the actual variable range, which is expected for imputations.

Figure 7.1.

Density distribution of mindset original data and imputed models.



The imputed models also had similar coefficients and standard errors to the original model, suggesting that the imputations were a good fit with the original data set. Although the mindset assessment scores had a negative coefficient in the original data set, it is only marginally negative at -0.31. The comparison coefficients are in Table 7.16.

Table 7.16

Coefficients and Standard Error for the mixed model linear regression based on the original data set, compared to that based on the imputed data set

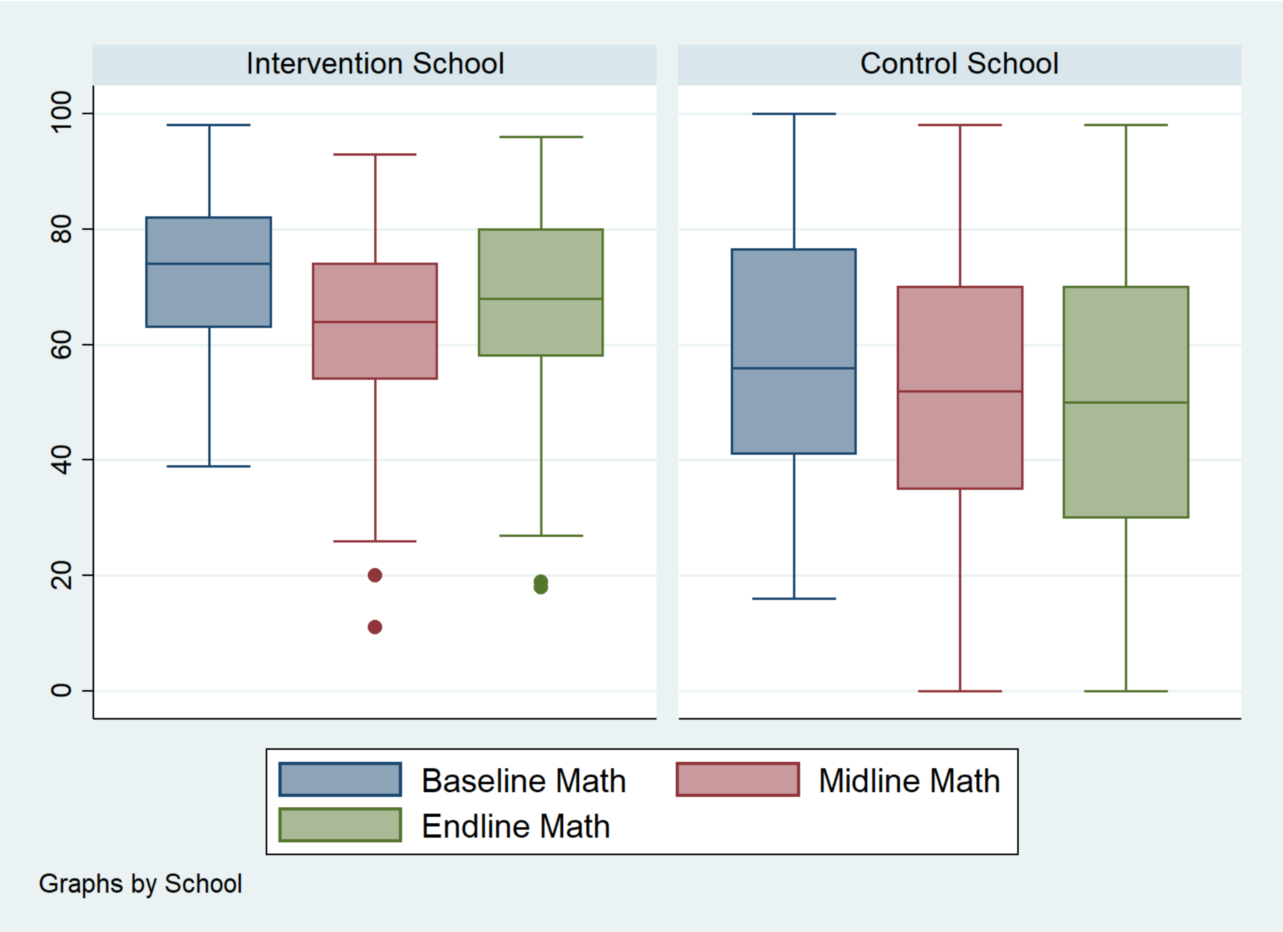
Variable	Original		Imputed	
	b	SE	b	SE
Time	-1.71	1.32	-2.87	1.32
School	-13.32	3.08	-9.43	3.04
School#Time interaction	-2.86	2.46	-3.92	2.45
Gender	-0.06	1.83	-0.43	1.82
Study Milieu	0.61	0.56	0.57	0.51
Mindset	-0.31	1.34	2.21	1.37

A mixed-effects linear regression model was built to test whether mathematics performance changed over time and school (intervention), with an interaction between time and school to specifically test the intervention. Gender, mindset and study milieu were added as covariates, as described earlier (and in the pre-registered data analysis plan on Open Science Framework). The model built using the original data set showed no significant effect on mathematics performance for school over time. Nor was there a significant effect for mindset on maths performance. Study milieu was significant in the model at b = 0.61, SE(b) = 0.56, 95% CI [0.30, 0.90], $p < 0.01$, indicating that mathematics performance is strongly related to study environment. In consideration of students learning from home during school closure, home study environments and access to resources were likely of even greater importance than during a regular school year. The random effects parameters showed high variation between students, SE = 15.69, 95% CI [33.60, 98.10], more so than between schools. Postestimation intra-class correlation ICC= 0.22, SE = 0.68, 95% CI [0.11, 0.38]. Further model details are included in Appendix D, Table D3.

After data imputation the mixed-effects linear regression model was repeated using the pooled imputed data sets. With imputed values there was a significant interaction effect between school and time indicating that the intervention may have made a difference to mathematics performance, b = -3.9, SE(b) = 1.43, 95% CI [-6.76-, -1.07], $p < 0.01$ providing tentative support for hypothesis 5. The negative coefficient indicates that School 2, the control school had worse mathematics performance than School 1, the intervention school, when all aspects of the model were taken into consideration. The boxplot in Figure 7.2 shows that whilst marks declined at both schools between baseline and midline (after Covid), end line marks at the intervention school recovered after the intervention, but performance at the control school continued to decline.

Figure 7.2

Mathematics marks at baseline, midline and end-line



In the imputed model, study milieu was still significant with similar values at b = 0.57, SE(b) = 0.51, 95% CI [0.28, 0.94], p < 0.01. Mathematics mindset was significant in the multiple-imputation model at b=2.21, SE (b) = 1.06, 95% CI [0.10, 4.32], p<0.05. The second model is reported in more detail in Appendix D, Table D4.

Discussion

WhatsApp Intervention

It has been central to the development of this intervention that all aspects from the mindset assessment questions, through to content and medium of delivery, be culturally appropriate and relevant to disadvantaged students in Cape Town. For this reason, teacher and student consultation was considered immensely valuable. The final intervention "success" is at least partially measured by the student appreciation of the content and interaction with medium of delivery, forming process measures.

Four YouTube clips were shown to students. Mathematics teachers were asked to show these during mathematics classes. It was unexpected that some teachers did not comply with this request and three of the four teachers expressed distress at this expectation during the COVID-19 compromised teaching conditions. However, there was evidence from the student intervention feedback that even when teachers did not show the clips, students still accessed two or three of them during their own time. All four clips were mentioned by students as amongst their favorite messages indicating that the medium of delivery was appropriate for teenagers and that each clip added subjective value to the intervention.

There was no relationship between the WhatsApp group interaction level, or number of videos watched or teacher self-rating of participation in class conversations and change in mindset or mathematics scores. This was contrary to the expectations outlined in my first hypothesis. There was good evidence that students self-regulated dosage by watching missed class videos in their own time and by participating more on the WhatsApp groups if there was less interaction in class time. This has interesting implications for stipulated dosage in experimental interventions. If dosage is driven by participant choice to engage with available material, then possibly the length and depth of intervention set by the researcher is of less importance.

WhatsApp as a medium of intervention delivery attracted student attention, indicated by almost all messages being read. It was also a medium where students felt comfortable to share and debate ideas, as indicated by the interactions within the groups. Interaction was not uniform, day to day. Some groups had more consistent engagement than others over the course of the intervention, as indicated by the number of engagements on challenge days and the depth of these engagements. The content of the engagements on WhatsApp shows that the key intervention messages were understood by some students and those students were able to integrate learning into their own situation. Students also used the WhatsApp platform to troubleshoot problems, covering both strategies from the intervention and introducing new strategy content.

When students did engage on WhatsApp, their engagements showed that they did not always understand the lessons or strategies or may have understood but still disagreed. Mentors did not attempt to convince or correct students, rather they tried to create a forum for open discussion of ideas. Mentors found that there were some strategies that assisted group engagement including: setting a time for the conversation, having a good opening question, using emoticons and teen-friendly language, using examples from their own lives and summarizing at the end. The mindset ideas had some social currency measured by student reports of in-class and outside class discussions and observed participation in the chats. Whilst the program was not unpopular with students they did not report it becoming a popular topic of conversation. It is likely that COVID-19 was the topic with most social currency throughout the duration of Maths Brain Tricks. Running the program at another time may generate more social currency.

Hypothesis 1 & 2- Change in Mindset Scores

Mindset scores significantly improved from baseline to end line, 18 months later, at both schools, although improvements were only expected at the intervention school leading to a rejection of my second hypothesis. There are several possible explanations for this. Firstly, whilst the end line test incorporated all the baseline questions, the baseline had additional SOM items that were not repeated at the end line due to the publisher, JVR Psychometrics, withdrawing from the research partnership. The additional questions at baseline may have assisted in disguising the mindset questions and reducing demand characteristics. Hence, the end line measure for mindset may not be as reliable when presented in a reduced question set.

A second explanation may arise from the unique period, coinciding with COVID-19 school closures and at-home learning. It is possible that schools attempted to compensate for lack of teaching time by encouraging learners to work hard and have a positive mindset towards their work. Some online learning sites used more frequently during COVID-19 promote growth mindset. Khan Academy[63] is one such example popular in South Africa. Hence the control school may not have been a completely passive control given the unusual teaching circumstances.

There was a significant amount of missing end line data for mindsets with only 140/303 participants returning results leading to the speculation that students with lower marks may have been less likely to return their forms, however it was established that the data was missing at random.

[63] https://www.khanacademy.org/

Hypothesis 3 & 4 – Change in Mathematics Performance

Study 2 and Study 4 baseline produced a similar positive correlational relationship between mathematics performance, mindset and anxiety, so the third hypothesis is accepted. This repeat measure adds reliability to the mindset assessment tool developed for use in South Africa.

The differing patterns of correlation between mindset, anxiety and performance for males and females in Study 2 were not observed in Study 4. There are two possible explanations for this. The findings in Study 2 may have been ‘false positives’, highlighting the importance of repeating experiments to check findings. A second explanation may be that the samples were different in ways that affected the correlations. The Study 4 sample had higher study milieu scores, an indication of family and school resources. In Study 2 boys had a strong correlation between poor study milieu and math anxiety whereas there was no significant correlation for girls. It is possible that the gender differences only exist in the poorest contexts.

Having established the stable relationship between mathematics performance, mindset and anxiety, I expected that changes in these variables over time would reflect the same relationship. However, in this study the control school showed the same change to growth mindset scores as the intervention school, as noted above. This meant that the change in variables did not correlate as expected, leading to the rejection of the fourth hypothesis.

Hypothesis 5 – Intervention versus Control Group

There was general mathematics performance decline across the 18 months of the study. The intervention school cohort was compared to the Study 2 cohort from the same school, prior to Covid-19. The performance decline was similar. The reliability of the mathematics marks between schools is in question due to Covid-19 related changes to syllabus coverage, delivery and assessment. Under normal conditions the schools would have followed very similar teaching and assessment trajectories.

Missing data was imputed, and five models were generated. The models showed good fit, likely due to the fact that several of the variable data sets were complete or near to complete. These models were pooled and used to build a mixed-effects linear regression model. The model showed a significant interaction effect between school and time (baseline, midline, end-line) and mathematics scores. Mathematics mindset was also significant even when study milieu was controlled for (related to family and school resources and environment and accounting for around 60% of the learning gap between richer and poorer students) (Shepherd 2016).

Students at both schools improved their mindset scores over the course of the study and improved mindset is related to relatively better mathematics performance - however, the intervention school still showed a performance advantage over the control school, considering baseline, midline, and end-line results, hence the fifth hypothesis was tentatively supported, pending a repeat study under normal teaching conditions. Notwithstanding the weaknesses of the intervention study, already noted, the relationship between mindset and mathematics performance have been established by both international research and my own repeated correlational study. Hence, we can be reasonably certain that the relationship between mindset and performance in this model is an accurate representation. However, the intervention school still had an additional boost, over the control school. One or more of the following ideas might explain the interaction effect.

Students at the intervention school were not only introduced to mindset ideas, but they were also introduced to specific strategies to implement these ideas. These strategy lessons were reinforced by mentors in WhatsApp conversations. Mindset proponents are clear that believing is not enough. Belief needs to be followed through with action (Dweck, 2013). Bettinger et al., in their Norwegian adaption of the PERT mindset program, added measures of perseverance and willingness to try more difficult questions (2018). This was of particular concern in South Africa where students are often given the message "you can be anything" without the necessary tools and resources to realise their aspirations (Morse, 2019). The boost to performance at the intervention school over the control school, even with similar improvements in mindset scores, can be explained by the specific teaching of strategies and the chance to integrate these ideas through discussion.[64]

Individual change in mathematics interactions is not only explained by a growth mindset. The model illustrated in Figure 3.1 can be referred to. Change begins with establishing psychological relevance, seeing growth mindset statements as consistent with current and future identity. This influences an individual to interpret difficulty as positive, creating an opportunity for learning and growth. Finally, the individual must take actions to optimise learning by developing strategies and habits that support learning, such as taking notes in class. The intervention did not just teach growth mindset beliefs but offered students an opportunity to integrate these ideas through group conversation, developing psychological relevance. This was followed through with

[64] The control school was offered the intervention in early 2022, which could potentially correct any gaps between mindset messaging and strategies, as the control school did significantly increase in mindset scores but did not show the expected accompanying increase in mathematics grades. To date, the school has not accepted the offer.

teaching of new ways to interpret difficulty, based on an understanding of neural development and reinterpretation of physiological arousal. Finally, strategies were explicitly taught through the intervention content. The WhatsApp chat platform gave students additional opportunities to discuss strategies with each other. Hence, although students at both schools improved in their mindset scores, students who experienced the intervention (mindset + reinterpretation of difficulty + strategies) had an advantage over students who did not have the intervention, and this is evident in their mathematics grades.

Table 7.16

Theory of Change - original assumptions and observations regarding the assumptions.

Assumption	Result
1.Dose of information and integration is sufficient	Although different classes had varying doses of the intervention, dose was sufficient for the intervention school to show an advantage over the control school.
2.There will be students in the sample group who have fixed mindsets and below average mathematics performance resulting in a "can't do mathematics" identity	Student interaction on the WhatsApp groups shows that the intervention was relevant.
3.Brief strategy prompts will be sufficient for students to engage with new strategies	Students engaged in discussion about strategies and listed strategies as something that would visibly change in their approach to mathematics.
4.Mathematics assessments will have internal consistency	Due to the COVID-19 teaching conditions, the reliability of the dependent variable is uncertain. Reduced teaching time should have affected mathematics results negatively. Analysis comparing mathematics results in the intervention school at the time of the study and in a previous cohort (Study 2) show a similar pattern over time. Teachers at the intervention school explained that they had reduced the content taught and tested for the COVID-19 affected cohort.
5.The relationship between high mathematics achievement, low mathematics anxiety and growth mindsets is correct.	The validity and reliability of the mindset assessment was confirmed through a repeated correlational study using the baseline of Study 4 and comparing it to Study 2. The relationship between

	low mathematics anxiety and high achievement was not confirmed.
6.The effect of confounding variables is minimized.	There are always uncontrolled variables in a field experiment. Repeating the intervention in different contexts is the only way to be sure that it was the intervention that caused the interaction effect between schools over time.
7.WhatsApp will be an appropriate method for delivery of a social psychology intervention.	WhatsApp was a successful mode of delivery with nearly 100% of messages read and substantial engagement.
8.WhatsApp group will be a safe and supportive chat mechanism	Students shared openly even though their teacher was present on the group.

There are additional possible reasons why the intervention school may have improved beyond the control school. Firstly, the social support offered by the mentors at the intervention school may also have been influential in boosting mathematics performance. Future iterations of this study should add a control group receiving non-specific support via WhatsApp. Secondly, the baseline mathematics grades in the control school were lower than those in the intervention school. The two schools were selected because they are similar in racial profile, SES and academic matriculation mathematics performance. This should have reduced the chance of selection bias. Even though baseline grades were controlled for in the MVA there still may be selection bias with stronger performing students possibly more likely to maintain or improve grades and weaker performing students possibly more likely to decline.

Study Assumptions and Anticipated Risks

Whilst these results seem positive, the quasi-experimental, field-based model of the study introduces uncertainties. Referring to Table 3.3, there were anticipated risks associated with the assumptions of this study. Observations about these assumptions and risks are outlined in table 7.16.

This quasi-experiment was run with one whole school in the intervention condition and one whole school in the control. The whole school intervention and whole school control design was chosen to minimise intervention leakage and to make use of the existing class WhatsApp groups in which students already reliably participated. The schools were chosen because they were similar in terms of mathematics achievement and demographic profile of students. However, whilst the design should have strengthened the outcome, the unfortunate overlap of COVID-19-related school close downs makes the reliable measurement of the dependent variable between schools less certain. Repetition of the intervention, after COVID-19 teaching instabilities have passed, will help establish its reliability.

In conclusion, Study 4 yielded additional data suggesting the validity and reliability of the mindset assessment tool developed for South African use – Thinking About Maths. There is a positive and significant correlation between mathematics mindset and performance for South African students. The intervention delivered on WhatsApp was well accepted by students who actively engaged with the mindset messages and strategies. Mindset scores improved for both intervention and control school participants, but the intervention school still showed an advantage over the control school. Apart from mindset messaging, the intervention also taught students to reframe difficulty as worthwhile, rather than something to avoid. Additionally, the intervention explicitly taught strategies to apply mindset concepts. It is likely that reframing and /or strategies gave the intervention school an advantage over the control school. This emphasises the importance of teaching follow-through actions and not just mindset beliefs alone.

CHAPTER 8 – CONCLUSIONS

This research began with the desire to better understand variation in mathematics performance for disadvantaged youth in South Africa. I was interested in whether mathematics growth mindset theory, assessment and interventions developed in the United States could be applied to a South African context. I aimed to develop a contextualised assessment tool and establish validity and reliability for it. I selected other variables that I thought might reasonably contribute to mathematics performance, specifically mathematics anxiety, study attitude and study milieu (or environment). I intended to compare the amount of variance explained by mindset to these alternative variables. Further, I planned to use a consultative design-based method to develop and pilot a South African mindset intervention and assess whether a mathematics mindset intervention could significantly impact mathematics performance in a field based quasi-experiment. In this final chapter I highlight findings that may have applications.

"Thinking About Maths" – A South African Mindset Assessment

I found that students did express mathematics mindset theories. Using an iterative process, students assisted me to adapt the wording of a pre-existing mindset tool so that there was general conformity of understanding on the meaning of the statements.

I was able to refine the assessment tool and establish validity for it, finally naming it "Thinking About Maths". In Study 2, the mindset results correlated with mathematics performance at $r = 0.30$, $p < 0.01$, 95% CI [0.10, 0.35], which was within the expected range (see pp 63-64). The final questions selected for the mindset assessment tool, "Thinking about Maths", are described in Table 8.1.

Table 8.1

Final items selected for "Thinking About Maths" mindset assessment

Item	
1	I can learn new things but I don't have the ability to change how smart I am at maths.
2	With enough time and effort I could significantly improve my maths.
3	I don't think I can change how clever I am at maths.
4	I believe I have the ability to increase how maths smart I am, over time.

In Study 4 I repeated the correlational study (Study 2) with a different sample and achieved similar results, $r = 0.25$, $p < 0.01$, 95% CI [0.13, 0.37], establishing reliability. The weaker correlation in Study 4 is likely due to the more homogenous sample which were selected from two schools with very similar performance and SES profiles (i.e., attenuation due to restriction of range). The sample in Study 2 was selected from four schools with very different performance and SES profiles.

Thinking About Maths is a tool that easily can be used in future research as well as in school or scholarship-based testing. The administration is quick and doesn't require any specific training. The tool uses simple language that English second language speakers can understand. It also avoids the use of the word "intelligence" which does not have a consistently understood meaning in the South African context, a finding from Study 1. These adaptations improve its content and construct validity in the South African context.

A note of caution, the assessment tool is not designed to be a school-based measure of achievement, rather it is designed to identify students who might benefit from targeted interventions. It should also be noted that students with fixed mindsets are not necessarily hampered in their mathematics achievement, a fixed mindset does not necessarily equate to underachievement. California's CORE districts are experimenting with including non-cognitive skill measures, inclusive of mindset, as part of the school accountability systems (West, 2016). This move is controversial and Duckworth (proponent of the Grit test), Yeager and Dweck have all spoken against self-rated non-cognitive testing as a fair or reliable measure between schools (West, 2016). However non-cognitive skills measures may be of assistance in identifying students who are at risk of a declining performance trajectory and the often-associated non-compliant school behaviour so that timeous intervention can be offered (Soland & Kuhfeld, 2021).

In terms of application, there were indications that the test may be more effective if embedded in a longer list of questions, to better disguise their intent. In Study 2, I randomly combined mindset questions with questions from the SOM. In Study 3, I only presented the mindset questions and students who gave feedback on this pilot intervention said that the undiluted questions were repetitive. Students who completed the Study 4 end line assessment, also undiluted questions, were more likely to rate themselves as having a growth mindset regardless of whether they were in the intervention or control group. One possible reason for this is that the repeated similar questions resulted in a social desirability bias, that is, the purpose of the questions was revealed to the students, and they discerned that growth mindset was a desirable behaviour.

Explaining Variation in Mathematics Performance

I was interested in the role of mathematics anxiety and mathematics mindsets in explaining mathematics performance. I hypothesised that there would be a relationship between the two, such that a growth mindset would correlate with reduced mathematics anxiety. I also considered that there might be an interaction effect between the two. In addition, I considered the role of mathematics study attitude, which relates to how important student think mathematics is and how likely they are to prioritise it. I included a control variable, study milieu, which refers to study environment and stands as a proxy for SES. The tool to measure mindset was the Thinking About Maths instrument, developed in Studies 1 and 2. The other measures were subscales of the Study Orientation to Mathematics (SOM) developed in South Africa (Maree et al., 1998). Students were also asked to indicate their gender.

For the full sample, regression modelling showed that mathematics mindset and anxiety contributed significantly when alone in the model. In the full model though, only study attitude and study milieu contributed significantly to the full model, with non-significant contributions from mathematics mindsets and anxiety. The full model explained 19% of the variance. A good portion of the remaining variance is likely explained by prior performance, as mathematics is a cumulative learning subject. There was a significant interaction effect for mathematics mindset and anxiety in the full sample and in males only, but not in females only. This relationship is likely complex and worth further study. Foley, et al., (2017) showed that mathematics anxiety and performance have a reciprocal relationship. My model (Figure 3.1) shows a possible explanation for the interaction between mindset and anxiety. Beliefs lead to interpretation of difficult and arousal responses which lead to actions.

Gender, poverty, and mathematics performance

I had not expected to find gender differences in the variables that contribute to mathematics performance, however, initial correlations showed that there was a difference. For males there was a non-significant correlation between mindset and performance, but mathematics anxiety and study milieu were both significant predictors of performance, and correlated with each other ($r = 0.73$, $p < 0.01$, 95% CI [0.24, 0.57]). These patterns were evident in regression modelling. The model that best explained performance for males included mathematics anxiety and explained 17% of the variance in performance.

A poor study environment appeared to be anxiety-inducing for males, negatively impacting on performance. Should a gender specific intervention be developed, it would be important to teach males to notice and reinterpret their feelings of mathematics anxiety. Additional analysis showed that mathematics growth mindsets were most important for those with the poorest study milieu. Hence, promoting growth mindsets for males living in lower SES circumstances could help improve mathematics performance. Finally, males could also benefit from a positive study attitude that helps them relate the relevance of mathematics to their current and future identity and career plans.

For females, mindset did correlate with performance at $r = 0.27$, $p < 0.01$, 95% CI [0.71, 0.91]. Additionally, study milieu and study attitude correlated with performance, but mathematics anxiety did not, indicating that high anxiety did not impair performance in females. The model that best explained performance for females was the full model, which explained 24% of the variance. Interestingly, the coefficient for mathematics anxiety is negative for females in the full model, indicating that they experience mathematics anxiety as motivating and that it promotes mathematics performance.

Females in poor study environments are likely protected from the negative effects felt by males by the stronger relationships between mindsets and performance, and study attitude and performance. It appears that females in impoverished study environments place a higher value on mathematics and its relevance to their lives; possibly drawing associations between mathematics skills, future employment, and escape from poverty. Whilst females, historically, have been less inclined towards mathematics careers, no gender bias was found in this sample group, as noted in the concurrent research completed by my co-researcher, Omar (2019). Indeed, referring to the discussion themes emerging in Study 1, females appeared much more likely than males to discuss the relevance of mathematics to their future career goals. They talked about mathematics as being integral to life. Even when career goals were not dependent on mathematics, they stated that plans could change and that they should leave their options open. These findings are congruent with utility theory, which states that a person will choose to do something costly in the present if it leads to a meaningful future goal (Wigfield & Eccles, 2000).

Interestingly, these gender patterns were not visible when the correlational study was repeated with a more homogenous sample with very little representation from the very lowest SES band. This adds weight to the idea that the gender difference is only visible when there is extreme poverty. Poverty effects mathematics anxiety and study attitude of males and females differently leading to different trajectories for mathematics performance. A brief review of the literature indicates that this is an emergent finding and one worthy of further research. A deeper understanding of gender differences in the response to poverty could lead to better targeted, gender-oriented, interventions.

Delivering a Mindset Intervention on WhatsApp

In Study 3, I developed a growth mindset intervention in consultation with students and teachers. I adapted this intervention from the original blended design of face-to-face and WhatsApp messages to WhatsApp group messaging and chats only. This adaption was necessary due to Covid-19 teaching restrictions - however it offered a unique opportunity to deliver a psycho-educational intervention via social media. I developed a theory of change for the intervention based on mechanisms of change: information, integration, social support, and social currency, shown in Figure 8.1.

Information was delivered over four weeks in the form of short neuro-biology lessons on WhatsApp, brief supporting videos and descriptions of strategies to promote students engaging with mathematics. Students did engage within the groups, offering diverse opinions on the themes and debating ideas. On some occasions students took the information to a deeper level. For example, one student thought through the role of the school system in creating mathematics mindsets. Another applied neuroplasticity to a dancer's recovery from brain injury. It was evident from the interactions that some students did not understand the content or did not agree with it. I found that students moderated their own engagement such that classes who watched the YouTube clips and discussed these during class time were less talkative on the WhatsApp group. Additionally, some students who missed clips in class watched them in their own time. Almost all intervention messages to the group were read, over 90% in most weeks. All four themes were mentioned by students on their feedback form.

Integration of information was encouraged via WhatsApp conversations, inviting students to witness and engage in conversation about mindsets. The engagements invite personal application. Whilst not all students participated, most students did read the conversation messages. Information plus integration task is the standard form of social psychology interventions (Cohen et al., 2006). WhatsApp group discussion on strategy emerged either directly from the intervention content or spontaneously as students thought through how their change in beliefs might lead to change in actions. For example, students spontaneously discussed strategies of practice, linking prior knowledge to current problems, skipping hard questions, and coming back to them and slowing down and thinking deeply. Students also discussed fixed mindset strategies such as avoidance and giving up.

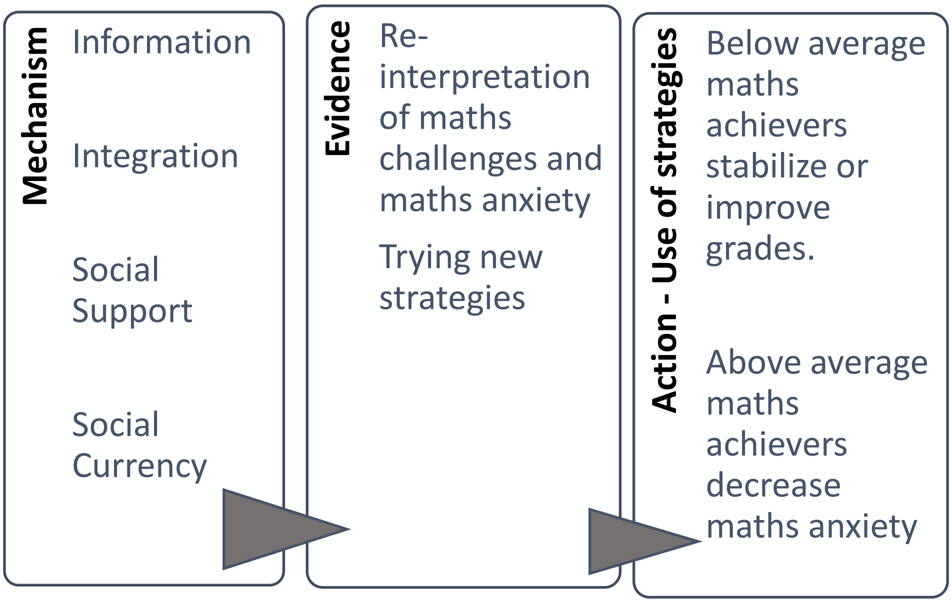
Social support theory prompts participants to encourage one another (Cohen & Wills, 1985) Levels of engagement are associated with the success of programs built on SNS (Yang, 2017). Social support is modelled by group mentors who are active on the group for 30 minutes per day over the 16 days of the program. 96% of students said that they felt supported by their mentor.

Three of the four classroom teachers also agreed or strongly agreed that they had talked with their classes about the intervention content and kept up with the WhatsApp group conversation. Teacher participation might have added an element of social support to the program.

Finally, social currency refers to the number of times the promoted ideas get mentioned both on the WhatsApp group and off the group. The more social currency the ideas get, the more likely it is that the group will implement them (Wendel, 2020). Students reported that there was some informal discussion both in class and outside class, but this is difficult to measure. As students seemed to have self-regulated their dosage it is difficult to ascertain how much effect social currency mindset theory and strategy had, and whether or not it had an impact on final outcomes. However, in eight of the nine groups mentors agreed or strongly agreed that the groups enjoyed the intervention, which would seem to indicate that there was social currency, and it did promote the uptake of new beliefs and strategies.

Figure 8.1

Theory of Change for a WhatsApp based Mathematics Mindset Intervention



Yang's (2017) meta-analysis on health interventions delivered on Social Networking Sites (SNS) showed that SNS interventions should be relevant to the participants, should include messages to target beliefs as well as strategies to target behaviour, should offer opportunities for engagement and should offer support over time to best facilitate behaviour change. My intervention design followed these recommendations. I established that the topic was relevant through semi-structured group discussions in Study 1. The design included messages to target belief as well as strategies to change behaviour, in line with social psychology intervention recommendations discussed above (Cohen et al., 2006). The groups were interactive with group mentors facilitating discussion of strategies and integration of information. The length of WhatsApp group support was increased between pilot and roll-out from two weeks to four weeks to allow for new behaviours to become habitual.

The WhatsApp delivery of the intervention was a learning experience for the group mentors and for me. We discovered that the following strategies helped facilitate group interactions with teenagers:

- Set a time to talk and set the agenda
- Have an opening question that everyone can relate to
- Use emoticons
- Keep the conversation open to diverse opinions and avoid using comments or emoticons that praise “right” answers
- Use examples from own life to engage students
- Summarise at the end of the conversation

Can A Growth Mindset Intervention Boost Mathematics Performance?

Mixed linear regression modelling was used to assess whether the intervention condition significantly improved mathematics performance, when compared to the control condition. In Study 4, baseline, midline, and end line mathematics results were collected over a 15-month period with end line mathematics performance assessed 5 weeks after the conclusion of the intervention. The Thinking About Maths assessment was completed at baseline and end line and study milieu, a proxy for SES, was collected at baseline.

The intervention school had significantly better mathematics performance at end line. There was a significant interaction effect between school and time, indicating that the intervention may have made a difference to mathematics performance, $b = -3.9$, $SE(b) = 1.43$, 95% CI: [-6.76, -1.07], $p < 0.01$. Mathematics mindset was significant in the model at $b = 2.21$, $SE(b) = 1.06$, 95% CI [0.10, 4.32], $p < 0.05$. There was no significant difference in effectiveness of the intervention between males and females.

South African youth in this study tended towards the growth end of the mindset spectrum. Both schools in the intervention improved mindsets, even though only one school was exposed to the intervention, and mindset did not correlate with mathematics performance at end line. As noted, above, there may have been issues with the presentation of the end line Thinking About Maths assessment, as it was not disguised amongst other questions, as for previous presentations. Alternatively, it is possible that the improvement in the control school is an accurate representation of change in beliefs. Covid-19 teaching restrictions lead to extended contact between teachers and students on WhatsApp, at both schools. In the context of a discouraging learning situation, it is possible that positive messaging and encouragement from teachers did make a substantive difference in promoting student's expressions of growth mindset beliefs.

However, it appears to be that the intervention still made a difference to mathematics performance beyond the actual or expressed change in mindset beliefs present at both schools. I should note that the intervention offered something beyond growth mindset messaging. It offered strategies that included practicing mathematics at home, taking good notes in class, not being afraid to ask questions, and reinterpreting mathematics anxiety as a sign of readiness to take on a challenge. Additionally, it offered opportunities for students to discuss strategies that hadn't worked and to share strategies with each other that had worked. Weekly challenges helped students integrate their learning by developing self-encouragement messages for when mathematics work is challenging, convincing a Grade 8 student that there is no such thing as 'smart' or 'not smart' at mathematics, and listing ways to change their relationship with mathematics that would surprise their teacher.

These results seem to emphasise the importance of actions that follow through on expressed change in mindset. However, it will be important to repeat the intervention under normal teaching conditions and with a properly disguised end line mindset test, to assess whether the intervention results are reliable.

A careful redesign could help pinpoint the critical mechanism(s) of change in the intervention model. I would suggest:

- Active control with non-directional but supportive WhatsApp groups (to control for effects from the social support element of the intervention)
- Intervention condition 1 targeting mindset beliefs only
- Condition 2 – beliefs + strategies

- Condition 3 – beliefs + interpretation of anxiety + strategies

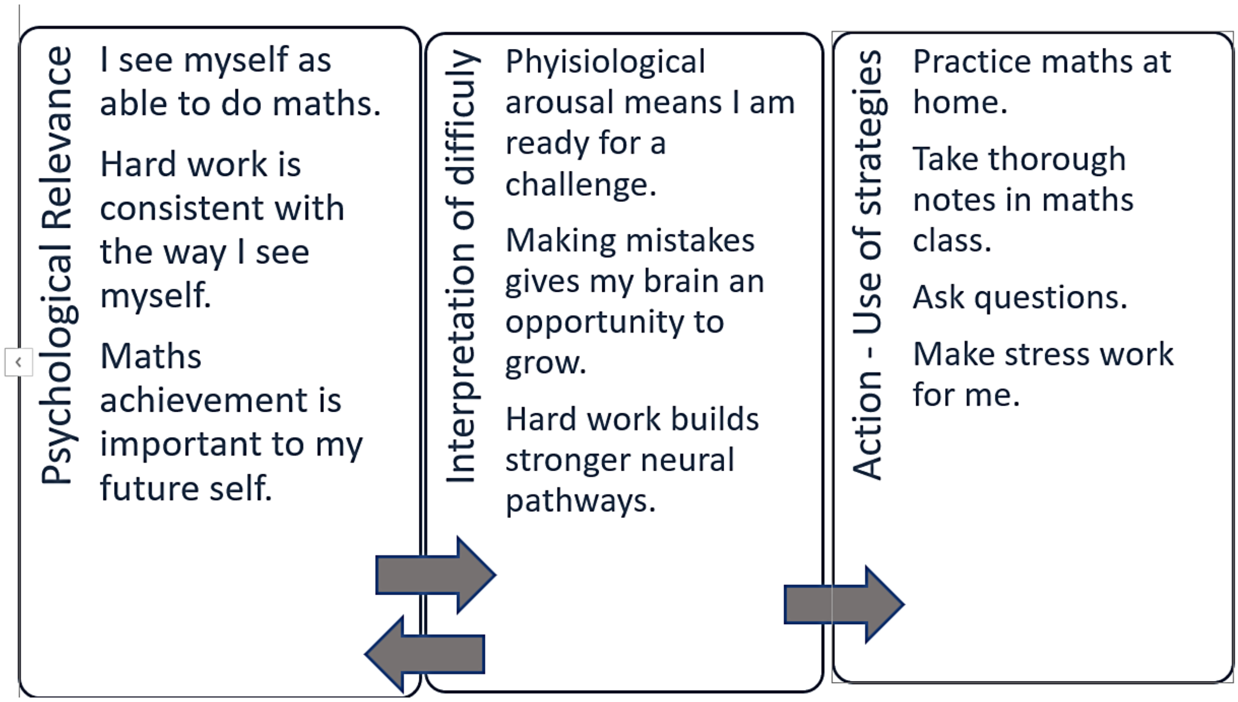
Theoretical Developments

Oyserman's Identity Based Motivation formed the basis for my theoretical model of change, described in Figure 8.1 (Oyserman, 2015). The first stage of my model is "psychological relevance". In this stage an individual or group sees themselves as able to do mathematics. Targeting mindset beliefs is important in opening this possibility. The individual must also see the hard work required as consistent with their current and future identity. This has a strong resonance with the variable "study attitude" included in my analysis. Students with a positive study attitude see mathematics as relevant and worthwhile in their current school career and to their future career plans or to life in general. "Psychological relevance" seems to have been particularly beneficial to boosting mathematics performance for females, who had positive correlations between mathematics mindsets and performance as well as between study attitude and performance. Study attitude was still significant for females even when controlling for study milieu or environment.

"Interpretation of difficulty" is also important to the change process. Part of the way individuals or groups interpret difficulty is determined by their beliefs about difficulty, hence the need to target mathematics mindsets so that there is understanding of what happens when mistakes are made, or work is demanding. There is also a need to reinterpret the feeling of physiological arousal as readiness for a challenge rather than deterring a person from engaging further. This section of the model seems particularly important for males living in lower SES circumstances, who are detrimentally affected by mathematics anxiety. Teaching males to notice and reinterpret physiological arousal may lead to changes in mindset and study attitude. Future researchers may wish to investigate this.

Figure 8.2

Framework for Understanding Individual Change in Mathematics Interactions Based on IBM (based on Oyserman, 2015).



Once relevance is established and growth beliefs embraced, the final stage of the model is to change behaviour with "Action – Use of Strategies". Examples of these are included in the model but are not exhaustive – practice mathematics at home, take thorough notes in mathematics class, ask questions, and make stress work for the student (the anxiety dumping exercise taught in week 4 of the intervention). Students discussed additional successful and unsuccessful strategies during WhatsApp group conversations. The importance of strategies is underlined by the results from Study 4 which showed that mindsets improved at both schools but only the intervention school, who were taught strategies, had an improvement in mathematics performance.

My adaptation of Oyserman's model was useful in explaining behaviour change both between genders and between schools. Should future researchers wish to develop this model, it may be helpful to include goal orientation which has its origins in attribution theory (Elliott & Dweck, 1988). There is a substantial body of work on goal orientation, exploring whether individuals are motivated by the process of learning or the performance outcome. Students with learning goals are more likely to embrace challenge whilst students with performance goals are more likely to avoid challenge, particularly if they expect failure (Yeager & Dweck, 2020).

Final words

I have shown that mathematics mindsets are relevant to South African youth. I have developed the "Thinking About Maths" mindset assessment tool for use in South Africa and it has both validity and reliability. My intervention revealed that teaching growth mindset along with appropriate study strategies, can change the trajectory of mathematics performance.

My research offers important findings for researchers wishing to adapt social psychology assessments and interventions to varying cultural contexts. I have contributed to the understanding of mathematics mindsets in South Africa and my research may have application to contexts with a similar lack of school resources and community poverty. My research directs future interventions, for the poorest of students, to consider gender-based differences in the experiences of poverty and anxiety and the importance of creating psychological relevance for the study of mathematics. I have established WhatsApp as a viable means for delivering a social-psychology intervention, which is inexpensive, accessible, and able to lead to measurable change. Finally, my findings emphasise the explicit teaching of strategies in mindset interventions, reminding us that expressing a change in belief must be followed through with change in actions for mathematics performance to change.

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APPENDIX A – ETHICS APPROVALS

Ethical Approval Letter from Western Cape Education Department

Western Cape Government
Education

Directorate: Research
Audrey.wyngaard@westerncape.gov.za
tel: +27 021 467 9272
Fax: 0865902282
Private Bag x9114, Cape Town, 8000
wced.wcape.gov.za

REFERENCE: 20181121–8975
ENQUIRIES: Dr A T Wyngaard

Mrs Katherine Morse
11 Camelia Close
Bergvliet
7864

Dear Mrs Katherine Morse

RESEARCH PROPOSAL: CLOSING THE MATHS ACHIEVEMENT GAP: EXPLORING THE APPLICABILITY OF GROWTH MINDSET IN SOUTH AFRICA

Your application to conduct the above-mentioned research in schools in the Western Cape has been approved subject to the following conditions:

1. Principals, educators and learners are under no obligation to assist you in your investigation.
2. Principals, educators, learners and schools should not be identifiable in any way from the results of the investigation.
3. You make all the arrangements concerning your investigation.
4. Educators' programmes are not to be interrupted.
5. The Study is to be conducted from **02 April 2019 till 27 September 2020**
6. No research can be conducted during the fourth term as schools are preparing and finalizing syllabi for examinations (October to December).
7. Should you wish to extend the period of your survey, please contact Dr A.T Wyngaard at the contact numbers above quoting the reference number?

UNIVERSITY OF CAPE TOWN

Department of Psychology

University of Cape Town Rondebosch 7701 South Africa
Telephone (021) 650 3417
Fax No. (021) 650 4104

26 February 2021

Katherine Morse
Department of Psychology
University of Cape Town
Rondebosch 7701

Dear Katherine

I am pleased to inform you that ethical clearance has been given by an Ethics Review Committee of the Faculty of Humanities for the changes you have made to your study, *Closing the maths achievement gap: Exploring the applicability of growth mindset in South Africa*. The reference number is PSY2018-066.

I wish you all the best for your study.

Yours sincerely

Lauren Wild (PhD)
Associate Professor
Chair: Ethics Review Committee

8. A photocopy of this letter is submitted to the principal where the intended research is to be conducted.
9. Your research will be limited to the list of schools as forwarded to the Western Cape Education Department.
10. A brief summary of the content, findings and recommendations is provided to the Director: Research Services.
11. The Department receives a copy of the completed report/dissertation/thesis addressed to:

    The Director: Research Services
    Western Cape Education Department
    Private Bag X9114
    CAPE TOWN
    8000

We wish you success in your research.

Kind regards.
Signed: Dr Audrey T Wyngaard
Directorate: Research
DATE: 22 November 2018

APPENDIX B – STUDY 2

Table B1

Distribution of Mindset items 1-8 by gender 1 (male), gender 2 (female)

```
. sum dweck_av if gender==1, detail

                          dweck_av
-------------------------------------------------------------
      Percentiles      Smallest
 1%         2.75           2.75
 5%            3          2.875
10%         3.25              3       Obs                  77
25%         3.75              3       Sum of Wgt.          77

50%        4.125                      Mean           4.095779
                        Largest       Std. Dev.      .5684611
75%          4.5          4.875
90%        4.875              5       Variance       .3231481
95%        4.875              5       Skewness      -.3769257
99%            5              5       Kurtosis       2.386472

. sum dweck_av if gender==2, detail

                          dweck_av
-------------------------------------------------------------
      Percentiles      Smallest
 1%        2.125              2
 5%            3          2.125
10%        3.125          2.375       Obs                 122
25%        3.375           2.75       Sum of Wgt.         122

50%        3.875                      Mean           3.891393
                        Largest       Std. Dev.      .6494099
75%          4.5          4.875
90%         4.75              5       Variance       .4217332
95%        4.875              5       Skewness      -.3137264
99%            5              5       Kurtosis       2.612002

.
```

Note: dweck_av = mindset items 1-8

Table B2

Correlations between Mathematics performance and variables, by school

```
. pwcorr g8t4 g9t2 dweck_av morse_av som_sa som_ma som_sm if school==1, sig
```

	g8t4	g9t2	dweck_av	morse_av	som_sa	som_ma	som_sm
g8t4	1.0000						
g9t2	0.8288	1.0000					
	0.0000						
dweck_av	0.2736	0.2914	1.0000				
	0.0571	0.0422					
morse_av	0.3600	0.2433	0.3845	1.0000			
	0.0111	0.0921	0.0064				
som_sa	0.5510	0.5790	0.3739	0.6131	1.0000		
	0.0000	0.0000	0.0081	0.0000			
som_ma	0.2803	0.3303	0.3583	0.4378	0.1938	1.0000	
	0.0511	0.0204	0.0115	0.0017	0.1821		
som_sm	0.2384	0.3741	0.4615	0.3462	0.3040	0.5772	1.0000
	0.0990	0.0081	0.0008	0.0148	0.0337	0.0000	

```
. pwcorr g8t4 g9t2 dweck_av morse_av som_sa som_ma som_sm if school==2, sig
```

	g8t4	g9t2	dweck_av	morse_av	som_sa	som_ma	som_sm
g8t4	1.0000						
g9t2	0.5496	1.0000					
	0.0000						
dweck_av	0.1696	0.2479	1.0000				
	0.2441	0.0859					
morse_av	0.5796	0.6199	0.2551	1.0000			
	0.0000	0.0000	0.0769				
som_sa	0.4854	0.5920	0.3532	0.5499	1.0000		
	0.0004	0.0000	0.0128	0.0000			
som_ma	0.3010	0.4019	0.2234	0.2720	0.0715	1.0000	
	0.0356	0.0042	0.1229	0.0586	0.6255		
som_sm	0.1610	0.3944	0.2720	0.3281	0.2781	0.5582	1.0000
	0.2690	0.0050	0.0587	0.0214	0.0530	0.0000	

Notes :
g8t4 = math grades collected in Grade 8, term 4
g9t2 = math grades collected in Grade 9, term 2
dweck_av = mindset items 1-8
morse_av = mindset items 9-16
som_sa = study anxiety subtest on the SOM
som_ma = math anxiety subtest on the SOM
som_sm = study milieu subtest on the SOM (proxy for SES)

```
. pwcorr g8t4 g9t2 dweck_av morse_av som_sa som_ma som_sm if school==3, sig
```

	g8t4	g9t2	dweck_av	morse_av	som_sa	som_ma	som_sm
g8t4	1.0000						
g9t2	0.9203	1.0000					
	0.0000						
dweck_av	0.2881	0.2597	1.0000				
	0.0269	0.0451					
morse_av	0.2802	0.3324	0.4793	1.0000			
	0.0316	0.0095	0.0001				
som_sa	0.3657	0.3923	0.4640	0.6423	1.0000		
	0.0044	0.0019	0.0002	0.0000			
som_ma	0.3231	0.2971	0.4739	0.7038	0.5914	1.0000	
	0.0125	0.0212	0.0001	0.0000	0.0000		
som_sm	0.3486	0.3883	0.2622	0.5027	0.5220	0.6516	1.0000
	0.0068	0.0022	0.0430	0.0000	0.0000	0.0000	

```
. pwcorr g8t4 g9t2 dweck_av morse_av som_sa som_ma som_sm if school==4, sig
```

	g8t4	g9t2	dweck_av	morse_av	som_sa	som_ma	som_sm
g8t4	1.0000						
g9t2	0.5898	1.0000					
	0.0001						
dweck_av	0.2727	0.1924	1.0000				
	0.0846	0.2406					
morse_av	0.3068	0.1530	0.5493	1.0000			
	0.0511	0.3523	0.0002				
som_sa	0.4123	0.2291	0.4251	0.7063	1.0000		
	0.0074	0.1607	0.0056	0.0000			
som_ma	0.4964	0.1660	0.3402	0.3050	0.1821	1.0000	
	0.0010	0.3124	0.0295	0.0525	0.2546		
som_sm	0.3944	0.4077	0.1480	0.0622	0.0302	0.7147	1.0000
	0.0107	0.0100	0.3556	0.6992	0.8514	0.0000	

```
.
```

Notes :
g8t4 = math grades collected in Grade 8, term 4
g9t2 = math grades collected in Grade 9, term 2
dweck_av = mindset items 1-8
morse_av = mindset items 9-16
som_sa = study anxiety subtest on the SOM
som_ma = math anxiety subtest on the SOM
som_sm = study milieu subtest on the SOM (proxy for SES)

Table B3

Mindset variables, Factor Analysis

```
Factor analysis/correlation                        Number of obs    =        199
    Method: principal factors                      Retained factors =          8
    Rotation: (unrotated)                          Number of params =        100
```

Factor	Eigenvalue	Difference	Proportion	Cumulative
Factor1	3.96400	2.35676	0.6490	0.6490
Factor2	1.60724	0.73636	0.2632	0.9122
Factor3	0.87089	0.50913	0.1426	1.0548
Factor4	0.36175	0.06162	0.0592	1.1140
Factor5	0.30013	0.12525	0.0491	1.1631
Factor6	0.17488	0.10919	0.0286	1.1918
Factor7	0.06570	0.01948	0.0108	1.2025
Factor8	0.04622	0.08682	0.0076	1.2101
Factor9	-0.04060	0.03540	-0.0066	1.2035
Factor10	-0.07600	0.04693	-0.0124	1.1910
Factor11	-0.12292	0.01014	-0.0201	1.1709
Factor12	-0.13306	0.05396	-0.0218	1.1491
Factor13	-0.18702	0.02290	-0.0306	1.1185
Factor14	-0.20992	0.01322	-0.0344	1.0841
Factor15	-0.22314	0.06745	-0.0365	1.0476
Factor16	-0.29059	.	-0.0476	1.0000

LR test: independent vs. saturated: chi2(120) = 950.91 Prob>chi2 = 0.0000

Table B4

Study Milieu, Factor Analysis

```
. factor som_5 som_10 som_15 som_20 som_32 som_37 som_42 som_47 som_52 som_59 som_64 som_66, ipf factor(1)
(obs=198)

Factor analysis/correlation                        Number of obs    =        198
    Method: iterated principal factors             Retained factors =          1
    Rotation: (unrotated)                          Number of params =         12
```

Factor	Eigenvalue	Difference	Proportion	Cumulative
Factor1	2.66920	2.11382	1.0000	1.0000
Factor2	0.55538	0.23011	0.2081	1.2081
Factor3	0.32527	0.06863	0.1219	1.3299
Factor4	0.25664	0.10587	0.0962	1.4261
Factor5	0.15077	0.15121	0.0565	1.4826
Factor6	-0.00044	0.07613	-0.0002	1.4824
Factor7	-0.07656	0.01125	-0.0287	1.4537
Factor8	-0.08781	0.08285	-0.0329	1.4208
Factor9	-0.17066	0.06293	-0.0639	1.3569
Factor10	-0.23359	0.06628	-0.0875	1.2694
Factor11	-0.29987	0.11926	-0.1123	1.1570
Factor12	-0.41914	.	-0.1570	1.0000

LR test: independent vs. saturated: chi2(66) = 452.16 Prob>chi2 = 0.0000

Factor loadings (pattern matrix) and unique variances

Variable	Factor1	Uniqueness
som_5	0.3746	0.8597
som_10	0.1244	0.9845
som_15	0.3670	0.8653
som_20	0.4535	0.7943
som_32	0.4329	0.8126
som_37	0.4916	0.7583
som_42	0.5581	0.6885
som_47	0.3648	0.8669
som_52	0.6223	0.6127
som_59	0.5000	0.7500
som_64	0.6028	0.6366
som_66	0.5466	0.7012

.

Table B5

Study Attitude, Factor Analysis

```
. sum som_1 som_6 som_11 som_16 som_21 som_28 som_33 som_38 som_43 som_55 som_60 som_65 som_70
```

Variable	Obs	Mean	Std. Dev.	Min	Max
som_1	198	3.272727	1.244832	1	5
som_6	198	4.29798	.8995746	1	5
som_11	205	3.053659	1.28416	0	5
som_16	198	3.494949	1.362096	1	5
som_21	198	3.979798	1.15745	1	5
som_28	198	3.949495	1.041024	1	5
som_33	205	3.009756	1.260214	0	5
som_38	205	2.580488	1.375418	0	5
som_43	198	2.661616	1.396748	1	5
som_55	197	3.64467	1.222925	1	5
som_60	197	3.395939	1.334619	1	5
som_65	197	3.746193	1.256229	1	5
som_70	197	3.670051	1.264817	1	5

```
Factor analysis/correlation                    Number of obs    =        197
    Method: iterated principal factors         Retained factors =          1
    Rotation: (unrotated)                      Number of params =         13
```

Factor	Eigenvalue	Difference	Proportion	Cumulative
Factor1	4.23092	3.53910	1.0000	1.0000
Factor2	0.69182	0.45462	0.1635	1.1635
Factor3	0.23720	0.08019	0.0561	1.2196
Factor4	0.15701	0.01433	0.0371	1.2567
Factor5	0.14268	0.08842	0.0337	1.2904
Factor6	0.05426	0.08003	0.0128	1.3033
Factor7	-0.02577	0.05908	-0.0061	1.2972
Factor8	-0.08485	0.02316	-0.0201	1.2771
Factor9	-0.10801	0.05429	-0.0255	1.2516
Factor10	-0.16230	0.08775	-0.0384	1.2132
Factor11	-0.25004	0.05545	-0.0591	1.1541
Factor12	-0.30549	0.04108	-0.0722	1.0819
Factor13	-0.34657	.	-0.0819	1.0000

LR test: independent vs. saturated: chi2(78) = 770.80 Prob>chi2 = 0.0000

Factor loadings (pattern matrix) and unique variances

Variable	Factor1	Uniqueness
som_1	0.6342	0.5979
som_6	0.6460	0.5827
som_11	0.3389	0.8851
som_16	0.6823	0.5344
som_21	0.5726	0.6721
som_28	0.6114	0.6262
som_33	0.4663	0.7826
som_38	0.4052	0.8358
som_43	0.5978	0.6426
som_55	0.4933	0.7566
som_60	0.5059	0.7441
som_65	0.6286	0.6048
som_70	0.7043	0.5040

Table B6

Regression Analysis – full sample, then by gender 2(female) and gender1(male), then including mindset x anxiety interaction

```
. regress g9t2 dweck_select somr_ma som_sa som_sm

      Source |       SS           df       MS      Number of obs   =       196
-------------+----------------------------------   F(4, 191)       =     12.03
       Model |  15950.7119         4  3987.67798   Prob > F        =    0.0000
    Residual |   63298.533       191  331.405932   R-squared       =    0.2013
-------------+----------------------------------   Adj R-squared   =    0.1845
       Total |  79249.2449       195  406.406384   Root MSE        =    18.205

------------------------------------------------------------------------------
        g9t2 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
dweck_select |   2.468035   1.526481     1.62   0.108    -.5428902     5.47896
     somr_ma |  -.3074827   .1825244    -1.68   0.094    -.6675051    .0525396
      som_sa |   .4358009   .1305699     3.34   0.001     .1782568    .6933451
      som_sm |   1.016327   .2250478     4.52   0.000     .5724292    1.460226
       _cons |  -11.39095   8.808926    -1.29   0.198    -28.76622    5.984326
------------------------------------------------------------------------------

. regress g9t2 dweck_select somr_ma som_sa som_sm if gender==2

      Source |       SS           df       MS      Number of obs   =       121
-------------+----------------------------------   F(4, 116)       =      9.38
       Model |  12337.1974         4  3084.29935   Prob > F        =    0.0000
    Residual |  38132.3398       116  328.727067   R-squared       =    0.2444
-------------+----------------------------------   Adj R-squared   =    0.2184
       Total |  50469.5372       120  420.579477   Root MSE        =    18.131

------------------------------------------------------------------------------
        g9t2 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
dweck_select |    3.44543   1.919205     1.80   0.075    -.3557969    7.246657
     somr_ma |  -.5325852   .2085863    -2.55   0.012    -.9457167   -.1194537
      som_sa |   .5925678   .1605345     3.69   0.000     .2746089    .9105267
      som_sm |   .8679908   .2830201     3.07   0.003     .3074339    1.428548
       _cons |  -12.04071   10.87341    -1.11   0.270    -33.57687    9.495441
------------------------------------------------------------------------------

.

. regress g9t2 dweck_select somr_ma som_sa som_sm if gender==1

      Source |       SS           df       MS      Number of obs   =        75
-------------+----------------------------------   F(4, 70)        =      4.91
       Model |  6147.86587         4  1536.96647   Prob > F        =    0.0015
    Residual |  21901.6808        70  312.881154   R-squared       =    0.2192
-------------+----------------------------------   Adj R-squared   =    0.1746
       Total |  28049.5467        74  379.047928   Root MSE        =    17.688

------------------------------------------------------------------------------
        g9t2 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
dweck_select |  -1.847959   2.715483    -0.68   0.498     -7.26382    3.567901
     somr_ma |   .4685067   .3932901     1.19   0.238    -.3158857    1.252899
      som_sa |   .2269272   .2252866     1.01   0.317    -.2223927    .6762471
      som_sm |   .7633252   .4074284     1.87   0.065    -.0492651    1.575916
       _cons |   5.688761   15.43791     0.37   0.714    -25.10117    36.47869
------------------------------------------------------------------------------
```

```
. regress g9t2 tam_select somr_ma som_sa som_sm c.tam_select#c.somr_ma, beta
```

Source	SS	df	MS			
				Number of obs	=	196
				F(5, 190)	=	9.66
Model	16067.7363	5	3213.54727	Prob > F	=	0.0000
Residual	63181.5085	190	332.534256	R-squared	=	0.2027
				Adj R-squared	=	0.1818
Total	79249.2449	195	406.406384	Root MSE	=	18.236

g9t2	Coef.	Std. Err.	t	P>|t|	Beta
tam_select	4.907124	4.386694	1.12	0.265	.2231556
somr_ma	.0068749	.5605672	0.01	0.990	.0029703
som_sa	.4299031	.1311693	3.28	0.001	.2263046
som_sm	1.038263	.228443	4.54	0.000	.3598336
c.tam_select#c.somr_ma	-.0941558	.1587183	-0.59	0.554	-.204966
_cons	-19.83544	16.74793	-1.18	0.238	.

Notes :
g9t2 = math grades collected in Grade 9, term 2
dweck_select / tam_select= 4 mindset items selected for final assessment tool
somr_ma = math anxiety items selected from SOM subtest
som_sa = study anxiety subtest on the SOM
som_sm = study milieu subtest on the SOM (proxy for SES)

APPENDIX D – STUDY 4

Intervention – Additional Notes

Full story (abbreviated in main text Table xx)

After years of working as a cleaner, with only a matric qualification, Dietrich has packed away her overalls and has been teaching Grade 5 and 6 mathematics and social science since January this year. "As I worked in ResLife, where the students spent time studying, I found myself surrounded by an environment of learning. I also witnessed the students' commitment and their struggles. I thought to myself, 'If they can do it, so can I'". She attended classes at UWC during the day, before starting her eight-hour cleaning shift at 3pm. Most of her assignments were completed at night. "I knew that I had to do something, and that I had to make a difference. I come from a very poor community where there is a lot of unemployment and gangsterism," explained Dietrich.

Intervention - Mentor conversation prompts

<table>
<tr><th>Week 1</th></tr>
<tr><td>Key terms: Neuron/ neural pathway
Mon:
• Was anyone surprised by that news story about Pam Talbert?
• Do you know any other stories like this one?
Tues:
• What is a neuron?
• What did you learn in the video?
Wed:
• Who knows that feeling when you thought you understood something in mathematics class, but it comes up on the test and you can't remember how to do it?
• What can you do to make sure you can get to answers quickly and accurately?
Thurs:
• What can you see in Nelson Mandela's life that makes him a good model for not giving up?
• They say that you are your own best cheerleader. What message cheers you on when your mathematics work is hard?</td></tr>
<tr><th>Week 2</th></tr>
</table>

Mon:

- Do you think some people are born smart or not smart at mathematics?
- What happens if you believe you are not smart at mathematics?

Tue:

- Who can tell us a story from the video?
- In your school what do people believe about mathematics ability?

Wed:

- In your class, who do you notice taking notes?
- Do you think taking notes is important?

Thurs:

- What did you believe about your mathematics ability when you first started highschool?
- How has that changed?

Week 3

Key term: Neuroplasticity

Mon:

- Did anything surprise you about the London taxi driver?
- How does it make you feel to know that your brain is able to change and grow new connections?

Tues:

- What does neuroplasticity mean?
- What challenges are you working on that you haven't nailed yet?

Wed:

- Were you surprised to find out that Barack Obama has to ask questions?
- How do you feel about asking questions (in class, out of class, to friend, to internet, to family)?

Thurs:

• If I came back at the end of the year and you had actually done one thing that would surprise your teacher, what difference would I notice? • If you did that one thing, what would your mathematics teacher tell me?
Week 4
Mon: • Knots and bows are shoelaces in different shapes. What do you think would change if we understood that mathematics anxiety is not telling us we are stuck but that we are ready to try hard? Tues: • Is mathematics like the teacher you never want to pass in the corridor or like the teacher you like to joke around with? • What would you say to someone who is struggling with mathematics anxiety? Wed: • Here are the anxiety thoughts I struggle with when something is challenging: (make up your own, e.g. I'm going to fail, this is too hard, what if I forget everything?) I need to dump those thoughts. What anxiety thoughts do you need to dump? Thurs: • This is our last week together! What was your favourite message from the last month? • Be a game changer for someone else and send your favourite message on to them. Please make sure to complete the end of group survey.

Analysis – Additional Tables

Table D1

No gender difference in mathematics or mindset scores in Study 4.

```
. ttest t1_tam == t2_tam if gender==1

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
  t1_tam |      61    3.110656    .1535692    1.199414    2.803472     3.41784
  t2_tam |      61    4.262295    .0778437    .6079786    4.106585    4.418006
---------+--------------------------------------------------------------------
    diff |      61   -1.151639    .1797728     1.40407   -1.511238   -.7920402
------------------------------------------------------------------------------
     mean(diff) = mean(t1_tam - t2_tam)                           t =  -6.4061
 Ho: mean(diff) = 0                              degrees of freedom =       60

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 0.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 1.0000

. ttest t1_tam == t2_tam if gender==0

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
  t1_tam |      75        3.19    .1223678    1.059736    2.946177    3.433823
  t2_tam |      75    4.356667    .0535188    .4634866    4.250028    4.463305
---------+--------------------------------------------------------------------
    diff |      75   -1.166667     .141766     1.22773   -1.449142   -.8841918
------------------------------------------------------------------------------
     mean(diff) = mean(t1_tam - t2_tam)                           t =  -8.2295
 Ho: mean(diff) = 0                              degrees of freedom =       74

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 0.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 1.0000

. ttest t2_math== t1_math if gender==0

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
 t2_math |     160     58.9375    1.698933       21.49    55.58211    62.29289
 t1_math |     160      66.575    1.546998    19.56815    63.51968    69.63032
---------+--------------------------------------------------------------------
    diff |     160     -7.6375    1.247119    15.77495   -10.10056   -5.174445
------------------------------------------------------------------------------
     mean(diff) = mean(t2_math - t1_math)                         t =  -6.1241
 Ho: mean(diff) = 0                              degrees of freedom =      159

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 0.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 1.0000

. ttest t2_math== t1_math if gender==1

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
 t2_math |     138    56.91304    1.722634    20.23637    53.50665    60.31943
 t1_math |     138    64.38406    1.668506    19.60051     61.0847    67.68341
---------+--------------------------------------------------------------------
    diff |     138   -7.471014    1.466657    17.22932   -10.37123   -4.570801
------------------------------------------------------------------------------
     mean(diff) = mean(t2_math - t1_math)                         t =  -5.0939
 Ho: mean(diff) = 0                              degrees of freedom =      137

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 0.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 1.0000

.
```

Table D2

Original model (m=0) and imputations (m=1,2,3,4,5)

m=0 data:

-> summarize math* tam* t_som* atmi*

Variable	Obs	Mean	Std. Dev.	Min	Max
math0	303	65.75908	19.58674	16	100
math1	302	58.04967	20.79933	0	98
math2	295	59.31186	23.59662	0	98
tam0	277	3.176895	1.103079	0	5
tam1	0				
tam2	141	4.312057	.549477	2.5	5
t_som0	307	13.72747	5.264406	0	20.66667
t_som1	0				
t_som2	0				
atmi0	0				
atmi1	0				
atmi2	141	3.495035	.7569041	1.6	5

m=1 data:

-> summarize math* tam* t_som* atmi*

Variable	Obs	Mean	Std. Dev.	Min	Max
math0	307	65.85568	19.52582	16	100
math1	307	57.95091	20.78504	0	98
math2	307	58.87038	23.76007	0	104.9091
tam0	307	3.172978	1.094328	0	5.523568
tam1	0				
tam2	307	4.325551	.5974514	2.5	5.945782
t_som0	307	13.72747	5.264406	0	20.66667
t_som1	0				

```
      t_som2 |          0
       atmi0 |          0
-------------+---------------------------------------------------------
       atmi1 |          0
       atmi2 |        307     3.49478    .8054385        1.6   5.721281
```

m=2 data:

-> summarize math* tam* t_som* atmi*

```
    Variable |        Obs        Mean    Std. Dev.       Min        Max
-------------+---------------------------------------------------------
       math0 |        307    65.58743    19.64598         16        100
       math1 |        307    58.16547    20.76834          0         98
       math2 |        307    59.06268    23.53638          0         98
        tam0 |        307    3.151202    1.102477          0   5.029922
        tam1 |          0
-------------+---------------------------------------------------------
        tam2 |        307    4.268078    .6172828        2.5   6.391703
      t_som0 |        307    13.72747    5.264406          0   20.66667
      t_som1 |          0
      t_som2 |          0
       atmi0 |          0
-------------+---------------------------------------------------------
       atmi1 |          0
       atmi2 |        307    3.423976    .7691699   1.209364   5.620765
```

m=3 data:

-> summarize math* tam* t_som* atmi*

```
    Variable |        Obs        Mean    Std. Dev.       Min        Max
-------------+---------------------------------------------------------
       math0 |        307     65.8513    19.62809         16   103.8863
       math1 |        307    58.11423    20.86488          0         98
       math2 |        307    58.74324    23.76076          0         98
        tam0 |        307    3.170501    1.081112          0          5
        tam1 |          0
-------------+---------------------------------------------------------
```

```
        tam2 |       307    4.363601     .561673        2.5   5.970792
      t_som0 |       307    13.72747    5.264406          0   20.66667
      t_som1 |         0
      t_som2 |         0
       atmi0 |         0
-------------+---------------------------------------------------------
       atmi1 |         0
       atmi2 |       307    3.494251    .7412227   1.597146   5.679666
```

m=4 data:

```
-> summarize math* tam* t_som* atmi*

    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+---------------------------------------------------------
       math0 |       307    65.80486    19.59709         16        100
       math1 |       307     58.1256    20.82961          0         98
       math2 |       307    58.87448    23.74496          0         98
        tam0 |       307    3.157143    1.103579          0   5.665909
        tam1 |         0
-------------+---------------------------------------------------------
        tam2 |       307    4.319948    .6051565        2.5   6.059592
      t_som0 |       307    13.72747    5.264406          0   20.66667
      t_som1 |         0
      t_som2 |         0
       atmi0 |         0
-------------+---------------------------------------------------------
       atmi1 |         0
       atmi2 |       307    3.512556    .7262148        1.6   5.279249
```

m=5 data:

```
-> summarize math* tam* t_som* atmi*

    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+---------------------------------------------------------
       math0 |       307    65.74483    19.64003         16        100
       math1 |       307    58.29744    20.83683          0         98
       math2 |       307    59.01866    23.76763          0   105.2273
```

```
        tam0 |        307    3.124303      1.1178          0   5.425789
        tam1 |          0
-------------+---------------------------------------------------------
        tam2 |        307    4.263246    .5500969        2.5   6.110753
      t_som0 |        307    13.72747    5.264406          0   20.66667
      t_som1 |          0
      t_som2 |          0
       atmi0 |          0
-------------+---------------------------------------------------------
       atmi1 |          0
       atmi2 |        307    3.481015    .7699749   1.311298   5.745676\
```

Notes:
Math0 – Math performance baseline
Math1- Math performance midline
Math2- Math performance endline
Tam0- Thinking About Maths baseline
Tam1- Thinking About Maths midline
Tam2- Thinking About Maths endline
T_som0-Math Anxiety baseline
T-Som1-Math Anxiety midline
T_Som2- Math Anxiety endline
ATMI0- Attitudes Towards Mathematics Inventory baseline
ATMI1- Attitudes Towards Mathematics Inventory midline
ATMI2 – Attitude Towards Mathematics Inventory endline
Further Notes:
The ATMI was used experimentally as a possible replacement for the SOM at endline however the two tests did not correlate well with one another and the plan was disbanded.

Table D3

Mixed-effects linear regression, original data set, no imputed values.

```
Mixed-effects REML regression                   Number of obs     =        401
Group variable: ID                              Number of groups  =        273

                                                Obs per group:
                                                              min =          1
                                                              avg =        1.5
                                                              max =          2

                                                Wald chi2(6)      =      90.33
Log restricted-likelihood = -1712.5903          Prob > chi2       =     0.0000

------------------------------------------------------------------------------
        math |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        time |  -1.707798   1.324259    -1.29   0.197    -4.303297    .8877009
    2.School |  -13.32132   3.036506    -4.39   0.000    -19.27276   -7.369873
             |
School#c.time |
           2 |  -2.859082   2.448652    -1.17   0.243    -7.658352    1.940187
             |
    1.gender |  -.0646336   1.823835    -0.04   0.972    -3.639284    3.510017
       som_5 |   .6073734   .1519853     4.00   0.000     .3094878    .9052591
         tam |  -.3093563    1.36725    -0.23   0.821    -2.989117    2.370404
       _cons |   48.18495   7.304214     6.60   0.000     33.86895    62.50094
------------------------------------------------------------------------------

------------------------------------------------------------------------------
  Random-effects Parameters  |   Estimate   Std. Err.     [95% Conf. Interval]
-----------------------------+------------------------------------------------
ID: Identity                 |
             var(time _cons) |   57.40918   15.69304       33.5971    98.09817
-----------------------------+------------------------------------------------
               var(Residual) |   200.2929    30.0773      149.2257    268.8361
------------------------------------------------------------------------------
LR test vs. linear model: chibar2(01) = 20.72         Prob >= chibar2 = 0.0000

.
```

Table D4

Mixed-effects linear regression, imputed values.

```
. mi estimate:mixed math c.time i.School i.School#c.time i.gender som_5 tam||ID: , cov(identity) reml

Multiple-imputation estimates                 Imputations       =          5
Mixed-effects REML regression                 Number of obs     =        592

Group variable: ID                            Number of groups  =        298
                                              Obs per group:
                                                           min =          1
                                                           avg =        2.0
                                                           max =          2
                                              Average RVI       =     0.0509
                                              Largest FMI       =     0.2369
DF adjustment:   Large sample                 DF:     min       =      83.53
                                                      avg       = 140,125.29
                                                      max       = 903,935.93
Model F test:       Equal FMI                 F(   6, 4952.9)   =      19.65
                                              Prob > F          =     0.0000
```

math	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
time	-2.869673	.7219263	-3.98	0.000	-4.284633	-1.454712
2.School	-9.437795	2.803252	-3.37	0.001	-14.94027	-3.935321
School#c.time						
2	-3.920965	1.438165	-2.73	0.007	-6.767572	-1.074359
1.gender	-.4279078	2.042858	-0.21	0.834	-4.431841	3.576026
som_5	.5750871	.1646054	3.49	0.000	.2524644	.8977098
tam	2.208893	1.062432	2.08	0.041	.0959548	4.321831
_cons	39.82276	7.839763	5.08	0.000	24.44952	55.19601

Random-effects Parameters	Estimate	Std. Err.	[95% Conf.	Interval]
ID: Identity				
sd(_cons)	15.12306	.8827769	13.48733	16.95716
sd(Residual)	12.46426	.527679	11.47123	13.54327

Table D5

No significant correlations in width and depth of engagements in WhatsApp groups

```
Bootstrap results                               Number of obs     =        161
                                                Replications      =      1,000

      command:  pwcorr breadth t2_tam
        _bs_1:  r(rho)
```

	Observed Coef.	Bootstrap Std. Err.	z	P>|z|	Normal-based [95% Conf. Interval]	
_bs_1	-.0056517	.1070588	-0.05	0.958	-.2154831	.2041797

```
Bootstrap results                               Number of obs     =        161
                                                Replications      =      1,000

      command:  pwcorr unique t2_tam
        _bs_1:  r(rho)
```

	Observed Coef.	Bootstrap Std. Err.	z	P>|z|	Normal-based [95% Conf. Interval]	
_bs_1	.1219313	.1025936	1.19	0.235	-.0791485	.3230111

```
Bootstrap results                               Number of obs     =        161
                                                Replications      =      1,000

      command:  pwcorr video t2_tam
        _bs_1:  r(rho)
```

	Observed Coef.	Bootstrap Std. Err.	z	P>|z|	Normal-based [95% Conf. Interval]	
_bs_1	-.1219313	.1042982	-1.17	0.242	-.3263521	.0824895

Notes:

Breadth = number of WhatsApp to and fro conversations on challenge days

Unique = number of unique users in WhatsApp on challenge days

Video = number of videos shown by class teacher

t2_tam = Thinking About Maths (mindsets) at endline