‘You see it differently once you calm down’: Developing an Intervention to Support Learners to Address their Mathematics Anxiety.

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ABBREVIATIONS

ALIVE	Accessible, Linked, Inclusive, Valued, Engaging
BPD	Borderline Personality Disorder, see page 35
CBT	Cognitive Behaviour Therapy
C, CI, L	Cycle, Clinical Interview, Line
DBR	Design-Based Research
DBT	Dialectical Behaviour Therapy
fMRI/MRI	(functional) Magnetic Resonance Imaging

GCSE	General Certificate of Secondary Education
GZM	Growth Zone Model
HMB	Hand Model of the Brain
KS2	Key Stage 2
MA	Mathematics Anxiety
MARS	Mathematics Anxiety Rating Scale
MAS	Mathematics Anxiety Scale
MBTI	Myers-Briggs Type Indicator
NHS	National Health Service
NLS	National Literacy strategy
NNS	National Numeracy Strategy
OECD	Organisation for Economic Co-operation and Development
RCT	Randomised Controlled Trial
SAT	Standard Assessment Test
SDT	Self Determination Theory
SPSS	Statistics Package for the Social Sciences
STEM	Science, technology, Engineering and Mathematics
TIRED/TRIED	Tedious, Isolated, Rote-learning, Elitist, Depersonalised
UK	United Kingdom
UKRIO	United Kingdom Research Integrity Office
Y7	Year 7
ZPD	Zone of Proximal Development

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This thesis is also dedicated to my two granddaughters, Adeline and Lydia, with the hope that they always remember that adventure is the best way to learn.

DECLARATION

The work in this thesis was developed and conducted by the author between October 2017 and June 2021. I declare that, apart from work whose authors are explicitly acknowledged, this thesis and the materials contained in this thesis represent original work undertaken solely by the author. I confirm that this thesis has not been submitted for a degree at another university.

Papers in publication by the author:

Johnston-Wilder, S., Baker, J. K., McCracken, A. & Msimanga, A. (2020) A Toolkit for Teachers and Learners, Parents, Carers and Support Staff: Improving Mathematical Safeguarding and Building Resilience to Increase Effectiveness of Teaching and Learning Mathematics. *Creative Education*, Vol.11, No.08 24.

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ABSTRACT

Mathematics anxiety is a widespread problem that inhibits learning, despite it being preventable and manageable. This thesis reports a study which developed an intervention to support learners directly in the recognition and management of their mathematics anxiety. The research was conducted in two phases. Firstly, the existence of a substantial level of mathematics anxiety was established in eleven-year-old pupils in a Midlands comprehensive school, through an adapted mathematics anxiety scale. Secondly, pupils from this group with the highest levels of mathematics anxiety were offered the opportunity to take part in an intervention, and 13 pupils agreed. Three Design-Based Research cycles generated 32 clinical interviews which were delivered, recorded and analysed. The thesis supports the literature in that mathematics anxiety is negatively correlated to mathematical achievement, and more common in female learners than male learners. Qualitative analysis of the intervention found it to be efficacious. The thesis develops the Growth Zone Model introduced by Johnston-Wilder and Lee (2010) through the application of psychological strategies to reduce general anxiety and introduces a dynamic view of the model that is based in learner autonomy. Implications for future research and practical applications in school settings are discussed.

Chapter 1 Introduction

1.0 Chapter Introduction

The thesis begins by describing my personal motivation for studying mathematics anxiety, then outlines the more recent experiences that led me to doctoral study at the University of Warwick. The development of my research focus is then described. The chapter ends by outlining the structure of the remaining thesis chapters.

1.1 Personal Motivation

Mathematics has always been a sheltered harbour for me – a place of safety where the steps are logical, and answers are clearly right or wrong. One of my earliest memories is of my father sharing the fun and joy in mathematics by joking about squircles and tringles (circles and triangles). For me, mathematics was always attainable and enjoyable. As a teenager, I chafed under the school's expectations for girls to study biology at A level, and took a stand, by choosing mathematics and physics instead. Gaining high grades at A level meant that I could have studied either at university, but my interests lay elsewhere. So, although mathematics has always been a sheltered harbour, it is not my home port. I do not regard myself as a mathematician, although I can appreciate a little of its beauty and elegance.

I chose to study psychology at degree level, hoping to find out more about how individuals think, feel and learn. Unfortunately, there was a mismatch between my expectations and the course curriculum, and this and various other reasons resulted in a less than satisfactory learning experience. However, I completed the degree and moved on to study education. I gained a Post Graduate Certificate in Education and started to learn about learning. In my first year of teaching, I was given the responsibility of coordinating mathematics for the junior school (seven- to eleven-year-olds), and here I realised that my positive attitude towards the subject of mathematics was relatively uncommon amongst my colleagues. I experienced a prevailing lack of confidence in, competence in and appreciation of the necessity and value of good mathematics teaching which resulted in ineffective teaching approaches, in my opinion.

Teaching mathematics in Oxfordshire in the 1980s involved giving the learners work-cards to work through individually and helping them when they struggled. This approach resulted in a very inefficient system whereby those who could already understand the mathematics involved worked their way through the syllabus in isolation and without any level of challenge, whilst those who did not understand either the mathematics or the words on the card queued at the teacher's desk waiting in line for attention. The main thing they were learning was how to amuse themselves without getting into trouble - they certainly were not learning much mathematics. I started to focus on actually teaching mathematics, first to groups and then to the whole class. I made mathematics real and relevant by using actual money rather than plastic coins and introducing mathematical investigations and problems. The work-cards were abandoned, I enjoyed the teaching, and the learners enjoyed learning. However, when I tried to share this approach with my colleagues, I was met with resistance. It seemed that my fellow colleagues preferred using the cards to teaching the class, as they lacked confidence in the mathematics involved.

With a few more years teaching experience under my belt, I was offered the opportunity to influence primary teacher practice. The National Literacy Strategy (NLS) was launched, with an emphasis on curriculum, planning and timings. I was already trying out the pilot version of the National Numeracy Strategy (NNS), and felt that it had many useful aspects, including explicit teaching of strategies, an appreciation of mathematical processes and interesting lesson exemplars. This approach was very different from the previous approach of individualised learning through work-cards, and I was concerned that the slightly mechanistic approach of the NLS would be applied to the NNS and that the emphasis on deep understanding, evident in the NNS pilot would be overlooked. I applied for the role of NNS Numeracy Consultant, expressed my concerns in the interview, and was offered the job. I spent several interesting years working with the Oxfordshire Mathematics Centre, promoting the teaching and learning of mathematics through deep understanding and cooperative learning.

My time as a Numeracy Consultant taught me many things about teaching and learning, not least that the subject knowledge of the teacher is of paramount importance. However, I felt the growing need to speak with my own voice, from my own views, rather than repeating the views of the NNS. I wanted to be able to critically assess the strategy and judge its merits and deficits for myself. This led me to a master's degree in mathematics education at Oxford Brookes University, where I discovered the writing of Richard Skemp on relational and instrumental understanding, and Mike Askew's research on connectionist, discovery and transmission teaching methods. I finally had the academic evidence to support what I had long believed from personal experience, that mathematics teaching that explicitly made connections within topics, between topics and to real life, based on relational understanding, was most effective.

My studies then led to the opportunity to teach on the initial teacher training programmes at Oxford Brookes University. The strong collegiate support from the primary mathematics team supported my ideas around the importance of teaching for understanding, and my pedagogical principles were confirmed and strengthened. I began to notice that, over their teacher training, students became more confident in teaching mathematics. Students would often approach me at the end of the very first lecture or seminar, to tell me not to expect much about their ability to teach mathematics, as they were not very good at it. These very same students would often tell me at the end of their course that mathematics was their favourite subject to teach. I wanted to find out what had changed, and what we as lecturers could do to encourage this shift in attitude. I developed my interest from a focus on good mathematics teaching and learning to the area of mathematics anxiety.

The opportunity, funding and encouragement arose to study for an educational doctorate on a part-time basis whilst still teaching at Brookes, and I decided to focus on researching the nature of teaching styles to address mathematics anxiety. I learnt much about the nature of mathematics anxiety and the teaching styles associated with exacerbating or minimising mathematics anxiety. I continued to share these teaching styles with my students but became disillusioned when I noticed that these good teaching practices did not seem to last once students had been in school for a few years. The pressure of a demanding curriculum and intense scrutiny from management and Ofsted often resulted in less creative teaching styles. I began to question the value of my research and my doctoral studies ground to a halt.

This doubt coincided with a move away from Oxford Brookes University, where I had been teaching for ten years. I was now in the wilderness, questioning my next career move. I floundered in the doldrums, wondering what to do next. In the meantime, I made a little money by tutoring mathematics to learners from 8 to 20 years old. As this situation was not ideal for my career, I realised that I was ready to resume my doctoral studies, but this time I could study on a full-time basis, and as a PhD rather than an EdD. I hoped that these changes would improve my chances of success in studying. Most importantly, I had a new angle for my research.

I had previously been studying the avoidance of mathematics anxiety in learners through the actions of the teachers. My recent experience of supporting individual learners through tutoring had shown me the transformative effect of reducing mathematics anxiety on learning. I began to wonder about the applicability of psychological strategies to address generalised anxiety to learners of mathematics. Thus, my research focus shifted from the avoidance of mathematics anxiety through educating teachers to the treatment, management or reduction of mathematics anxiety through direct education of the learner. My passion for good mathematics education was now supported by my interest in how individuals think and feel. My psychological training had not been an unnecessary detour, but rather an early step towards a particular position.

1.2 DEVELOPING THE RESEARCH, AND INTRODUCING RESEARCH QUESTIONS

My particular positionality as a researcher is one which I think is a little unusual in the mathematics education community but follows in the shadow of great minds like Richard Skemp, who studied both mathematics and psychology to degree level. I am not a qualified secondary mathematics teacher, although I have tutored individuals to GCSE level. I do not consider myself to be a mathematician, although unlike many people I do not find the subject intimidating. I see myself positioned where education studies and psychology overlap. I am not an accredited educational psychologist, but nevertheless I believe I have the perspective of a psychologist, in that my deep interest in all aspects of effective learning is complimented by a psychological approach that includes neuroscience, child development, cognitive and clinical psychology. Though, as will be discussed below, mathematics anxiety is closely related to mathematical performance, it cannot be reduced just to a problem with mathematics. It seems to be as much an aspect of "anxiety" as an aspect of "mathematics." (Dowker, Sarkar & Looi, 2016: 2).

The majority of mathematics anxiety research is focused on the existence and potential causes of mathematics anxiety, which include cultural stereotypes and attitudes (Brown, Ortiz-Padilla & Soto-Varela, 2020), gender expectations (Hill et al., 2016) and teaching styles (Johnston-Wilder & Moreton, 2018). In my opinion, the existence of mathematics anxiety as a distinct problem in teaching and learning is well proven, and future research should now concern itself with both the prevention and management of mathematics anxiety. Whilst further research into solutions from the perspective of mathematics teachers is clearly valuable and worthwhile, the research in this thesis adopts a complementary and equally important approach, namely the pressing need to give immediate support to those learners who already suffer from mathematics anxiety.

Discovering this fresh perspective on the topic scooped me out of the doldrums and gave me the confidence to resume my doctoral journey. Although geographical commitments were a demanding consideration, as my family was in the process of relocating from Nottingham to Stratford upon Avon at the time, I knew from my previous unsuccessful attempt, and the varied experiences of my children's doctoral support, that the process of securing a supportive and expert supervisor was of paramount importance. I was therefore delighted when an initial inquiry to the University of Warwick resulted in an email introduction to Dr Johnston-Wilder, who is not only a recognised expert in the field, but also a prolific author and creative researcher. I approached our introductory meeting with great trepidation but was instantly put at ease by Dr Johnston-Wilder's encouraging and engaging personality. When she declared a strong interest in my research, I felt sure that this mammoth task was finally achievable.

Finding out more about Dr Johnston-Wilder's research strengthened my confidence in my positionality, having a foot in each camp of mathematics education and psychology. The key to Dr Johnston-Wilder's insight into mathematics anxiety is that normal brain functioning should be viewed holistically, with emotions, or affect, being intertwined with cognitive processes. Once the outdated assumption that feelings are irrelevant and unimportant to learning mathematics is abandoned, then the view that feelings are an integral part of effective learning and should be considered and managed as part of the learning process, can be accepted. Dr

Johnston-Wilder gives a vivid metaphor to illustrate her argument – that of the emotional handbrake (Findon & Johnston-Wilder, 2018). If a car was driven while the handbrake was still engaged, the progress of the car would be significantly impeded. If an individual is trying to learn mathematics whilst experiencing mathematics anxiety, then their progress would be similarly impeded. The easy solution to the car situation is to release the handbrake. In the mathematics anxiety analogy, releasing the limiting effect of mathematics anxiety is a little less straightforward, but still possible. The Growth Zone Model (Johnston-Wilder & Lee, 2010) is a mechanism which helps to release the limiting impact of mathematics anxiety. Studying the impact of emotional processes on mathematical learning thus demands to be informed from both the field of psychology, particularly positive psychology, and mathematics education.

I allowed myself time to explore the possible research questions which might capture and focus the impact of emotional processes on mathematical learning. As I explain in more detail later in the thesis (Section 4.1.1) my research questions changed significantly through their evolution. However, a consistent aim was to both contribute to theory and develop something of practical use, by researching the process of addressing rather than preventing mathematics anxiety, and by supporting the learners directly rather than advising the mathematics teachers. I therefore developed my research based on the initial overview question of 'How can an intervention support learners to manage and overcome their mathematics anxiety'. The following chapters describe this research in depth, although as is explained below, the structure of the thesis is necessarily complex to accommodate the dual fields of influence and the multiple types of outcome.

1.3 THESIS STRUCTURE

The structure of this thesis is more complicated than the expected norm, and so demands explanation. Two separate literature review chapters follow this introductory chapter, as the thesis draws from the separate fields of psychology and mathematics education. The methodology chapter is then presented. Instead of one findings chapter, three separate chapters for findings are then presented, including a chapter for the quantitative findings, a chapter for the Design-Based Research findings and finally a chapter which presents the findings from the thematic analysis of the data. The discussion chapter draws together the findings form all three of these chapters in the light of the two literature review chapters. The final chapter of the thesis presents the conclusions of the study. The thesis continues by explaining the rationale for separating the review of the literature into two separate chapters.

Chapter 2 First Literature Review: The Psychological Perspective

2.0 Introduction

The structure of this chapter and the next reflect the nature and theoretical position of this thesis, which have evolved over the course of my doctoral studies. Early iterations reflected my experiences as a teacher trainer, where I adopted a view that was limited to the effects of mathematics anxiety on learners and subsequent impacts on learning. However, as described in the previous chapter, I found renewed research motivation with one foot in the field of education and the other in the field of psychology. I began to research into anxiety, specifically as it is experienced and addressed in more general situations, as I hoped to find strategies that would be efficacious for learners with mathematics anxiety. Additionally, as I analysed the data, the need to move away from a deficit or illness-based model to look at how normal or wellness-based psychology systems work became apparent. These new perspectives therefore necessitated an adaptation of the initial structure of the literature review. Subsequently, having all four dimensions in one chapter was proving to be too unwieldy and unmanageable. Dunleavy (2003) advises that a thesis chapter should be straightforward and warns against the tendency to try to include too much information. Once I had identified that this was indeed what I was doing, then dividing the literature review into two chapters seemed the obvious solution.

Thus, this first literature review chapter considers the psychological domain, specifically positive psychology and relevant research on anxiety. The second literature review chapter focuses on mathematical anxiety and mathematical learning.

The order of the sections and chapters reflects my perception of the steps required to consider the nature of effective mathematical learning, which is the main objective of the literature review. The reader is therefore prepared to consider effective mathematical learning by preceding chapter sections on positive psychology, anxiety in general and mathematics anxiety.

This thesis concerns itself with the impact of negative mental health experiences on learning. However, section one begins by considering theories and constructs from the field of positive psychology that best explain the benefits of positive mental health on learning, as this perspective suggests realistic expectations to work towards. The scope of section one does not permit the inclusion of the entire field, but the section endeavours to represent theories and constructs of positive psychology that relate to the research. The second section considers theory and research on anxiety. It comprises three subsections. The first explores anxiety as part of the human condition and identifies the inherent evolutionary purpose of the emotion. This subsection also explores the relationship between anxiety and stress. The second subsection challenges the commonly-held assumption that stress is always detrimental. The third subsection explores ways to manage anxiety that would be appropriate for the mathematics learning environment, particularly in secondary education. This approach enables information relevant to the specific phenomenon of mathematics anxiety to be drawn from the wider field of generalised anxiety. The next section begins by considering the impact of positive mental health on learning.

2. 1 POSITIVE PSYCHOLOGY

2.1.0 Introduction

The first topic under consideration in this section is self-efficacy (Bandura, 1990b), a construct that is closely aligned with agency, confidence and autonomy. The second aspect to be considered is motivation, where the Self-Determination Theory of Ryan and Deci (2017) will be evaluated in depth. Lastly, wellbeing is considered, specifically the work of Seligman (1991) on optimism. This aspect is admittedly more amorphous than the well-defined and researched aspects of self-efficacy and Self-Determination Theory; however, it is included as the construct is increasing in currency. The positive psychology section as a whole will therefore describe how emotions impact on thinking and learning, and how the intention to help learners understand mathematics also involves safeguarding them from psychological harm.

2.1.1 Agency and Self-Efficacy

A consideration of the importance of learner autonomy can be found in the self-efficacy aspect of Bandura's (1990b) social cognitive theory. Here the construct of self-efficacy relates to, but is more sharply defined than, the generally amorphous term 'confidence'. It may be argued that such psychological theories would more accurately sit within a section on learning than positive psychology. They are included here as they contribute to the necessary discussion on effective learning, being based in an approach that starts with the power and agency of the individual. Agency is described as an individual's actual ability to 'exercise control over events' (Bandura, 1990b:128) whereas self-efficacy is described as 'people's beliefs about their capabilities to exercise control over events that affect their lives' (ibid., 1990:128). This distinction between reality and personal belief is a useful one for this thesis, and the terms will be used according to these definitions throughout.

The construct of self-efficacy describes a specific focus on a task. For example, an individual might believe that they will be able to answer a question on arithmetic fractions but not on algebraic fractions. This construct is pertinent because, for mathematics anxiety, a learner's perception of their ability or chance of achievement can vary from topic to topic (Pajares & Miller, 1994). Self-efficacy supports effective learning: it is a reliable predictor of achievement (Beatson, Berg & Smith, 2020); can be improved to increase attainment (Zuffiano et al., 2013; Komarraju & Nadler, 2013); and is linked to the construct of a growth mindset, created by Dweck (2000), as discussed in the next paragraph.

Dweck's theory, which explains the impact of mindsets on learning, is based on many years of research (Dweck, 2000, 2017) and draws from Bandura's (1990b) constructs of self-efficacy and agency. Dweck's (2000) theory identifies the assumptions of the learner around the nature of learning as influential in the effectiveness of any learning event. The link between growth mindset and self-efficacy is supported by researchers such as Komarraju and Nadler, who found that "students who have high self-efficacy and confidence in their academic performance are also more likely to believe that intelligence is changeable and determined by effort" (2013:70).

Dweck found that she could categorise learners broadly into two distinct groups according to their attitude to learning. She describes some learners as having a fixed approach to learning. These learners believe that their ability to learn is unchanging and that their success is unrelated to their personal effort. They think that an experience of struggle indicates a lack of ability. Dweck describes the other group of learners as having a growth mindset, who see learning as an active process involving effort, and sometimes struggle, but that some level of achievement and success is always possible. These learners believe that ability can be increased through effort, and therefore have a very different view of their self-efficacy compared to learners with a fixed mindset.

A deficit of self-efficacy results in an increase in anxiety as the learner's perceived 'control over potential threats plays a central role in anxiety arousal' (Bandura, 1988:77). This biopsychosocial model explains a further nuance in the process of assessing challenge and threat by suggesting that a negative or damaging stress response results from the learner analysing the situation as threatening if it demands more resources than they perceive to be available, as opposed to a challenging but non-threatening situation where the learner's perception is that available resources are sufficient to meet demands (Jamieson et al., 2018; Crum, Jamieson & Akinola, 2020). If the learner does not think they can do the task, then the perceived deficit of resources to meet demand will result in an experience of threat, causing anxiety. Thus, the construct of self-efficacy provides an explanation for the link between the learner's cognitions and their stress responses (Karademas & Kalantzi-Azizi, 2004).

Self-efficacy is recognised as influential on effective learning. One study (Zuffiano et al., 2013) found that, for 170 13 and 14-year-old students, self-efficacy at the start of the year was a strong predictor of academic success at the end of the year.

This study was short-term in nature and would have benefitted from having a more longitudinal approach. Nevertheless, the authors have a strong message about the importance of improving self-efficacy to increase achievement. A larger sample (over 400) of college psychology students (Komarraju & Nadler, 2013) confirmed that self-efficacy can be improved and developed. Arguably the authors failed to explore the causal relationship between self-efficacy and achievement with enough depth and rigour. However, the findings support Bandura's argument (1990b) that self-efficacy improves with achievement, as does other research in the area, such as Magnano, Ramaci and Platania (2013) who examined the relationship between self-efficacy of Italian primary school pupils and their teachers' evaluation of each pupils' academic performance, and Fenning and May (2013) who found a similar positive relationship in American university students. Self-efficacy can therefore be seen as influential on learning outcomes at all ages and stages of education, from primary school to university level, and indeed throughout lifelong learning.

This subsection argues that the learner's sense of agency, their level of self-efficacy for learning specific topics and whether they have a growth or fixed mindset, all impact on learning outcomes. Additionally, the preceding paragraphs argue that self-efficacy and the anxiety resulting from learning situations are negatively correlated. An intervention that encourages the learner to develop their personal agency, increases their level of self-efficacy for specific topics and develops a growth mindset towards learning, would arguably both mitigate any increase in feelings of anxiety associated with that learning and also improve the outcomes of the learning.

Later in the thesis this view will be specifically applied to mathematical learning. Furthermore, the opportunities for development of agency, self-efficacy and growth mindset in typical secondary level mathematics classrooms will be explored. However, as learning is a complex and multifaceted activity, it seems wise to consider other influences on positive psychological health which impact on learning. The next section therefore considers the importance of motivation to psychological health and effective learning.

2.1.2 Self-Determination Theory

Motivation is an important element of the learning process. Motivation is typically viewed as either intrinsic, which stems from the desire of the individual, or extrinsic, where the desire is to satisfy an external demand (Ryan & Deci, 2017). Ryan and Deci's Self-Determination Theory (SDT), (2000) takes this categorisation and develops it further in a productive way. Ryan and Deci see motivation as relating to whether the learner's psychological needs are met or not. Specifically, they identify the need for relatedness, competence and autonomy as essential for motivation. This section describes Ryan and Deci's theory in detail as it is pivotal for the later thesis. An overview of the theory is followed by detailed descriptions of the three needs, then the sub-categorisation of intrinsic and extrinsic motivation is re-considered. Finally, the link to anxiety is clarified.

Self-Determination Theory assumes that the individual normally takes a proactive approach and only adversely reacts or responds passively as a learned response. So SDT assumes that individuals normally have agency to meet their basic needs of autonomy, relatedness and competence. If needs are met, then the individual thrives and experiences growth through psychological health and wellbeing (Durmaz & Akkus, 2016; Ryan & Deci, 2017; Mackrell & Johnston-Wilder, 2020). Conversely, if the needs of a learner are not met, then opportunities for growth and wellbeing are either limited or non-existent. If a learner's needs are frustrated, then the result can be anxiety (Vansteenkiste & Ryan, 2013). The explanation of this resulting anxiety will be explored after an explanation of each need.

Ryan and Deci (2000) identify an individual's sense of competence as a basic need. They describe competence developing in a variety of environments, for example, in social interactions, physical activities and educational settings. A growth of competence arises from opportunities for the individual to develop their skills and experiences in order to increase understanding. Importantly for the focus of this thesis, an individual's competence in emotional coping strategies and their use of emotional resources are included as part of this construct. The need for competence when managing emotions relates to mathematics anxiety as the experience of learning mathematics can be a highly emotive one (Buxton, 1981; Devlin, 2000; Evans, 2000; Haylock 2010; Boaler, 2016). It can be argued that, to meet the need of growing competence, whether of the emotions or more generally, learners require the opportunity to work things out gradually and appreciate that their understanding progresses rather than emerges fully formed (as is also described by Dweck's growth mindset theory—Dweck, 2000, 2017). As will be discussed later, this opportunity is not always offered in the mathematics classroom.

Relatedness is described by Ryan and Deci (2017) as the experience of involvement in and appreciation by a wider community. For a learner, relatedness is developed through opportunities to learn collaboratively in an accepting environment where growth is mutually experienced and supported. Acceptance is recognised as an important factor in relatedness, in that the individual is seen and valued for their current abilities. Ryan and Deci explain the damaging impact of a lack of relatedness by referring to such early psychological (albeit ethically contested) research such as that of Harlow, Dodsworth and Harlow (1965). The experience of a deep sense of threat arising from rejection or alienation from a community can be applied to the mathematics classroom, where a fear of abandonment following experiences of academic failure or even ridicule can be experienced. The physiological response to this fear will be further discussed in the section on anxiety.

Deci and Ryan (2017) describe autonomy by recognising certain limitations in Bandura's (1990b) constructs of agency and self-efficacy and addressing these by developing a more nuanced and subtle meaning of autonomy. For Deci and Ryan, autonomy is characterised by the individual's control over their actions specifically to develop competence and relatedness. Autonomy is therefore seen not as an independent, separate strength as described by Bandura but rather the ability and facility of the individual to meet all their basic needs. Deci and Ryan view autonomy as deeply rooted in the individual's environment, whereas Bandura sees autonomy as independent from the environment.

As mentioned above, Ryan and Deci (2017) adopt a nuanced approach for motivation. An important aspect of this nuance is the categorisation of extrinsic motivation into four points on a spectrum, helpfully illustrated by Haerens et al. (2015: 26) as 'the bright and dark side of motivation'. Intrinsic motivation is placed at one end of the spectrum and at the opposite end of the spectrum sits a-motivation, which is described as a state of incompetence and non-control, much like the learned helplessness state described later (Peterson, Meyer & Seligman, 1993). Learners who are a-motivated are more likely to fail to achieve their academic potential (Ryan & Deci, 2017:364) and this state does not encourage learning (Mackrell & Johnston-Wilder, 2020; Carr, 2020).

Extrinsic motivation can range from the volition to conform with expectations and demands to avoid punishment and achieve external rewards (called 'external regulation'), which is not much more productive than a-motivation, to an internal recognition that the activity is worth doing because, although it might not be satisfying, it is nevertheless valued (called 'integrated regulation'). This theory could arguably be developed by application to the mathematics classroom, where an initial extrinsic motivation or integrated regulation encourages the learner to engage in the learning because a certain level of mathematics ability and knowledge is valued by others or by themselves, but then experiences of engagement resulting in success build a sense of satisfaction and enjoyment, developing motivation that is more intrinsic in nature. Between intrinsic motivation and external regulation there is controlled motivation, where the learner is motivated by a wish to avoid harm or to gain external reward. Limited learning can happen here, but there is a risk for anxiety to develop as competence, relatedness and autonomy opportunities are necessarily lacking (Vansteenkiste et al., 2009; Mackrell & Johnston-Wilder, 2020).

Deci and Ryan (2017) contend that when an individual's needs of autonomy, competence and relatedness are met, then they will experience growth and wellbeing, and conversely, if these needs are not met, then growth will be severely curtailed, and wellbeing will be adversely affected. However, a third state is also proposed, where an individual recognises the need for competence, autonomy and relatedness, but environmental factors result in these needs being frustrated. Durmaz and Akkus (2016) argue that anxiety can develop in such situations. As explored above, it is possible that the needs would be frustrated in a mathematics classroom, for example if a learner has no choice over how to answer a mathematics problem, has to work independently and is judged on arriving at an incorrect answer even though they have developed their understanding through the process. Thus, both Self-Determination Theory and biopsychosocial theory are likely explanations for the cause of mathematics anxiety.

This subsection describes Self-Determination Theory in depth because it is used later in the thesis as a theoretical framework to evaluate the findings of the research. Deci and Ryan's theory (2017) compares favourably to Dweck's mindset theory (2000) as it recognises the importance of adopting a holistic view of the learner and their key psychological needs. However, like any theory, it has limitations. Self-Determination Theory focuses on three specific (if admittedly influential) needs. This compares to Maslow's (1943) hierarchy of needs, which takes a wider and hierarchical view that is more encompassing of the whole human experience, including such needs as physiological (sustenance and warmth) and safety (predictability and structure in the home and school environment). Deci and Ryan address the absence of a hierarchy in the structure of their identified needs, by arguing that there are many situations where individuals sacrifice a lower need to meet a higher need (an example from my own experience is the months I chose to spend in a cold room working on this thesis, sacrificing the need for warmth and prioritising the need for self-actualisation). Deci and Ryan's categories of relatedness, competence and autonomy can be aligned to Maslow's needs of belongingness, esteem and self-actualisation. Deci and Ryan include safety as a 'deficit' need (2017: 254). Physiological needs are considered by the authors to be outside the boundary of psychological processes, which is the level at which they focus their attention. After much careful consideration, and with the caveat that this theory focuses on the psychological level rather than including physiological needs, this thesis recognises Self-Determination Theory to be a useful theoretical framework with which to interrogate the findings of my research, as it enables an analysis of effective mathematics learning by indication that mathematics learning is less effective when specific needs are not met.

2.1.3 Wellbeing

This section explores a third perspective on psychological health, namely wellbeing, which is broadly understood to be the feelings and functionality of an individual (Stewart-Brown, 2015). This area has recently grown in terms of both research activity and recognition of importance, particularly in areas such as student wellbeing (see, for example, Hughes and Wilson, 2017) as well as in the more general area of the wellbeing of the UK population (for example, NHS 2019). Wellbeing covers a broad range of areas, so the key concepts of optimism, confidence, persistence and perseverance are described in this section as they inform the thesis. These terms are widely used to mean a range of characteristics in general parlance so their intended usage for the purposes of this thesis will be defined. Subsequently, links to previously discussed theories will be made. The section finishes by recognising the value of the growth of the wellbeing perspective, whilst acknowledging the lack of theoretical frameworks with which to evaluate an intervention.

The key concepts mentioned above are principally informed by the theories of Seligman, dubbed ‘the father of positive psychology’ (1991: back cover). Seligman has published extensively on the characteristics of mental health, an approach which he has named ‘Learned Optimism’. Optimism is defined by Seligman as the individual’s response to either positive or negative experiences, depending on whether they are perceived to be permanent or temporary, perceived as influenced by personal or external factors, and perceived to be caused by general or specific circumstances. Thus, the person who sees a setback as temporary, caused externally and due to specific circumstances will have a more optimistic response to the situation than a person who views a setback as permanent, caused by themselves, and likely to recur as it is caused by general circumstances. Additionally, the person who sees a positive experience as permanent, caused by themselves and due to general circumstances will have a more optimistic response to the situation than a person who views a positive experience as temporary, caused externally and so outside their control, and not likely to recur as it is caused by specific circumstances.

Seligman (1991) suggests that learning to become more optimistic results in beneficial outcomes in terms of both mental health and tangible achievements. One can learn to be more optimistic through adopting a positive approach, recognising personal strengths, building relationships and finding meaning. Seligman emphasises that a more optimistic approach to life can be achieved by an individual identifying and using their ‘signature strength’ (1995). It should be recognised that there is a parallel here with Bandura’s (1988) construct of self-efficacy and Ryan and Deci’s (2017) construct of autonomy. In terms of mathematics learning, this could be achieved by a learner finding the best way to engage with mathematics. Seligman also recognises that relationships with significant others are important, much like Deci and Ryan’s (2017) construct of relatedness. For mathematics learning this could involve interaction and collaboration with teachers and other learners, such as those described by Cousins et al. (2019). For an optimistic approach, finding meaning is important. In terms of mathematics, this can be related to the perceived value of mathematics. This could be at a personal level, but Seligman also encourages a collaborative and encouraging approach, for example, being part of a learning community in a school. There are clear links here to Ryan and Deci’s (2017) construct of relatedness.

Seligman (1995) defines confidence by describing a pervasive outlook or general perception on life, which is significantly different to the construct of self-efficacy as described by Bandura (1988) as feelings of expected competence towards specific situations or tasks. Individuals who are confident and optimistic in their everyday life can also have mathematics anxiety, if they have low self-efficacy for mathematics tasks and learning (Dowker, Sarkar & Looi, 2016). Seligman additionally recognises the importance of accomplishment, achieved through grit or persistence. Persistence is defined as the capacity to continue working towards goals despite the hindrance of obstacles. The characteristic of perseverance is closely associated with persistence, but the two terms are helpfully distinguished by Williams (2014). Williams identifies perseverance as the ability to overcome, circumvent or avoid obstacles through adopting a reflective approach. This is not the same as persistence, which she describes as a continuing effort in a fixed direction. In a mathematical learning environment, persistence could be exemplified by a learner continuing to struggle with a problem, whereas perseverance could be exemplified by a learner stopping to review, and then adopting an alternative approach to solve the problem or alternatively recruiting support from another source such as the internet.

Both Bandura's (1988) construct of self-efficacy (which can be increased through experiences of success), and Ryan and Deci's (2017) construct of competence resonate here. However, it should be noted that expectations of grit or persistence can add to the stress of learner, as they can feel that it is doubly their fault if they fail (Boaler, 2016). The encouragement of persistence can arguably have negative effects in a learning environment, if learners assume that they need to exert more effort rather than adopt a self-efficacious approach which might involve asking for appropriate support. A recognition of the importance of psychological wellbeing can only benefit the learning experience, however, it does not seem, for the purposes of this thesis, to offer as robust or appropriate a theoretical framework. Learned optimism is a personal response to situations, and therefore has a focus on the individual in isolation. In contrast, Self-Determination Theory considers the individual's needs in the context of provision from the environment, and so takes an entirely different perspective. For a thesis that aims to consider the wider domain of the learner in their learning environment, this is an important consideration. Nevertheless, the constructs of learned optimism and perseverance offer useful lenses through which to examine findings and will be employed appropriately in later chapters. Additionally, the notion of wellbeing will be further explored in the following chapter, in the context of mathematical wellbeing (Tobias, 1995).

2.1.4 Section Summary

Following an exploration of some possibly relevant theories on motivation, this thesis takes the view that Self-Determination Theory is very relevant to any consideration of effective mathematics learning. Additionally, Self-Determination Theory is well researched (Niemiec & Ryan, 2009). As will be explained in a later section, the experience of mathematical learning for many, however, is that these needs are not met sufficiently.

The first two subsections in this section explore very specific areas of the positive psychology field, namely agency/self-efficacy and Self-Determination Theory. The third section takes a more general approach. These topics have been included in this chapter as they impact the thinking behind the thesis, and support the argument that a sense of control and ability to make a choice, described variously as agency or autonomy in the sections above, is vital in creating a learner with both the motivation and the perseverance to achieve their full potential. Self-efficacy is a slightly different construct, in that it is specifically concerned with a particular task. This thesis will draw upon both these ideas in the discussion section. Self-Determination Theory will be used to support discussion on the social aspect of mathematical learning, and perceptions of competence. Self-efficacy will be used to support discussion on the capacity of the individual learner to direct their own learning. These constructs will be considered in terms of mathematical learning and mathematics anxiety in the next chapter. The current chapter continues with a review of the general literature on anxiety, in particular aspects which are relevant for learners who experience mathematics anxiety.

2.2 ANXIETY

2.2.0 Introduction

In this section of the chapter, the focus of the literature review moves from positive psychology to a consideration of mental ill health. This section makes the important distinction between stress and anxiety and continues by reviewing literature which reports the preponderance and prevalence of anxiety in its different forms in various subgroups of the population. The section also considers the often-overlooked benefits of stress, and concludes by considering some approaches for addressing, overcoming or managing distressing levels of anxiety that are recommended by mental health professionals.

2.2.1 Who is Prone to Anxiety and Why?

Anxiety is frequently viewed as an aberration of, dysfunction of or departure from normal emotional function. However, current theories on the evolution of anxiety as a human emotion position the experience as a useful, if uncontrolled and extreme, response to a novel and therefore potentially dangerous situation. If anxiety is perceived as a vital response that has got out of hand, then it follows that it is appropriate to manage it in a way that recognises the value of the response whilst lessening its impact. As will be explained below, acceptance of anxiety is an important element of many treatments, and it is much easier to accept something that has inherent value. Anxiety is widely recognised as a disorder - a problematic, unhelpful and unnecessary mental anguish, even by health professionals (for example

NHS, 2019). However, if a contrasting view of anxiety as a sensitivity to potential threats is taken, the result is a ‘coordinated mental, behavioural and physiological response’ (Miloyan et al., 2017: 1). This view has a doubly beneficial outcome as it offers both the potential of an appropriate level of intervention and some consolation for those experiencing anxiety.

When filled with a sense of overwhelming anxiety that makes little or no sense, it seems counter-intuitive to appreciate that human emotions, anxiety among them, have evolved through natural selection to preserve the continuing existence of an individual’s genes (Nesse, Bhatnagar & Ellis, 2016). Nesse et al. describe anxiety as a self-preservation mechanism, one that errs on the side of caution. This mechanism has evolved as a lifesaving response to an uncertain world, triggering the automatic response of fight, flight or freeze (Maack, Buchanan & Young, 2014). The value of a warning that alerts the individual to potential risk is clear. However, just as a smoke alarm sometimes rings when there is no significant danger, for example, when toast has burnt, anxiety causes false alarms (Nesse, 2005).

The process of natural selection has resulted in the unpleasantness of the false alarms being selected over the catastrophic results of a lack of caution (Smits, Powers & Otto, 2019). Moreover, the human amygdala does not differentiate between physical and psychological threats such as exclusion and humiliation and triggers a similar response to all threats (Penzo et al., 2015).

The tendency to experience unpleasant levels of anxiety varies across the population. This can be explained by variations in personality types as well as gender, age and medical history. A recent systematic review identified women, young adults, those with chronic medical conditions and Europeans as more prone to anxiety than men, older adults, healthy individuals and those from African, Asian or Indian cultures (Remes et al., 2016). The issue of gender will be explored in more depth in the section on mathematics anxiety. The following paragraphs will explore the impact of personality type on propensity to anxiety, by considering and comparing three approaches to categorisation. An appreciation of the nature of this variation is important to the present thesis as prevention can then either be focused on particular needs or applied wholesale, depending on need. The use of a model to think about variation in sensitivity across the population can therefore assist the practitioner in delivering interventions appropriately.

The Myers Briggs Type Indicator (MBTI) is a tool to categorise personality with the intention of helping people to recognise their individual personality type and make best use of their abilities (Quenk, 2009). It was designed by a mother and daughter who were neither psychologists nor experienced in psychometric testing but has been adopted and developed by the business community (Peterson & Rutledge, 2014). It is based on Jungian theory of personality (Girelli & Stake, 2010). The MBTI divides personality types into four broad categories, with each category described by two extremes. This thesis concerns itself with just one of those categories, that of ‘thinkers’ and ‘feelers’ (Myers et al., 1998) as previous research has shown that more people who identify as ‘feelers’ develop mathematics anxiety (Hadfield & McNeill, 1994). Individuals who look for logical explanations to enable their decision-making process are described as thinkers, whilst feelers are more in touch with their emotions which they use to guide them in making decisions. Feelers are more likely to become anxious, as they both pick up on the anxiety of others and appreciate the impact of their actions on the emotions of others.

One explanation for the variation in levels of anxiety can be found in the work of Baron-Cohen (1995, 2003) who studies individuals on the autistic spectrum and uses the insights gained to inform views on neurotypical differences. Baron-Cohen initially adopted a gendered approach by describing the female brain to be more likely to empathise with others than male brains, and male brains to be more analytical and focused on systems and structures than female brains (Baron-Cohen, Knickmeyer, & Belmonte, 2005). This difference forms a spectrum, where extremes occur. The extreme male brain was linked by Baron-Cohen to autism. However, it is important to note that Baron-Cohen's male-female brain theory is contested on the grounds that it constitutes 'neurosexism' (Fine, 2017). Baron-Cohen has now distanced himself from this gendered view, recognising that women can have more analytic and less empathetic brains, and men can have more empathetic and less analytic brains. An alternative and preferable set of labels now used by Baron-Cohen is 'systemisers' for male brains and 'empathisers' for female brains (Baron-Cohen, 2009). These terms will be subsequently adopted in this thesis.

It is important to note that this description is not a fixed life sentence, as systemisers can learn to be more empathetic, and empathisers can learn to be more systematic. However, systemisers are drawn to STEM subjects such as science, engineering and mathematics, by the systematic nature of these subjects and subsequently some become teachers of mathematics (Baker, Cousins & Johnston-Wilder, 2019). Johnston-Wilder and Lee (2010) suggest that mathematics is a subject frequently taught by systemisers who lack the ability to empathise with the uncomfortable feelings of pupils, resulting in a lack of support which generates frustration and anxiety in those pupils, who are often empathisers and often female.

An alternative explanation of the variation in the tendency to anxiety in the population can be found in the Dandelions and Orchids theory (Pluess, 2015; Boyce, 2019). These separate research projects compared the physical sensitivities of children and the resulting impact on their mental health. Distinct variations were identified in an individual's sensitivity to their environment, with the resulting types being characterised as 'dandelions' and 'orchids'. Boyce's team found that around 20% of children studied, of a range of ages, were much more prone to infections and illnesses but also, surprisingly, more likely to have much better health, compared to the rest of the sample. These children, labelled as 'orchids' to represent their relatively high combined sensitivity and potential, could vary widely in physical and mental health, with individual outcomes depending on the care and nurture available in their particular environment. The remaining 80% of the sample were labelled as 'dandelions' as these children were not so sensitive to the care and nurture available to them, tending to survive in any situation.

Pluess' team (2015) took this distinction further by considering adults and identifying three groups, namely 'orchids', who are individuals at the highly sensitive end of the spectrum, 'tulips', in the middle, and 'dandelions' at the low sensitivity end of the spectrum. Further research (Lionetti et al., 2018) also recalibrated the proportions, identifying that 31% of the population can be characterised as orchids, 40% as tulips and 29% as dandelions. This research considered levels of mental health by examining personality traits and emotional reactivity. The variation in the general population could explain why, given the same or very similar environmental conditions, some children develop debilitating mathematics anxiety whilst others survive relatively unaffected.

Viewing anxiety as an evolutionary development which has perhaps got out of hand, rather than a mental aberration or deficit, is useful in terms of moving forward with efforts to prevent or manage it in the mathematics anxiety arena. This thesis accepts that some individuals are more prone to anxiety than others. However, the choice of which typology to adopt to describe the difference in sensitivity is a difficult one as each typology has something to offer the development of the thesis. The theoretical construct behind the terms 'thinkers' and 'feelers' allows the potential for the development of skills at the other end of the spectrum. The terms 'empathisers' and 'systemisers' are particularly appropriate to mathematics education, and indeed the construct is already in the mathematics literature (Johnston-Wilder and Lee, 2010). The thinking behind the terms 'dandelions' and 'orchids' is perhaps slightly more nuanced as it includes the third category of tulips.

2.2.2 Is Stress Always Bad?

Stress is often closely associated with anxiety. However, it is important to note a difference in the terms. Although in common parlance stress is described as a negative experience, not all experiences of stress are debilitating and damaging. Stress can be helpful in some situations. Some stress (perhaps more helpfully described as stimulation, or arousal) is needed to focus attention and encourage individuals to engage with the task of learning (Le Fevre, Matheny & Kolt, 2003). Individuals often need extrinsic motivation to engage in activities which lack appeal, and a manageable amount of stress can produce beneficial results. However, too much stress is debilitating (Benson, 1975). Fortunately, research has identified an optimal zone where there is enough stress to focus the mind but not too much to adversely affect performance. This concept is recognised in Management Theory as the Yerkes Dodson law (Corbett, 2015). The optimal zone is also recognised in general education situations (Cassady & Johnson, 2002) and particularly in outdoor or adventure education literature (Brown, 2008) where it is called the ‘stretch zone’ and bounded by the ‘comfort zone’, where stress is minimal, and the ‘panic zone’ where stress is distressing and debilitating.

Further evidence for the existence of an optimal zone where stress, or challenge, is supported by the resources (real or perceived) available to the individual can be found in the writings of Csikszentmihalyi (1997). Csikszentmihalyi describes the experience of being in the optimal zone as a state of flow, where a person finds fulfilment and satisfaction by being completely absorbed in a task. This is contrasted with anxiety, as shown below:

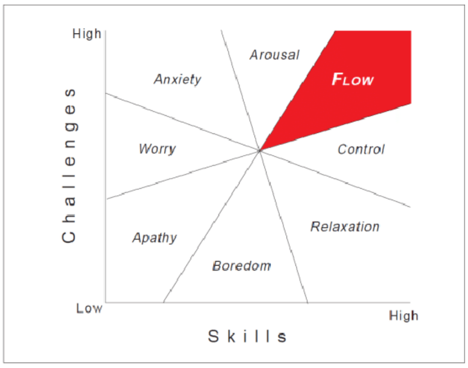


Figure 2.1 Quality of Experience as Relationship between Challenges and Skills. (Csikszentmihalyi, 1997 cited in Kahn, 2003).

The above diagram includes states other than anxiety and flow: states such as arousal, which is described by Csikszentmihalyi as the experience where the skills of the learner are not quite sufficient, but nevertheless learning takes place, and control, the state where skills are more than sufficient to meet the present challenge. Csikszentmihalyi's work therefore supports the contention that stress is not always detrimental to health and wellbeing. In addition, it can be argued that the construct of flow adds further strength to the argument of the benefits of a manageable level of stress, by including enjoyment and satisfaction as benefits (whether real or perceived) of a balance of challenge and resources.

Experiences of stress that are short-term can additionally enhance physiological protection and mental performance (Dhabhar, 2018). In an article that focuses mainly on the physiological and physical effects of chronic and acute stress, Dhabhar describes the chemical process which both enhances memory function and increases brain activity as a response to stress. For memory to be enhanced, research suggests that the experience should be a highly emotional one (McIntyre et al., 2007). The increase in brain activity, in other words having the ability to think quickly on your feet, is seemingly dependent on the perception of the individual (Jamieson et al., 2010). If the stressful event is viewed as an opportunity or a manageable challenge, then the brain chemistry of the individual reacts in a way that enhances brain processes. Dhabhar (2018) concludes by recommending that the ability to manage the 'fight, flight or freeze' response is one that can and should be taught and rehearsed, as this will improve performance.

This subsection has argued that stress is not a necessarily negative experience, and therefore the intention of the research described in the thesis is not to eliminate stress in the environment of mathematical learning. Conversely, some level of stimulation or arousal is arguably needed to secure engagement in learning activities. Furthermore, this can be an enjoyable, fulfilling or satisfying experience for the learner. A manageable level of stress can also improve memory and enhance the ability to think quickly. However, this potential benefit depends on the perception of the individual of the impact of the stress.

2.2.3 Managing Anxiety

This subsection will examine various approaches to managing anxiety, including an in-depth consideration of a therapeutic approach which has had a significant influence on this thesis, namely Dialectical Behaviour Therapy (DBT). As anxiety is a problem for many individuals, there is much advice available on avoiding or overcoming the distressing feelings it engenders. However, this section recognises the approach adopted by DBT that anxiety, much like stress, is best dealt with not by hiding from or fighting it, but rather through accepting and learning to manage it. DBT is the main and best researched approach considered here, but other therapies are considered in terms of what they can offer the mathematically anxious. The subsection concludes by summarising the links between general anxiety disorders and mathematics anxiety and identifying the therapies that will be adopted and evaluated in the main research section of the thesis.

Dialectical Behaviour Therapy (DBT) is a ‘talking therapy’ which aims to balance acceptance and change (Linehan et al., 1991). It was developed by Marsha

Linehan as an adaptation of Cognitive Based Therapy (CBT). CBT focuses on helping the individual to recognise and then rewrite their negative thought patterns (Tolin, 2010). Linehan’s patients were distressed by the implicit criticism involved in CBT, where negative thoughts are seemingly blamed on the individual. DBT differs from CBT in that it begins with assuring the individual that they are good enough as they are. Before change can be addressed, ‘radical acceptance’ must be achieved. An overwhelming situation can be tolerated through the approach of letting go of the struggle to change and letting things be exactly as they are (Chapman et al., 2011). This can be particularly hard when the past and the current situation are painful, but Linehan distinguishes between pain and suffering. Rather than trying to avoid pain, she advises that it is best accepted. It is important to note though that any subsequent suffering can be changed. In the same way, the individual is encouraged to accept themselves as they are, and then to work on changing themselves. This duality of contrast and interrelatedness is at the heart of the therapy, hence the inclusion of the term ‘dialectical’ in the name. DBT was developed as a treatment for Borderline Personality Disorder (BPD) but has been found to be effective in the treatment of anxiety (Neacsiu et al., 2014) as well as other mental health problems.

The individual is taught specific strategies for practical everyday use. These comprise mindfulness skills, distress tolerance strategies, interpersonal effectiveness skills and emotion regulation skills (Chapman et al., 2011). In order to manage overwhelming distress, DBT teaches crisis survival skills and reality acceptance skills. Crisis survival skills are self-soothing strategies that reduce the unpleasantness of physiological experiences such as raised heart rate, muscle tension and digestive upset. They include deep breathing (with a longer out-breath than in-breath), progressive muscle relaxation and distraction. Reality acceptance involves the deliberate letting go of the struggle to change the situation and to accept things the way they are. This involves acceptance of the past and present but does not mean that the predicted future has to be accepted. Interpersonal Effectiveness is supported by DBT through an emphasis on the importance of identifying personal goals and needs. DBT then develops self-efficacy through teaching assertive ways of asking, stating an opinion and saying no.

Emotion Regulation is addressed by DBT through recognition that thoughts and emotions are intertwined, and that changing thoughts can change the associated emotions. This approach is supported by Siegel's 'Mindsight' theory (2010). Firstly, emotions are identified and understood. This involves identification of physical sensations, urges towards specific actions and prevalent thoughts. Next, vulnerability to negative emotions is reduced. Lastly, skills to manage and change emotions are taught. DBT teaches that when the 'opposite action' is adopted, that is the contrary action to the one which is initially prompted by the emotion, the emotion is reduced (Chapman et al., 2011).

Anxiety has been described earlier in this chapter as a 'fight, flight or freeze' response to perceived danger (Maack, Buchanan & Young, 2015). The fact that the amygdala does not discriminate between physical or psychological danger has also been explored (Penzo et al., 2015). The resulting physiological outcomes from psychological stress are typically treated through medication. However, in the middle of the last century, an American cardiologist called Herbert Benson became increasingly concerned by the side effects of medication given to alleviate symptoms of stress such as high blood pressure, realising that they appeared to be more damaging than the initial symptoms (Benson, 1975). He developed the relaxation response, which prompts the body to reverse the ‘fight, flight or freeze’ response. Benson is careful to emphasise that the relaxation response does not replace medication or surgery to treat physical symptoms. Instead, he advocates a tripartite approach which he describes as a three-legged stool, where one leg represents medication, and a second leg represents surgery. The third leg which holds up the stool of health is self-care, within which the relaxation response plays a significant role.

The relaxation response has been reduced to two essential actions, namely a focus on a word, phrase or physical action like a breath or step, and then the continual refocusing of the attention onto this chosen focus over a short time period of around ten minutes. Coincidentally, Benson published his findings in 1975, around the time that awareness of mathematics anxiety was emerging (for example Buxton, 1981). The relaxation response is now widely recognised as a useful way of proactively recovering from the fight, flight or freeze response. It is efficacious for improving recovery from physical problems such as renal failure and dialysis (Rambod et al., 2014), dealing with chronic stress (Park et al., 2013) and reducing pain intensity after caesarean sections (Solehati et al., 2015).

Prescribed and over-the-counter medication is available for anxiety, but a blanket approach is not appropriate for those who only experience anxiety in specific situations. Additionally, the medical route is not ideal for children. In Belfast the answer to any problem, large or small, is always a ‘nice wee cup of tea’. Brunye et al., (2013) explored the efficacy of this folk remedy against mindful exercises. They tried administering l-theanine (the chemical found in black tea) and three mindful exercises (focusing on breathing, allowing the mind to wander and actively worrying) in a repeated measures design with 36 college students. The participants were then given a timed arithmetic test. The focus on breathing approach generated the most correct answers in the test. The authors concluded that 'A brief focused breathing exercise appears to help students regulate negative emotions and marshal the cognitive resources necessary to control anticipatory anxiety immediately prior to a math testing situation' (2013: 6).

Mindfulness, a similar approach to focused breathing, has also proved effective in the alleviation of symptoms of anxiety (for example, the meta-review conducted by Hofmann et al., 2010). The use of mindfulness techniques to address anxiety meets the demands of a randomised controlled trial (Hoge et al., 2013). Many interventions have been based in therapeutic frameworks, but mindfulness has additionally shown to be efficacious in a stand-alone approach (Blanck et al., 2017). Mindfulness as a therapeutic intervention involves training the participant to be aware of the present moment, to focus their attention, and to accept the situation and be curious about it (Hofmann et al., 2010). Promising results have been reported for children as young as seven years of age (Semple, Reid & Miller, 2005).

The previous paragraphs have focused on the efficacy of breathing and awareness of the present moment to manage feelings of anxiety. A contrasting approach is taken by researchers at the Social Stress Lab at the University of

Rochester, USA, who study the impact of personal attitude on stress levels, specifically assumptions made about positive and negative outcomes of stress on performance. An intervention to reframe the perception of feelings of anxiety (Jamieson, 2010) demonstrated that if participants reframed their assumptions around the effects of stress on performance from being detrimental to appreciating that a certain level of stress could enhance their performance, then their performance was indeed improved. This simply involved a short intervention which encouraged participants to view their physiological feelings as excitement rather than nervousness and to assume that their senses were sharpened, and mental faculties enhanced, by the changes in their physiological state.

In a review of subsequent developments (Jamieson et al., 2018) the research team further supported their contention that the experience of stress can be optimised by challenging and changing previous assumptions towards stress. The research team are now calling this contention ‘stress optimisation’ (Crum, Jamieson & Akinola, 2020) which they promote as a tool to regulate emotions and enhance performance in stressful environments.

This section has described specific interventions which have proved efficacious in the treatment of anxiety, as ‘anxiety disorders are common, serious, yet eminently treatable’ (Chapman et al., 2011: xiii). The second literature chapter moves from a psychological view of anxiety to one that is rooted in mathematics education. It is therefore necessary at this point to identify the relevant links between the two fields of study.

The dialectical balance of accepting the current situation and learning for the future is particularly appropriate for mathematics anxiety. The importance of recognising the occurrence of mathematics anxiety is clear (Foley et al., 2017; Johnston-Wilder & Marshall, 2017). The tendency to avoid recognition of mathematics anxiety will clearly preclude any ability to accept the situation, and can lead to specific internal learned helplessness (Goodall & Johnston-Wilder, 2015), which is the persistent feeling that the sufferer is unable to change bad outcomes. Therefore, the dialectic between acceptance of the negative feelings towards mathematics and the will to improve both feelings and achievement promises to be a productive direction for research.

The importance of acceptance of any mathematics anxiety is further supported by Dweck's mindset theory, which was described above (2000, 2017). Dweck describes a growth mindset as optimal for sustained longitudinal learning success. In contrast to an individual with a fixed mindset, who typically focuses on meeting expectations, an individual with a growth mindset typically focuses on learning, which necessitates a realistic assessment of their current level of understanding. Only then can they ascertain the next appropriate steps and make progress with their learning. Dweck's construct of a growth mindset relates to Linehan's concept of 'radical acceptance' (Chapman et al., 2011) in that a growth mindset learner would be able to be very honest and accepting about their current level of learning and clear about the necessary next steps. Therefore, to reduce mathematics anxiety, the approach of Dialectical Behaviour Therapy would be to encourage the learner to accept both their emotional response to mathematics, and their current ability level.

Anxiety can be managed in a variety of ways. Translating the research above into the context of learning mathematics, it would seem advisable that in order to support learning, the steps taken to manage mathematics anxiety be both focused on the situation and free from side-effects. The interventions described above have, in contrast to chemical medications, met those criteria. Furthermore, they are appropriate and acceptable to the secondary classroom environment. For example, whilst anxiety levels may be relieved through vigorous exercise, it is not normally possible for students in a mathematics class to jump up and go for a run when they start to feel anxious. It can be concluded therefore that the principles of dialectical behaviour therapy, namely radical acceptance, emotional regulation and personal effectiveness, promise relevant benefits to an intervention which aims to relieve mathematics anxiety. Additionally, some form of method to reverse the effects of the 'fight, flight or freeze' response through mindfulness or breathing seems appropriate. Finally, any intervention would benefit from the inclusion of a reframing of assumptions around the impact of stress on performance, therefore changing assumptions so that the physiological experiences can be seen as non-threatening.

2.2.4 Section Summary

This section explored the evolutionary causes of anxiety and then explained why some individuals may be more prone to anxiety than others. Various categorizations were described which all indicate that the general population can be divided into two spectra, of thinkers and feelers (Myers et al., 1998), or systemisers and empathisers (Baron-Cohen, 2009), or dandelions and orchids (Pluess, 2015; Boyce, 2019). It is very likely that most teaching groups will contain both these types of learners, and so the needs of both types should be considered and addressed. However, the section went on to emphasise that stress is not always detrimental. The work of Yerkes and Dodson in creating an optimal stress to productivity graph (Corbett, 2015) has been developed by others (e.g., Dhabhar, 2018) to promote the perspective that a manageable level of stress is beneficial to learning. The section then considered possible ways of addressing anxiety which included more general approaches of being proactive, accepting the situation but then taking manageable steps to improve it, and active emotional regulation strategies such as focused breathing and mindfulness.

2.3 Chapter Summary

This thesis on mathematics anxiety is rooted in positive psychology. This first literature chapter acknowledges the importance of self-efficacy and agency (Bandura, 1990b), and follows the progression of these concepts into Self-Determination Theory (Ryan & Deci 2017). The three motivational needs of autonomy, relatedness and competence are described in detail. These three needs are then situated into a wider picture of psychological wellbeing. The attitude of the individual is recognised as an important factor throughout. However, the danger of exerting undue pressure on the individual are noted, and perseverance rather than persistence is recognised as a key quality.

This review of the literature on positive psychology and general anxiety informs the thesis by indicating a promising avenue for research. This avenue is the development of learner agency through self-improvement of autonomy, greater appreciation of personal competence in mathematics and encouragement to make greater use of the support relationships available. In order to achieve these goals, the learner can be shown how to accept themselves and their situation, to address the situation, and be given tools to regulate and reframe their emotions.

CHAPTER 3 SECOND LITERATURE REVIEW – THE MATHEMATICS EDUCATION PERSPECTIVE

3.0 INTRODUCTION

This chapter shifts the focus of the thesis from that of the psychological field, as in the previous chapter, to that of mathematics education, specifically mathematics anxiety and the process of learning mathematics. The reader is prepared for the final section on effective mathematical learning by a preceding section on mathematics anxiety. This approach enables the consideration of tools and strategies to prevent and address mathematics anxiety to be embedded as a vital component of any effective approach to mathematical learning. Thus, this chapter, along with the previous one, prepare the ground for the research involved in this thesis as they consider issues associated with mathematics anxiety within the wider contexts of mathematical learning, anxiety and positive psychology.

The first section of this chapter looks specifically at research and literature on mathematics anxiety. Justification for the recognition of mathematics anxiety as a domain specific condition is given, along with an account of widely agreed causes and prevalence, and proposed strategies for the prevention and management of mathematics anxiety. The second section considers the literature on effective mathematical learning. Relevant theories of learning are considered, specific literature on mathematical learning is described, and the need for learners to have mathematical resilience is emphasised. The construct of mathematical resilience and its relationship with mathematics anxiety is discussed, and then a model of emotional regulation for mathematical learning, which underpins the thesis, is described.

3.1 MATHEMATICS ANXIETY

3.1.0 Introduction

The following section introduces the debilitating phenomena of mathematics anxiety. Mathematics anxiety is defined, and its prevalence across age ranges, genders and levels of mathematical achievement is discussed. The suggested causes of mathematics anxiety are outlined. Then the evidence for the impact of mathematics anxiety on learning is presented. The section ends with an exploration of current advice to manage and prevent mathematics anxiety. A significant tool in the management and prevention of mathematics anxiety is the development of mathematical resilience. However, as this construct also relates to many aspects of effective mathematical learning, it will be addressed at the end of the following section.

3.1.1 Defining and Explaining Mathematics Anxiety

Mathematics anxiety has been recognised as a disabling condition for many decades, as is evidenced by the definition given by Richardson and Suinn (1972) nearly fifty years ago. It is not simply a side effect of poor academic performance in mathematics, where the individual concerned prefers to avoid a subject which they struggle to understand (Dowker, Sarkar & Looi, 2016). Rather, it is a visceral response to a situation involving mathematical thinking, or the prospect of such a situation (Richardson & Suinn, 1972). This response is often based on an assumption that mathematical ability is an innate talent and any personal inability to understand will be imminently revealed to the ridicule of all (Tobias, 1995).

The term ‘mathematics anxiety’ indicates a construct with two aspects, namely mathematics and anxiety, which begs the question of whether the construct is more related to mathematics or to anxiety. In a recent and comprehensive review of the literature, Dowker, Sarkar & Looi (2016) found that mathematics anxiety had a higher correlation with anxiety than with academic performance. This finding indicates that while mathematics anxiety has a foot in each camp, the construct is more related to anxiety than to mathematical learning. However, it is important to note that although it shares many characteristics of both generalised anxiety disorder and test anxiety, mathematics anxiety is a domain specific construct, in other words an anxiety that is just concerned with mathematical situations, independent of general anxiety and indeed intelligence (Hill et al., 2016). Given this distinction, it is still important to identify the relationship between mathematical anxiety and anxiety in general. Hembree’s description of anxiety being an umbrella term or ‘omnibus construct’ (1990:33) is a useful one for this thesis, as the intention is to explicitly draw from the literature on anxiety in general to inform the management of mathematics anxiety. It is therefore necessary in this case to see anxiety and mathematics anxiety as linked constructs which have both shared characteristics and shared possible solutions. Locating mathematics anxiety as a sub-group of anxiety in general enables both the utilisation of useful commonalities and the identification of important differences.

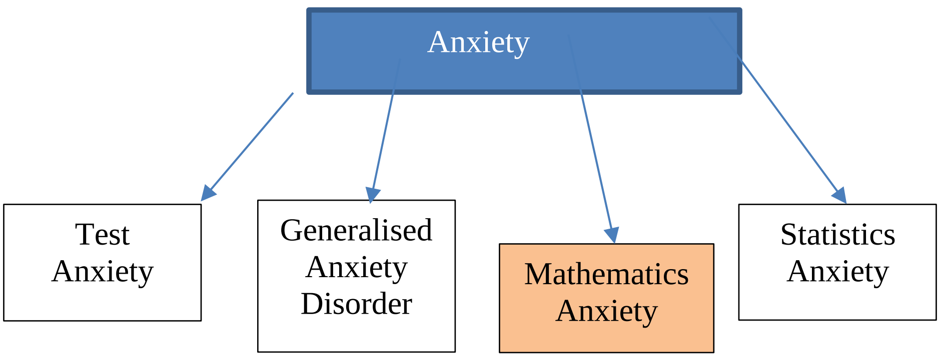


Figure 3. 1 Sub-Groups of Anxiety - after Hembree, 1990

Just as the umbrella term of anxiety is a multifaceted construct, so is mathematics anxiety in turn. Cavanagh and Sparrow (2011) distinguish three types of symptoms or indicators of mathematics anxiety, namely attitudinal, cognitive and physical outcomes. However, Dowker et al. (2016) take a narrower view by excluding attitudes in their description of mathematics anxiety, stating that mathematics anxiety is not comparable to poor attitudes to mathematics. They describe mathematics anxiety as a purely emotional construct, involving a cognitive dimension (the worrisome thoughts that can undermine and inhibit the learner) and an affective dimension (the emotions which can overwhelm the body in nervous tension). This narrower definition has been adopted for the present thesis, as although mathematical anxiety can be caused and exacerbated by poor attitudes to mathematics by influential adults and the wider society, this thesis is built upon personal experience of the impact and reality of mathematics anxiety and therefore is sharply focused on the emotional state of the learner.

Mathematics anxiety has been estimated as affecting as much as 59% of the general population (OECD, 2013). There is little agreement across estimates, as they depend on different measurement scales used, and variance in criteria for labelling levels of mathematics anxiety (Dowker, Sarkar & Looi, 2016). Nevertheless, the lowest estimate of 17% (Ashcraft et al., 2007) arguably remains an unacceptable level of a problem, as it reflects levels of anxiety significant enough to affect learning and performance (Johnston-Wilder, 2014). The Nuffield report, a large-scale UK research project, reported that ten percent of eight to 13-year-olds are thought to suffer from maths anxiety (Carey et al., 2019).

Although many studies have found a negative correlation between mathematics anxiety and mathematics achievement (Namkung, Peng & Lin, 2019), mathematics anxiety affects learners of all levels of achievement (Foley et al., 2017), independent of their intelligence (Jamieson, 2010). 11% of university students (Richardson & Suinn, 1972) report debilitating levels of mathematics anxiety, as do 30% of apprentices (Johnston-Wilder et al., 2014). Mathematics anxiety can be observed in primary school pupils, as young as seven years (Sorvo et al., 2017) and it becomes an increasing problem throughout secondary school education (OECD, 2013; Carey et al., 2019; Maths Anxiety Trust, 2018).

Mathematics anxiety is more common in girls (OECD, 2013). Some literature reports no gender influence in primary school (Hill et al., 2016) but more researchers have reported primary-age girls to have higher levels of MA than boys (e.g., Griggs et al., 2013; Yüksel-Şahin, 2008; Krinzinger, Wood, & Willmes, 2012; Devine et al., 2012). Mathematics anxiety certainly becomes apparent in secondary school (Ashcraft, Krause & Hopko, 2007; Dowker, Sarkar & Looi, 2016) and indeed increases in prevalence and impact (Hernandez-Martinez & Pampaka, 2017). Tobias (1978) suggests that teenage girls in particular are often disenfranchised by the secondary school education system, in that they are often not given a voice in mathematics learning environment and become isolated in their mathematical learning.

The causes of mathematics anxiety have been categorised in various ways in the literature. Jameson (2010) helpfully identifies three themes, namely causes arising from personal, behavioural, and environmental origins, and this structure will be employed in the next few paragraphs to explore the literature. Personal causes are described as individual characteristics such as self-efficacy or gender. Behavioural causes describe situations where an avoidance of mathematics activities because of distressing anxiety leads to poor performance. Environmental causes are experienced by all the individuals in a specific situation and include the teaching approach, the attitude of teachers and parental attitudes. These categories will be considered in turn and then the links between then explored.

Environmental causes of mathematics anxiety involve not just the environment of the mathematics classroom, but also the family environment and the wider culture. As reported above, mathematics anxiety has been observed to increase through secondary education (Hernandez-Martinez & Pampaka, 2017). This increase in anxiety has been variously attributed to homework (Eggison, 2017), teacher attitudes (Maloney, Schaeffer & Beilock, 2013) and teaching styles (Nardi & Steward, 2003). The level of teacher empathy has also been recognised as having an inverse correlation to mathematics anxiety (Griggs et al., 2013). Eggison (2017) found that 49% of her sample of pupils worried about their mathematics homework, the only subject identified as being problematic in this way. The attitude and expectations of the teacher towards mathematics has also been found to affect levels of mathematics anxiety (Maloney, Schaeffer & Beilock, 2013) as anxious teachers encourage anxiety in their pupils through social transmission.

However, the impact of teaching styles on levels of mathematics anxiety is the most widely reported factor (Ersozlu & Karakus, 2019). At the turn of the century, the experience of mathematics teaching in British secondary schools was described by those leaving it behind as TIRED (being **Tedious**, making learners feel **Isolated**, with a heavy dependency on **Rote learning**, **Elitist** in that it favoured the high achievers, and **Depersonalised** in that the learning bore little perceived relevance to the everyday life of the learners) and thus creating ‘quiet disaffection’ (Nardi & Steward, 2003). This observation was supported by further research which identified that an unrealistic pace of delivery and an undue emphasis on repetition, recall and speed on timed tests, disempowered learners (Geist, 2010). Most recently, mathematics anxiety has been correlated with didactic teaching strategies. This “high demand for correctness with little cognitive or emotional support” (Maloney, 2013: 117) will arguably not support the motivation of pupils, as it lacks all three elements of Self Determination Theory (Ryan & Deci, 2017), namely autonomy, relatedness and competence.

Outside the mathematics classroom, parental attitudes towards and anxieties around mathematics have been found to affect levels of mathematics anxiety in their children (Goodall & Johnston-Wilder, 2015) particularly if the parents are actively involved in supporting their children with mathematics homework (Maloney et al., 2015). Wider still, national culture, namely accepted shared attitudes towards mathematics, can affect mathematics anxiety (Dowker, Sarkar & Looi, 2016).

Personal causes of mathematics anxiety can be explained through reference to the concepts of agency and self-efficacy (Bandura, 1988), as described in the previous chapter. Bandura linked agency (the ability to effect change) and self-efficacy (the perceived ability to effect change) to anxiety by stating that ‘control over potential threats plays a central role in anxiety arousal (1988: 77). A sense of being in control allows learners to feel that they have the right to learn and make mistakes, thus reducing mathematics anxiety (Jain & Dowson, 2009).

An individual's working memory capacity has also been identified as correlated to personal levels of mathematics anxiety (Maloney, Schaeffer & Beilock, 2013). This cognitive predisposition (Ashcraft & Kirk, 2001), defined as a low-level deficit in numerical processing, is further reduced in stressful situations as the brain is distracted by perceived threats, such as having to complete a task in a given time, or answering in front of peers (Foley et al., 2017). Therefore, experiences such as those mentioned above may have the impact of decreasing the capacity of working memory of the learner, thus further inhibiting their ability to engage in the mathematics and increasing their anxiety levels.

As previously discussed, mathematics anxiety is found to be more common in females (OECD, 2013). This has also been linked to working memory capacity. Negative cultural stereotypes regarding the ability of the female brain to think mathematically support the development of stereotype threat (Beilock & Ramirez, 2011; Maloney, Schaeffer & Beilock, 2013) where stereotype expectations sabotage the capacity of the working memory.

When an environmental trigger is met with an individual sensitivity, then behavioural exacerbations can come into play. An individual's interactions with mathematics are influenced by their previous experiences and personal psychological disposition. This could be described as their perezhivanie (Blunden, 2016). Vygotsky describes perezhivanie metaphorically; significant factors from the environment are 'refracted through the prism of the child's emotional experience' (Smagorinsky, 2011:

336). Smagorinsky emphasises that, since every individual has unique personal experiences and interprets them in a unique way, each learner will engage with mathematics in a different, unique way. These influences can sometimes trigger a powerful emotional reaction which then limits new mathematical learning (Lee et al., 2018). A learner’s emotional responses to mathematics can change throughout their schooling (Hernandez-Martinez & Pampaka, 2017).

These personal factors are often compounded by a vicious circle with avoidance (Jameson, 2010; Lyons & Beilock, 2012; Dowker, Sarkar & Looi, 2016) where a negative experience prompts the learner to avoid future experiences which have the potential to be unpleasant. The necessary outcome of avoiding opportunities for learning is a lack of progress with learning, which in turn encourages further tendencies to avoid future learning, creating a vicious cycle of avoidance and missed learning.

This subsection has defined mathematics anxiety as a debilitating and distressing experience, a form of anxiety specific to mathematics learning, but also related to other forms of anxiety. This thesis concurs with the view of Dowker, Sarkar & Looi (2016) who identify mathematics anxiety as having cognitive and affective dimensions. The prevalence of mathematics anxiety among learners is significant enough to warrant efforts to address the problem. However, it is important to note that mathematics anxiety is not limited to those learners who are falling behind their classmates but can also affect those who are achieving their expected level of progress and even exceeding it. This fact, and that the causes of mathematics anxiety are varied and complex, make the task of addressing the problem a challenging one. The following subsection argues for the importance of attempting to do so regardless of the difficulties.

3.1.2 Impact of Mathematics Anxiety on Learning

Mathematics anxiety hampers mathematics learning and development, in that it interferes with teaching and learning (Ashcraft & Kirk, 2001), discourages further mathematical study (Richardson & Suinn, 1972), results in underperformance and underachievement (Beilock & Carr, 2005; Brunye et al., 2013) and influences the future career choice of the learner (Dowker, Sarkar & Looi, 2016). The impact of mathematics anxiety on the learner has been vividly described as an emotional handbrake (Findon & Johnston-Wilder, 2018). This analogy is particularly apposite as, just as the handbrake on a car impedes progress but can be released with a resulting improvement in performance, so the debilitating impact of mathematics anxiety can be released, as will be explored in the next section.

Mathematics anxiety is inversely correlated to achievement in mathematics design meaning that low achievers are likely to experience mathematics anxiety. However, mathematics anxiety also affects high achievers in that it has a similar, debilitating impact on performance (Foley et al., 2017). Therefore, if mathematics anxiety is addressed, the performance of learners across the achievement levels would be improved. The need for more STEM (science, technology, engineering and mathematics) graduates is widely recognised (see, for example, the article by STEM Learning, 2018) and this is currently addressed through direct action to increase mathematics and science qualifications (National Audit Office, 2018). Conversely, the need to address mathematics anxiety has been suggested as an alternative and more successful way to increase the number and quality of STEM graduates (Foley et al., 2017; Johnston-Wilder et al., 2014).

This subsection explored the barrier that mathematics anxiety presents to learning, a barrier with long term effects as the learner involved tends to avoid rather than engage with future mathematical learning. However, the barrier is a removable one. Given that the implications of mathematics anxiety are so pervasive and debilitating, and that there is a clear need for more STEM graduates, the requirement for both prevention and addressing of mathematics anxiety is incontestable. These two aspects will be considered in the next section.

3.1.3 Preventing and Managing Mathematics Anxiety

This subsection explores the literature which specifically addresses the management of mathematics anxiety. Two aspects are considered, namely prevention of mathematics anxiety and interventions which support those who already have mathematics anxiety so that further productive learning can take place. The balance between literature which focuses on prevention and literature which focuses on support requires some comment; arguably the balance has been heavily in favour of prevention of mathematics anxiety with comparatively little written about ways and means to support those who already experience mathematics anxiety to gain relief from the experience. The causes of mathematics anxiety must be addressed (Beilock & Ramirez, 2011) however there is a current and desperate need for treatment for those learners currently struggling to learn under the cloud of mathematics anxiety (Foley et al., 2017) and indeed early intervention will avoid the disruption of an individual’s mathematical education (Ramirez et al., 2012).

Fortunately, many interventions which both prevent and relieve mathematics anxiety exist. This subsection will consider literature which details interventions which aim to prevent mathematics anxiety, and then will consider the literature on supporting individuals and groups of learners who already have mathematics anxiety. The subsection concludes by reflecting on the imbalance between the two and implications for teaching and learning. The prevention of mathematics anxiety is of concern to teachers, policy makers and indeed society in general. In order to prevent mathematics anxiety, the causes must be considered. The causes of mathematics anxiety identified in the literature are categorised into environmental and personal factors.

Literature which advises on the prevention of mathematics anxiety focuses primarily on the environment of the mathematics classroom, presumably because that is the cause of mathematics anxiety (as detailed above) which is most easily fixed or addressed (as for example, in Baker, Cousins & Johnston-Wilder, 2019). However, to effectively prevent mathematics anxiety, mathematics should be valued as an important subject by society in general (Dowker, Sarkar & Looi, 2016). Furthermore, any mathematics anxiety existing in teachers and parents should be addressed to avoid the infection of their pupils and children (Beilock & Ramirez, 2011). This is clearly a task that will take many years to accomplish.

Returning to the classroom, it is important to clarify assumptions around the nature of mathematical understanding when discussing mathematical learning, as the nature of the goal will necessarily determine how it is achieved. For example, presenting an experience which is 'ALIVE' (**accessible** to all learners, **linked** to previous knowledge, **inclusive**, **valued** by learners and the wider society, and **engaging** (Johnston-Wilder & Marshall, 2017) rather than one which is 'TIRED' (Nardi & Steward, 2003) will not necessarily improve the recall of facts but will deepen mathematical understanding and therefore be an effective approach to teaching mathematics. This should include the use of activities which enable the engagement of all learners (Boaler & Greeno, 2000) in classes that have not been sorted according to perceived ability (Boaler, 2016).

To prevent the development of mathematics anxiety from personal causes, research recommends the encouragement of growth mindsets (Boaler, 2016) and that the problem of 'prevalent fixed mindsets' (Findon & Johnston-Wilder, 2017) should be addressed. This would allow the learner to take advantage of all learning opportunities with the confidence that progress in mathematical understanding is achievable.

Supporting the management and alleviation of mathematics anxiety that is already present should not be about avoiding mathematical challenges. Those suffering from mathematics anxiety are not affected by mathematics itself, but rather the dread of mathematics (Tobias, 1995). Therefore, if the dread of mathematics can be minimised, then it will be possible to engage with the mathematics. Early intervention is strongly recommended (Dowker, Sarkar & Looi, 2016) to build resilience (Johnston-Wilder & Lee, 2017). Similar to the prevention of mathematics anxiety, addressing mathematics anxiety should begin at the cultural level. Advice has been published to support parents in the task of supporting their children (Maths Anxiety Trust, 2018). However, most of the literature concerns itself with the learner.

The interventions suggested in the mathematics education literature can be characterised into three different types, namely approach or attitude, practical tasks and emotional control processes. Interventions which focus on transforming the approach or attitude of the learner include compelling research which describes the impact of the learner actively reappraising the situation (Crum, Jamieson & Akinola, 2020; Jamieson et al., 2018; Maloney, Schaeffer & Beilock, 2013) to recognise that a manageable level of stress will improve performance. This builds from the eustress theories of Yerkes and Dodson (Corbett, 2015). Additionally, practical tasks have been found to be effective in the alleviation of mathematics anxiety, including strategies to address physiological symptoms. These include a short period of intense focus on breathing (Brunye et al., 2013) and expressive writing (Beilock & Ramirez, 2011). Finally, emotional control processes have been promoted as integral in the management and alleviation of mathematics anxiety (Lyons & Beilock, 2012). A tool which supports the management of emotional responses to mathematics anxiety, the Growth Zone Model, (Johnston-Wilder & Lee, 2017) will be presented in depth in the subsequent section on mathematical resilience.

To critique the mathematics education literature on mathematics anxiety, it appears that there is more to be learned from the research on general anxiety. For example, the techniques used in Dialectic Behaviour Therapy (DBT, Linehan, 1991) of a radical acceptance of previous harm, the current situation and realistic future prospects, the technique of adopting the opposite action to that indicated by emotions, crisis survival techniques which focus on the emotional state, and the development of personal agency through interpersonal effectiveness training are very under-represented. The connection between one of the behavioural causes identified earlier, that of the vicious circle, indicates the DBT strategy of ‘opposite action’, where the urge for action which accompanies emotion, in the case of mathematics anxiety to avoid mathematical learning, is addressed with the opposite action of engaging with mathematics in order to reduce anxiety. This raises another important issue, namely that of safeguarding. Safeguarding is a very current problem in health and safety aspects of education (see for example DfE, 2021) but not considered in mathematics teaching. However, learners will need to safeguard themselves from potentially damaging situations if they are to ignore their coping mechanisms of avoiding the mathematics and try to engage with mathematics learning.

So why, when there may be strategies to relieve mathematics anxiety that can be tried, is most of the emphasis on prevention rather than support? Clearly prevention is important, as identified by Beilock and Ramirez (2011), but my concern is with those who already have mathematics anxiety as we have a lot to do now alongside the important job of supporting it. This thesis focusses on supporting it, in the hope that eventually interventions such as these will not be needed.

3.1.4 Section Summary

This section has considered the nature of mathematics anxiety, the impact mathematics anxiety has on learning, and current advice on the prevention and alleviation of mathematics anxiety. The reported prevalence of mathematics anxiety across all learners persists, despite the sterling work done by researchers, academics and educationalists. Mathematics anxiety is clearly not an easy fix, so while work continues on the prevention of mathematics anxiety, there is also a clear need for more efforts to address it and relieve it in learners. This is very important because mathematics anxiety has been shown to have a significant impact on the progress of learners, at all levels of achievement. The next section takes a wider view of what is involved in learning mathematics and then considers possible actions to alleviate mathematics anxiety.

3.2 LEARNING MATHEMATICS

3.2.0 Introduction

This section moves away from a focus on mathematics anxiety to consider the progress made in understanding about the learning of mathematics. It is divided into three subsections. First, theories of learning that have been specifically applied to the learning of mathematics are considered. Then research and theories on effective mathematics learning are covered. The section concludes with a subsection on mathematics resilience. This area is an important one for this thesis as it is a promising response for mathematics anxiety.

3.2.1 Theories of Learning

Although this section concerns itself with general theories of learning, it does not attempt to look at all theories of learning in detail. Rather, it will focus on the theories of learning which play a significant part in the mathematics education literature. Historically, much education in general and mathematics education was of the ‘Gradgrind’ approach described by Dickens, where the recall of facts was promoted in an overbearingly didactic manner (Dickens, 1994). In the early twentieth century, Dewey (Dewey & Hinchey, 2019) and Ausubel (Ausubel & Robinson, 1971) promoted a shift in view from the learner being an empty vessel to be filled with facts to the learner being a vital part of the process. Dewey stated that it was very important to account for the learner's previous knowledge and understanding (Dewey & Hinchey, 2019). Piaget (Gruber & Voneche, 1977) theorised that every child progresses through stages of cognitive competence, so that their readiness for learning depends on their individual cognitive maturity. This is described as the 'constructivist' approach. This was particularly important for maths learning, as it was previously taught by dissemination at a symbolic level, and Piaget's significant contribution was that children need to experience learning at a practical level (Donaldson, 1987).

In contrast to Piaget's individualistic view, Vygotsky's theory of sociocultural development introduced that idea that learning was not individual but rather a joint operation where a more knowledgeable other guided the learner through the zone of proximal development. (Vygotsky, 1978; Daniels 2001). This zone describes the space beyond where the learner can operate independently to where they need the support and guidance of a 'more knowledgeable other'. Beyond the zone of proximal development lies the space where the learner cannot operate even with appropriate support. Thus, the importance of appropriate social interaction and guidance was introduced to the understanding of learning.

Vygotsky began to consider the impact of the emotions on learning (Roth & Jornet, 2017) but died before this could be developed. However, his work on the construct of 'perezhivanie' (Smagorinsky, 2011) has been developed by others, which will be described below.

Another associated element of Vygotsky's theory that has been developed by others is the idea that learning happens not just in the individual sphere but in the wider social and cultural knowledge base (Zaretskii, 2009). If cultural norms such as expectations that girls cannot perform as highly as boys mathematically (Burton, 1986) are learnt alongside mathematical concepts then there will be a resulting impact on their learning. Zaretskii (2009) also extended the construct of the zone of proximal development into the emotional zone; this will be explored below.

Bruner built on Vygotsky's cognitive theories by taking the zone of proximal development, the space where learners can progress with appropriate support, and introducing the idea of scaffolding (Bruner, 1967). The construct of scaffolding uses the analogy of the temporary structures erected to support buildings as they are built and applies it to the learning environment. The temporary structure is the advice of the 'more knowledgeable other', which is gradually dismantled as it becomes redundant. Bruner also introduced the idea of the 'more knowledgeable other' breaking the task down into small, manageable steps. This relates back to the work of Dewey (Dewey & Hinchey, 2019), as the small steps can necessarily only be manageable if they start from the learner's current level and content of understanding. Bruner, like Piaget (Gruber & Voneche, 1977), promoted the construct of stages of understanding, namely enactive, where the concept to be learned is presented in a physical form, iconic, where a picture of the concept is presented, and symbolic, where a purely symbolic representation of the concept is presented. If a teacher follows these theories, then they would need to assess the understanding of each learner in their care. Bruner's theories were all at a cognitive level. However, they can be applied to emotional learning if a 'more knowledgeable other' supports the learner by helping them develop their emotional intelligence by scaffolding the ability to recognise and manage their emotions.

The previous paragraphs describe learning theories including constructivism and social constructivism. Both theories emphasise the importance of the engagement of the learner in the process of learning. Constructivism describes the learning process as one where the learner makes sense of the physical and social world around them and actively constructs their own version of knowledge internally. Social constructivism describes the process as a collaborative exchange between the individual and others, so the construction of knowledge is a shared activity.

Vygotsky defined ‘perezhivanie’ (this is the original Russian word as there is not a concise equivalent in English) as a significant emotional experience which determines the impact that physical and social environments have on future learning experiences (Smagorinsky, 2011). He used the vivid analogy of a prism refracting light, explaining that the learner’s previous emotional experiences will affect their view of future learning experiences in the same way that a prism bends and splits a beam of pure white light into refracted elements. Subsequent authors have developed the concept while interpreting it in slightly different ways (Clara, 2016). Smagorinsky (2011) agreed that the immediate learning environment has a significant influence on the learner’s experience, so much so that an experience will be unique for each learner, depending on their previous experiences and their personality. Veresov and Fleer (2016) saw perezhivanie as a powerful theoretical tool which enables understanding of the social environment as a source of development.

However, the element of ‘affect’ was otherwise largely unconsidered until relatively recently. Mathematics education academics generally understand the term ‘affect’ to mean the emotional states and traits of the individual learner, rather than the more general use of the term to include beliefs, values, motivations and attitudes (Hannula, 2014). As mentioned above, Zaretskii (2009) developed Vygotsky’s two-dimensional concentric circles model of zones of proximal development into a sphere. The same principle applies to the three-dimensional shape as with the two, namely that in many situations, a learner can achieve and progress much more with support. This includes emotional intelligence and the self-regulation and management of emotions. Thus, there are many aspects where the learner can be supported.

Others have developed Vygotsky’s construct by reinterpreting the different stages in the two-dimensional sphere. In the three concentric circles, Vygotsky saw the zone of proximal development (ZPD) as the middle zone. This has been reinterpreted as the learning zone, where learning takes place (Senninger, 2000). The zone in the very middle is described as the comfort zone, where there are no challenges, and the learner feels safe but does not learn anything new. The circle on the outside is called the panic zone where the learner also is unable to learn due to the presence of fear and anxiety. The sports and outdoor education field have developed a slightly different model, calling the middle zone the stretch zone (Rohnke, 1989). Both these models clearly draw from Vygotsky’s Zone of Proximal Development but also consider the involvement of affect by including the principles of the Yerkes Dodson law (Corbett, 2015) namely that optimal productivity, or learning in this case, happens when stress levels are neither too high but importantly, neither too low.

An important element when using either of these models is to recognise the current emotional state of the learner, then act accordingly to either stay in the learning or stretch zone or move to it. What is not always clear in discussions of these models is who makes that decision – the teacher (or coach) or the learner. This is a very important consideration for this thesis given the emphasis on autonomy.

This subsection has, very briefly and superficially, covered aspects of learning theories that have been drawn upon by mathematics education researchers when considering the process involved in learning mathematics. It is possible to link these theories to theories of motivation, specifically Self-Determination Theory (SDT, Ryan & Deci, 2017). The aspect of competence, one of the three elements of SDT, can be related to Vygotsky's Zone of Proximal Development, where the ability of the learner to understand and engage is of primary consideration. Competence can also be related to Bruner's scaffolding, where the support for the learner is directly matched to their current ability. If learning is appropriately scaffolded, then the learner will not feel a lack of competence and suffer an ensuing drop in motivation. Lastly, if Dewey and Piaget's principles of starting with the learner's current abilities are followed, then similarly the learner will not be in a position of feeling incompetent and losing motivation.

Another important aspect of Self Determination Theory (Ryan & Deci, 2017), namely relatedness, can be linked to the learning theories described above. This is through the development of the theory of social constructivism, where engagement and collaboration with others, both at a more knowledgeable level (Vygotsky, 1978;

Lave and Wenger, 1991; Rogoff, 2003) and at a similar level (Boaler & Greeno, 2000; Mason, Burton & Stacey, 2010) benefits the learning.

However, the third aspect of Self Determination Theory (Ryan & Deci, 2017), namely autonomy, is, in my opinion, much less represented by learning theories. The onus generally accepted is that it is the role of the teacher or ‘more knowledgeable other’ to identify and implement the steps needed to be taken by the learner. This could possibly be where the motivation for the learning process goes wrong.

3.2.2 Improving Learning through Good Teaching

This subsection moves specifically to a focus on the teaching of mathematics. In chapter one I wrote about my unusual position of being a mathematics educator and a psychologist. I am not the only one, and indeed am in very good company. Richard Skemp completed a doctorate in mathematics and then completed a doctorate in psychology, so he was very well positioned to write about this topic (Skemp, 1986). Skemp identified two types of mathematical understanding which he named ‘relational’ and ‘instrumental’. Instrumental understanding describes the learner following a set mathematical procedure or algorithm, but not able to explain how it works. In contrast, relational understanding involves the learner knowing why and how a procedure or algorithm works. For example, an instrumental understanding of how to multiply by 10 would be that you just add a zero, whereas relational understanding involves an understanding of the concept behind the procedure, and then knowing why it is not always appropriate to add a zero. Instrumental understanding can get you by to a certain level if you have a good memory and have practised (I achieved an A in A-level maths with just an instrumental understanding –

I know this as I did not really understand maths until I tried to teach it). Instrumental understanding is difficult to retain so requires regular practice. Relational understating takes longer to learn as the learner has to understand the reasoning behind the process, but once mastered is more easily remembered (Haylock, 2010). The importance of promoting relational over instrumental understanding continues to challenge mathematics education (Kent & Foster, 2015).

Shortly after Skemp's (1986) publication which concerned cognitive understanding, Tobias (1995) drew attention to the importance of the wellbeing of the learner. She promoted the importance of having a good attitude to learn mathematics, emphasising that the barrier for many people who struggle to learn mathematics is not an intellectual or cognitive lack of ability, but rather the presence of mathematics anxiety. Tobias' work has been referred to in the earlier section on mathematics anxiety but is also included in this section on mathematical learning to make the point that effective mathematical learning should include an appreciation of the affective domain.

While Skemp (1986) theorised types of understanding, Askew et al. (1997) researched types of teaching and teacher beliefs. Their extensive data analysis revealed three different orientations of the beliefs of mathematics teachers. The additional outcome of this research which made it particularly relevant to teacher training was the connection between each orientation and the associated mathematical progress of the learner. Askew et al. (1997) named the three orientations 'transmission', 'discovery' and 'connectionist'. Transmission teachers think that if information is presented clearly to the learner, then they will automatically absorb it.

Any lack of progress is a reflection of the lack of capacity of the learner. Discovery teachers take a Piagetian (Gruber & Voneche, 1977) constructivist approach, believing that the learner has to construct the knowledge for themselves by discovering it when they are ready. Any lack of progress is a reflection of the learners unreadiness. Connectionist teachers believe that the learner should be actively supported to make appropriate connections, adopting a social constructivist approach (Askew et al., 1997). Any lack of progress is a reflection on the quality of the learning experience. Askew et al. (1997) found that the connectionist teachers were the most effective in supporting mathematical progress in their learners.

As previously described in the mathematics anxiety section, Nardi and Steward (2003) researched the experiences of learners who were completing their mandatory mathematics education and had decided not to continue their mathematical studies. These learners reported that their experience of learning mathematics was tedious, isolating, dependant on practice and recall, elitist and depersonalised. To address the needs of students who were required to resit their mandatory mathematics qualification, Johnston-Wilder et al. (2015) promoted a pedagogy that they coined as ‘alive’ in contrast to Nardi and Steward’s (2003) ‘tired’. An ‘alive’ experience of mathematics learning involves an **A**ccessible curriculum that is **L**inked to real life, is **I**nclusive of all learners, has evident **V**alue to the learner, and is **E**ngaging.

The experience of struggling to understand a concept or solve a problem may appear to be undesirable in effective mathematical learning, however the opposite argument has been convincingly made (Mason, Burton & Stacey, 2010). In a process akin to the development of relational understanding (Skemp, 1976), Mason, Burton and Stacey promote the practice of giving learners opportunities to manage both the cognitive and emotional challenges inherent in difficult mathematical situations and supporting them to build personal insight and coping strategies (2010). This process allows purposeful struggle, and develops the ability to think mathematically, with relational understanding. Williams (2014) further developed this approach by distinguishing between two terms often associated with purposeful struggle, namely persistence and perseverance, and relating them to mathematical learning. Using Seligman's (1991) model of learned optimism, she described 'persistence' as the approach of viewing failure as temporary and success as personal, so therefore valuable. Williams defined 'perseverance' as the approach that recognises failure as indicating a specific difficulty. As this failure is down to external, not personal, causes, it can be overcome if a suitable solution is found. Williams views perseverance as the tendency to adapt when needed. Having a perseverant approach to mathematics learning is even more useful than having a persistent approach, as alternative solutions are sought rather than unsuccessful solutions continued.

This subsection considered relevant research and theories into improving mathematics learning. It now seems appropriate to consider how the psychological needs identified in Self-Determination Theory (Ryan & Deci, 2017) are represented. The first psychological need to be considered is competence. Skemp's (1986) promotion of relational understanding arguably develops competence in the learner, as relational understanding enables more flexible thinking and creative problem solving. However, it could also be argued that instrumental understanding develops a sense of competence, as is demonstrated by my personal experience of observing the satisfaction many learners demonstrate when completing a page of calculations and finding that they are all correct. This is an argument that is not visible in the literature, and so suggests the need for further research.

The second psychological need of self-determination theory (Ryan & Deci, 2017) to be considered is relatedness. This seems to be poorly considered in the mathematic education literature, with the notable exception of Mackrell and Johnston-Wilder (2020), whose argument will be considered more fully in the next section on mathematical resilience. Lastly, the psychological need of autonomy will be considered in the context of mathematical education research. Williams' (2014) view of perseverance links to autonomy as it is within the control of the learner to decide to persevere.

This subsection has briefly considered significant and relatively recent research and theories on mathematics education. An imbalance between consideration of cognitive elements compared to affect, or emotional considerations, is evident in the literature and reflected in this subsection. The next subsection will focus exclusively on the affective side of mathematics education. It seems timely to again raise the question of who should take the responsibility to manage the learning in terms of whether the responsibility of managing the learning process falls fully on the mathematics teacher, whether the onus is on the individual learner, or whether this is shared responsibility between both learner and teacher.

3.2.3 Mathematical Resilience

The initial section of this chapter considered mathematics anxiety in depth. The thesis now adopts a more positive perspective, namely mathematics resilience. Mathematical resilience, as will be detailed below, protects the learner against the development of mathematics anxiety (Johnston-Wilder & Lee, 2010). However, it is not the exact inverse or opposite to mathematics anxiety as the learner can still experience mathematics anxiety whilst increasing their resilience. Rather, becoming a resilient learner of mathematics involves both recognition of mathematics anxiety and knowledge of emotional management strategies to continue learning. The construct of mathematics resilience was introduced by Johnston-Wilder and Lee (2010) who defined it as “maintaining self-efficacy in the face of personal or social threat to mathematical well-being” (Johnston-Wilder & Lee, 2010: np). Mathematical resilience is not necessarily correlated to achievement. To be resilient a learner needs something to be resilient around so if no obstacles, barriers or struggles have been experiences in the learning process, then there have been no opportunities to build resilience. This is why some learners falter at relatively late stages – for example, one Oxford mathematics graduate faltered only in the second year of their doctoral studies (Baker, T - personal communication).

Mathematical resilience is a construct that gathers the attributes that enable learners to engage positively mathematical learning at all stages and in all situations (Lee & Johnston-Wilder, 2017). It involves 4 aspects, namely having a growth mindset, valuing mathematical knowledge and ability, persevering through difficulties and actively seeking support. The construct of a growth mindset (Dweck, 2000) as discussed in the previous chapter, is the attitude that learning can be achieved through engagement and effort rather than a predisposed talent. This is particularly pertinent to learning mathematics, where culturally mathematics ability is frequently seen as the talent of a small, elite group (Devlin, 2000; Nardi & Steward, 2003). Developing the attitude that mathematical challenges can be achieved by all learners creates resilience, however Boaler (2009) warns against the pressure placed upon learners when the inadequacy engendered by a lack of mathematical understanding is further compounded by inadequacy engendered by a lack of effort.

Knowing that any efforts towards learning mathematics are worthwhile as mathematical ability is a useful life skill as it adds motivation towards building resilience. However, as has already been discussed, many cultural voices including parents and teachers promote a counter argument (Dowker, Sarkar & Looi, 2016, Beilock et al., 2010). Additionally, to be mathematically resilient you need to be able to accept struggle and persevere, (Mason, Burton & Stacey, 2010; Williams, 2014), as has been explored in the section above. The final aspect of mathematical resilience is the ability to seek support.

In order to facilitate the process of building mathematical resilience, Johnston -Wilder and Lee created the Growth Zone Model (GZM), (2010). This model develops the comfort-learning -panic model described above (Senninger, 2000) and the comfort-stretch-panic model (Rohnke, 1989) with three concentric circles. The centre circle and outer rings each represent a different zone of mathematical learning. The centre zone denotes the comfort zone, where no new learning takes place, although consolidation is possible here. Learning takes place in the ring surrounding the comfort zone, which represents the growth zone. Outside the growth zone is the panic zone. Here panic is experienced, and no new learning takes place. Whilst engaging in mathematical activities, learners are encouraged to identify the section of the GZM they can best relate to, by recognising the emotions for each zone. These zones and their associated emotions will be further described below. It is possible for learners to identify their precise position on the model, for example at the edge of comfort and growth, or on the edge of growth and anxiety.

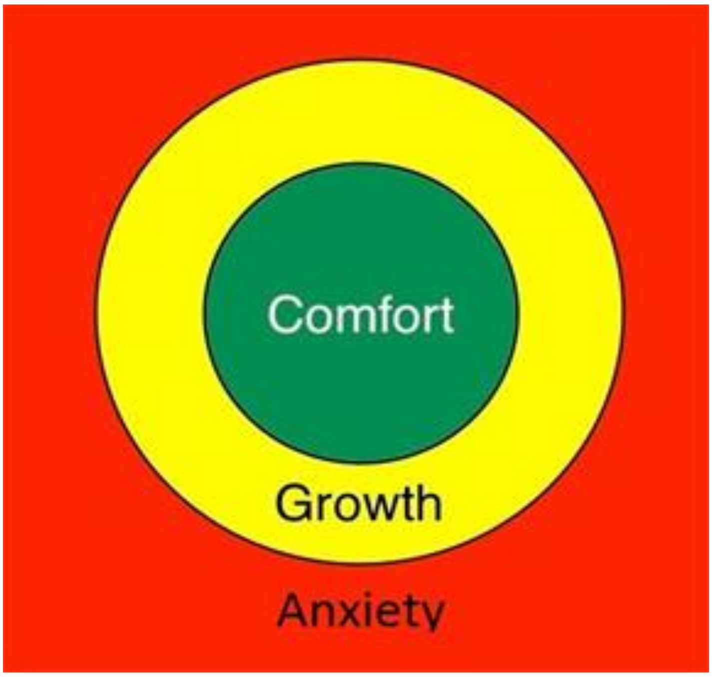


Figure 3.2 The Growth Zone Model, Johnston-Wilder and Lee, 2010

The anxiety zone is where the learner experiences the fight, flight or freeze response (Johnston-Wilder & Lee, 2010). This response has been discussed in the previous chapter (Bracha, Williams & Bracha, 2004). In the anxiety zone the fight, flight or freeze response is triggered not by the threat of physical harm, but by an equally strong fear of abandonment or shame (Penzo et al., 2015). The response becomes unhelpful as the ability to keep learning is compromised by the natural urge to either escape the situation (flight), to become aggressive (fight) or to evade detection (freeze). None of these responses helps learning. Once the learner realises that they are in this situation, they should self-safeguard by leaving the situation if possible, and recover their self-composure, for example by employing the recovery response (Benson, 1975) or other strategies as were described in the previous chapter. However any calming is achieved, the most important action for the learner to perform when they realise that they are in the anxiety zone is to take steps to recover and move back into growth, or possibly comfort for proper recuperation. The actions of recognising signs of anxiety, taking steps to self-safeguard, and addressing the anxiety all involve the learner having the appropriate level of autonomy, self-efficacy and knowledge.

The growth zone denotes the situation where learners experience feelings of excitement, engagement, interest and flow (Johnston-Wilder & Lee, 2010). It is important to note that the growth zone is not necessarily a comfortable place to be, otherwise it would be the comfort zone. Learners can feel challenged in the growth zone, and, to a manageable degree, stressed. However, much mathematics anxiety literature (see, for example, Carey et al., 2019) does not recognise the point made in the previous chapter, namely that a level of stress can be beneficial if managed well to sharpen focus and encourage flow (Csikszentmihalyi, 1997; Corbett, 2015). The challenge for the learner experiencing mild levels of stress is to stay in the growth zone. This can be achieved by cultivating a growth rather than a fixed mindset (Dweck, 2000), by the learner, teacher or coach scaffolding learning (Bruner, 1967), by the learner having the self-efficacy to request effective help (Bandura, 1994). Additionally, mathematically resilient attributes such as optimistic struggle (Mason, Burton & Stacey, 2010) and perseverance (Williams, 2014) and appreciating the value of mathematics so that the effort is seen to be worthwhile (Johnston-Wilder & Lee, 2010) will help the learner to remain in the growth zone rather than moving into the anxiety zone. Self-safeguarding is an important skill, as the learner may need to deliberately move to the comfort zone when they realise that they need to recuperate (Johnston-Wilder et al., 2020). Because the growth zone can be a scary place, learners need to look after themselves and pace themselves to maintain stamina. This is the difference between the handbrake impairing learning in the anxiety zone and managing/coping in the growth zone (Johnston-Wilder et al., 2016). For some learners the growth zone is very small, and they can move quickly or even directly from comfort to anxiety when facing challenges in mathematical learning. Building mathematical resilience will enable them to expand their growth zone and increase the time spent learning productively.

The comfort zone is normally represented by the central circle in the model (Johnston-Wilder & Lee, 2010). In the comfort zone, the learner feels safe from threats as they are not asked to engage with mathematical activities outside their competence level and experience. They have the opportunity to recover and recuperate (Johnston-Wilder et al., 2014). However, little or no learning takes place in the comfort zone, as learning involves challenge, although consolidation of learning can occur through practice exercises (Johnston-Wilder et al., 2020). Learners should be persuaded to creep out of the comfort zone to start to engage with mathematical learning, otherwise they will fall behind in the vicious cycle referred to by Dowker, Sarkar & Looi (2016).

This subsection has reviewed the literature on the relatively new construct of mathematical resilience. The Growth Zone Model (Johnston-Wilder & Lee, 2010), has been described as a key tool in the process of building mathematical resilience. It must be noted here that Johnston-Wilder and Lee, the creators of the Growth Zone

Model (GZM), warn against any unrealistic expectations for the learner to be resilient without support or scaffolding. Mathematical resilience is growing in awareness in academic community, with such events as the Maths Anxiety Summit in 2019 promoting awareness and the publication of guidance to develop resilience (Pearson, 2018; Johnston-Wilder et al., 2020). A gap in the literature concerns where the responsibility for developing resilience in school pupils lies. This could be with the mathematics teacher, the school as a whole, dedicated coaches, or with the learner themselves. The psychological need for autonomy (Deci & Ryan, 2017) has been established above, but this must be balanced with the danger of unrealistic expectations of the learner, and the need for scaffolding (Bruner, 1967).

3.2.4 Section Summary

This section on mathematical learning began by considering general theories of learning that have influenced mathematics education. It then described specific theories and research in the field of mathematics education, and highlighted the influence of Vygotsky's social constructivism theories and zone of proximal development, the influence of Bruner's scaffolding construct, and the growing appreciation of the need for the affective domain to be included alongside the cognitive domain. The section ended with a sharper focus on the construct of mathematical resilience, describing the aspects of resilience and detailing a specific tool to enable the growth of mathematical resilience.

3.3 CHAPTER SUMMARY

Following the previous chapter's consideration of positive psychology and then anxiety in general, this chapter has looked more specifically at maths anxiety, possible prevent and respond actions and then a deeper look at the relatively new construct of mathematical resilience. Thus, the thesis as a whole considers the problem of mathematics anxiety, justified as it is a barrier to learning, through the two lenses of positive psychology in general and mathematics resilience in particular to build good habits, scaffold beneficial practices that can prevent and support mathematics anxiety and explore what can be done to address specific problems. This chapter has highlighted the need for further work to support mathematics anxiety not only for prevent but particularly to address existing mathematics anxiety. Therefore, the need for a two-pronged approach is recognised, as while progress is made in preventing mathematics anxiety, some learners will need immediate support to address and relieve their already existing mathematics anxiety.

The target group for this research is learners in secondary school as mathematics anxiety exists in this group where mathematics is a mandatory subject. The need to focus on the youngest group stems from my previous personal experience with tutoring which indicated that interventions may be too late by GCSE stage or at least more effective. The most promising way to address mathematics anxiety is to support learners to build resilience. This can be achieved by providing learners with tools to recognise and manage anxiety, encouraging their sense of autonomy and self-efficacy, and showing them ways to reach out to others for support. Also need to encourage learners to self-safeguard and helping them to value mathematics learning as something worth persevering with.

Throughout the thesis, a pathway must be navigated between the needs of the learner to have autonomy, to make their own decisions and the responsibility of the school, whether senior staff, maths teacher or support staff, to appropriately guide and structure the learning journey. This is a difficult tension to balance, and there are no right answers.

My research question is … **'How can an intervention scaffold year 7 students in learning to manage and overcome their mathematics anxiety?'** This encapsulates my mission to assist young secondary school learners of mathematics with mathematics anxiety. The literature justifies the need for an intervention to address the mathematics anxiety at this stage, as prevention is not enough. The literature points towards an intervention which supports learners to manage and overcome, not necessarily eradicate, mathematics anxiety. As mentioned in section 1.2 of chapter 1. the detail of my research questions evolved throughout the research. The justification for the detailed breakdown of this initial overview questions into four research questions will be explained in section 4.1 of the next chapter.

CHAPTER 4 METHODOLOGY AND METHODS

4.0 INTRODUCTION

This chapter describes the assumptions I made and the approaches I took in my research. It begins by outlining the structure of my research and briefly highlighting some of the choices that I made. I set out to demonstrate the inherent integrity of the research by making evident the logic which underpins its structure.

The chapter begins by reiterating the research questions from the previous chapter, explaining them in more detail and then stating them as a whole. The chapter then explains how a pragmatic paradigm underpins the assumptions made in the research. I state the purpose of the research and describe the position that my experiences and opinions led me to take in relation to it. This is followed by a rationale of mixed methods as an approach to educational research, with the methodology of Design-Based Research explained in detail. I explain how the research questions are aligned to a Design-Based Research approach, then explain the quantitative and qualitative stages of the research in detail, justifying the data collection strategies and data analysis strategies. I address the ethical concerns encountered in the research at the end of this chapter, although it must be emphasised that, as recommended by many (for example, Stutchbury & Fox, 2009), I was mindful of my ethical responsibilities throughout the planning and execution of the research.

As this thesis uses a mixed methods approach, I considered the need to follow two rather different schools of thought, in that the paradigmatic assumptions associated with quantitative research differ from those of qualitative research. I was aware of the danger of just adopting one methods approach and forcing the other bit of the research to fit the pattern of the former, like the ugly sisters forcing their feet into Cinderella's glass slipper. I tried to avoid this pitfall by adopting certain principles from qualitative research reporting, and seeking to build bridges to quantitative reporting too, following the pragmatic paradigm, of which more below. Principally this involved a continual striving for transparent description of my actions and the relevant explanation of the rationale for those descriptions (Levitt, 2019).

4.1 RESEARCH QUESTIONS

4.1.0 Introduction

This section describes the evolution of the research questions which underpin this thesis. It then justifies and explains the main research question, followed by the same treatment of the secondary research questions. It ends by restating the research questions as a group to provide an overview of the aims of the research.

4.1.1 Creating research questions

As my understanding of both the process of doctoral research in general and the specific nuances of my own research developed, my research questions evolved. This is to be expected (Levitt, 2019) in any research. However, for me the evolution involved a significant change, namely from adopting an Action Research approach to a Design-Based Research approach. The need for this move became clear when I realised that I was intending to develop an intervention or tool that could be used by others rather than improving my own practice.

4.1.2 Explaining research questions

The previous chapters have shown how an examination of relevant literature shaped the development of the research questions. The main research question was: ‘How can an intervention scaffold year 7 students in learning to manage and overcome their mathematics anxiety?’ The design frame of the research (Thomas, 2013) was similar to action research, in that an intervention would be iteratively improved. However, as I was not a practitioner in a secondary school, and was not endeavouring to improve my own practice, this categorisation was not fully applicable to the research in this case. I sought an alternative approach, and found Design-Based Research, or Design Research (Bakker, 2018) to be more appropriate for my purposes. Design-Based Research enables the researcher to iteratively improve the design of an intervention without the expectation that the focus of the research is on their own teaching practice. The wording of the main research question supported the aims as it indicated the search for a balance between effective support from the deliverer of the sessions and opportunity for the learner to develop autonomy. In order to pursue this research question, I refined it into four secondary research questions. The following paragraphs will justify and explain these secondary research questions in detail.

This thesis makes the assumption that, in the first year of typical secondary schools in the UK (where such pupils are called Year 7s), a debilitating level of mathematics anxiety generally exists, as is predicted by the literature (OECD, 2013; Sorvo, 2017; Maths Anxiety Trust, 2018; Carey et al., 2019). However, in order to establish the need for an intervention to address mathematics anxiety in a particular school, it was first necessary to assess the level of mathematics anxiety in that particular cohort of pupils. Thus, the first sub-question asked for each participating institution: ‘What is the level of mathematics anxiety in the year 7 cohort?’ Once this was established, then the intervention itself could be justified, or indeed deemed to be unnecessary. Once this requirement has been established, then the second sub-question could be addressed.

A significant outcome of the research is the evaluation of the efficacy of the intervention. As the intervention was designed to be delivered on a one-to-one basis to individual learners, then the intervention should be evaluated by evaluating its impact on those learners. Thus, the second sub-question asked: ‘What is the impact of the intervention on individual learners?’

As the purpose of the research was to design an intervention that can be shared with secondary schools, it should be fit for purpose. It is therefore necessary to evaluate the manner in which the intervention was delivered, and how the delivery and the intervention itself might be improved by future users. The third secondary research question therefore asked: ‘How well was this intervention implemented? How might it be improved?’

The practical consequence of this research was a dissemination of several outcomes, namely, an update on the prevalence of mathematics anxiety in a typical UK secondary school in a particular year group, the operational details of an intervention to address any existing mathematics anxiety, and further advice on the delivery of the intervention. This is where any advice about achieving a workable balance between providing appropriate support and allowing adequate autonomy could be presented. The final secondary research question therefore asked: ‘What can be recommended for other schools?’

4.1.3 Stating research questions

To reiterate, the main research question asked:

How can an intervention scaffold year 7 students in learning to manage and overcome their mathematics anxiety?

With the related sub-questions:

- What is the level of mathematics anxiety in the year 7 cohort?
- What is the impact of the intervention on individual learners?
- How well was this intervention implemented?
- How might it be improved?

4.1.4 Section summary

Now that the main and secondary research questions have been stated, an explanation of the research principles which both support and direct the research can follow. Throughout this next section, the intentions behind, and aims of, the main and secondary research questions will be considered.

4.2 RESEARCH PRINCIPLES

4.2.0 Introduction

This section describes my paradigmatic stance and explicitly acknowledges my particular characteristics as a novice researcher in terms of the purpose of the research, my positionality, the intentions of the research to persuade others, and the political environment in which the research takes place. The section then justifies a mixed methods approach, whilst acknowledging some common problems of which I endeavoured to be aware. The section concludes with an explanation of the suitability of Design-Based Research and by showing how the research questions are aligned to the requirements of Design-Based Research.

4.2.1 Paradigmatic Stance

Novice researchers are warned to avoid being 'indifferent to underlying epistemological and ontological assumptions' (Baškarada & Koronios, 2018:2) which can result in a lack of rationale for their research approach. This thesis assumes a pragmatic paradigm (Creswell, 2009), where the scientific structure of quantitative research is balanced with the more naturalistic approaches of qualitative research. Although I initially naively adopted the label of pragmatism, seeing it as an opportunity to avoid methodological and philosophical deliberations and just 'do what works' without fully understanding the philosophy, I came to realise that the paradigm offers much more. Pragmatism is a complex and demanding stance to adopt, as the researcher needs to continually interrogate the nature of what is being researched and match this with the corresponding knowledge claim (Creswell, 2009; Hathcoat & Meixner, 2017). Pragmatism does allow the researcher to choose the most appropriate research method but demands that the purpose of the research is made clear (Creswell, 2009). By doing this, the incompatibility thesis, where the different ontological and epistemological foundations of qualitative and quantitative data are seen as conflicting, is overcome by an explicit reference to the philosophical basis of the research (Hathcoat & Meixner, 2017).

Sage advice from other literature on doctoral methodology also highlights the need for the novice researcher to be clear about their purpose in doing the research (Clough & Nutbrown, 2012; White, 2017). My purpose in this research is to address mathematics anxiety by meeting the needs of learners directly. This is partly because I did not want to add to the demands of teachers, or imply any unnecessary sense of blame (this links to positionality as I am a teacher myself), but also as the literature suggests that, in some if not all cases, the way in which mathematics is taught is a major part of the problem (Beilock et al., 2010; Carey et al., 2019). I therefore wanted to develop an intervention that could be used by pupils (initially at the year 7 stage), which was instigated and supported by either teachers, parents, or school support staff. This intervention would help the learners to develop tools which could then be of use in any future learning situations.

Clough and Nutbrown (2012) also advise the novice researcher to be transparent about their positionality, both to others and themselves. My interest in mathematics education began as a primary teacher when I was required to teach seven-year-olds in a manner which I felt to be very unsatisfactory and ineffective. I was lucky enough to be mentored by an enlightened mathematics advisor who encouraged me to try teaching techniques other than those adopted by the school. I was able to take advantage of this learning opportunity as I was a confident mathematician. However, I was very aware of the many children who were stuck with a 'TIRED' mathematical learning experience (Nardi & Steward, 2003) in that it was tedious, isolated, based on rote learning, elitist and depersonalised. This approach did not meet the needs of many learners, and I have worked to educate their teachers ever since, first by being the school mathematics coordinator, then a county council numeracy consultant, and then a teacher trainer focusing on primary mathematics. It was in this latter role that my frustrations over my efficacy came to the fore, as I observed many promising, creative and reflective primary teachers resorting to teaching mathematics in a 'TIRED' manner when they became oppressed by the demands of reporting, assessment and observations. Then I experienced academic anxiety for myself, not in mathematics but in academic writing, then anxiety in everyday life. The actions I took to address this more generalised experience of anxiety alongside the experience of tutoring mathematics anxious learners prompted deep reflection. This was the crucible where the present research was forged. I decided to explore the possibility of helping learners directly, using techniques rooted in dealing with general anxiety.

Through this research I hoped to generate evidence to persuade policy makers, educationalists and the wider public about the debilitating nature and prevalence of mathematics anxiety. Doctoral research can be a valuable tool in effecting change (Clough & Nutbrown, 2012). I planned to share the outcomes of this research in academic circles through conference presentations and publications, and to the wider public through links with publishers and events such as the 'The Power of Maths' workshops organised by Pearson.

The political influences on mathematics education in the United Kingdom are significant. The second literature review chapter explored the impact of the curriculum and teaching styles and approaches on mathematics anxiety in learners, and this is to a large extent directed by current and historical political decisions. Although I adopt a realistic approach that little change is likely to be achieved in terms of the primary and secondary mathematics curriculum, or the education system in general, nevertheless I am duty bound to do what I can. Small nudges to shift parental, professional, or cultural expectations may lead to larger changes.

4.2.2 A Mixed Methods Approach

The most appropriate methodological approach for any research is indicated by the specific research questions (Hesse-Biber, 2015), and the research questions at the heart of this research indicate a mixed methods design, as they demand both large scale quantitative evaluation and small-scale qualitative interrogation. Creswell (2008) defines a mixed methods approach as one where qualitative and quantitative approaches work together to produce an approach that is greater than the sum of both parts. I decided on a mixed method approach for the research undertaken by this thesis, as it offers the best of both worlds through the symbiosis of quantitative approaches, based on large data sets, giving findings that are commonly seen as reliable and generalisable (Newby, 2010), and qualitative approaches, which give a rich and thick description (Pring, 2000) that offers a way to create an explanation of the phenomenon in question. I do not adopt the view that mixed methods research is 'a third research paradigm that aims to transcend the traditional dichotomy' (Baškarada & Koronios, 2018:5). Rather I concur with Symonds and Gorard (2009) that this view is redundant.

The mixed methods approach to research combines quantitative and qualitative approaches, in a balance which reflects the particular characteristics and needs of the research (Green et al., 2015). Symonds and Gorard (2009) argue that most research is never entirely one or the other, as quantitative research will always involve an element of subjectivity, and qualitative research will always involve an element of comparison and quantity. Qualitative and quantitative approaches are therefore already connected, at either end of a continuum (Creswell, 2008). Therefore, an essential stage in mixed methods research is to determine the relative balance and order of qualitative and quantitative research types. The combination protects the integrity of the research by avoiding potential problems encountered when one approach is used exclusively.

The key danger of a mixed methods approach is the potential for the researcher to miss the step of establishing their rationale for adopting this approach, and therefore lose sight of the purpose of the research (Baškarada & Koronios, 2018). This oversight potentially leads to a lack of alignment between the paradigmatic assumptions adopted by the researcher and their research methods (Hathcoat & Meixner, 2017). This can then lead to an inconsistency in the analysis and evaluation of the data. It is therefore imperative that, for this research, a carefully considered rationale is included in the planning stage.

The purpose of this research, as indicated above, is to develop an intervention with which to support mathematically anxious learners, by offering them an appropriate balance between support (to manage their emotions), and autonomy (to increase their motivation). The first step is to establish the levels of mathematics anxiety in the whole cohort. This requirement suggests a quantitative approach. The resulting data will also then allow the identification of possible participants for the second stage of the research. To evaluate the process and outcomes of the second stage, an open ended and interrogative approach is required. This suggests a qualitative approach, which will allow unexpected outcomes to be recognised and explanatory details to be gathered. The nature of the mixed methods approach in this case is therefore to begin by using quantitative approaches to gather information about prevalence and then continue by using qualitative approaches to offer explanations and descriptive detail, in a sequential design (Terrell, 2012). The greater proportion of methods will be qualitative, namely 32 clinical interviews involving 13 learners, whilst being informed by initial quantitative information which is a short mathematics anxiety questionnaire and scale involving 223 learners. These methods are described in more detail below.

The initial stage of the research is quantitative in nature, with a mathematics anxiety questionnaire and scale, based upon a previously validated scale (Betz, 1978), being used to identify existing levels of mathematics anxiety in a year 7 cohort of a comprehensive school in a central Midlands town. The second stage is qualitative; as it seeks to evaluate an intervention, the research frame (Thomas, 2013) of Design-Based Research (Bakker, 2018) was adopted. Design-Based Research is described in the next section.

4.2.4 Design-Based Research

Design-Based Research emerged in the 1970's (Bakker, 2018) as an umbrella framework, often within a mixed methods approach. Like Action Research (McNiff, 2013), it adopts an iterative process to finely hone and craft the results. Design-Based Research involves the improvement and development of either a specific artefact or a distinct intervention (Bakker, 2014). Moreover, Design-Based Research should be deeply immersed in relevant theory and informed by relevant publications and should in turn disseminate any outputs back to the wider literature (McKenney & Reeves, 2018). Although it can be argued that dissemination is an integral part of all research and every methodological approach, this is an important point to make as will become clear in chapter six.

Design-Based Research has three key characteristics. The first is that Design-Based Research is iterative (Anderson & Shattuck, 2012). This involves repeated cycles of creation, testing, evaluation and refinement where the artefact or intervention is gradually improved through a systematic and reflective process. The approach of 'research through mistakes' (ibid., 2012: 17) appeals to me as it feels authentic, being very much related to the needs of the context yet informed by theory. The second key characteristic is that Design-Based Research aims to improve an artefact or intervention rather than improving practice (ibid., 2012). Therefore, as the researcher adopts the role of an observer of the process, rather than being an active participant, they are then able to adopt a more objective stance (Bakker, 2018). Thirdly, Design-Based Research should draw from theory and in turn feedback to theory (McKenney & Reeves, 2018). As noted above, the connection to theory is a valued element of this research.

Design-Based Research (DBR) provides a 'robust and relevant' approach to educational research (McKenney & Reeves, 2018) as practical outputs are combined with theory (Kennedy-Clark, 2013). The Design-Based Research Collective (2003) argue that DBR develops knowledge through the combined approaches of theoretical study and practical research, unlike much educational research which does not connect theory with practice. Additionally, DBR allows the meaningful development of knowledge in a robust manner, unlike Randomised Control Trials (RCTs) which validate existing theory and hypotheses (Bakker, 2018). DBR therefore offers a research approach that both adds to knowledge in a reliable and valid way, and seeks solutions to practical and pressing problems in real world situations (see also below).

Given that Design-Based Research (DBR) promises to be an appropriate and effective research approach, it is nevertheless important to consider any associated weaknesses or problems. Barab and Squires (2004: 10) highlight potential issues with the ability of the DBR researcher to be objective, stating that "if a researcher is intimately involved in the conceptualization, design, development, implementation, and researching of a pedagogical approach, then ensuring that researchers can make credible and trustworthy assertions is a challenge". This is a valid comment and therefore in my research I endeavoured to be transparent with myself through reflective journal writing and in my reporting about the decision-making process. I tried to make conclusions that were both credible and trustworthy, by explicitly justifying them to both myself and my supervisor. The Design-Based Research Collective takes a slightly different view of the same issue from Barab and Squires, asserting that DBR researchers could find it challenging to manage the 'dual intellectual roles of advocate and critic' (2002: 7). This is perhaps less of a problem for the education field, as many practitioners, including myself, are experienced in reflecting on their practice as it plays an integral role in continuous professional development (Bolton & Delderfield, 2018), provided the researchers aim for transparency. The process of shifting roles between promoting an intervention and critically reflecting upon it is very familiar to myself and many colleagues.

This particular study describes an exploration of Self Determination Theory (Ryan & Deci, 2017) alongside the Growth Zone Model (Johnston-Wilder & Lee, 2010), and therefore is more than an evaluation of an intervention. This research aims to develop and evaluate an intervention informed by theory and published research, and in turn to contribute to the sum of knowledge on the topic through publication and dissemination. Additionally, as a novice researcher, the iterative approach of Design-Based Research was very appealing to me, as I hoped to learn throughout the process and develop my research skills without the expectation of excellence from the start. Finally, rather than improving my personal practice, I planned to develop an intervention in a robust and rigorous manner.

4.2.5 Ensuring Alignment between the Research Questions and Design-Based Research

This subsection aligns the research questions which were identified following a review of the literature to the stages of Design-Based Research (Bakker, 2018). The learning goal is identified, and the strategy to meet that goal then outlined. The intention to evaluate the implementation as well as the impact of the intervention is stated. Finally, an extra stage is added, namely the dissemination of the findings.

Bakker (2014: np) suggests that the main research question of a design-based research project might have the following structure:

> *How can learning goal X be achieved for a particular group of learners (in particular conditions or under particular constraints)?*

The research question for this research meets the Design-Based Research structure as follows:

> **How can an intervention** (*the particular conditions*) **scaffold year 7 students** (*the particular group of learners*) to **learn to manage and overcome their mathematics anxiety?** (*the learning goal*)

The research question for this research further suggests secondary research questions to address the following:

1) *Based on the literature and expert opinion what would be a suitable learning goal for a particular group of learnings?*
2) *What is a teaching-learning strategy that would help students to achieve this goal?*
3) *How well was this strategy implemented?*
4) *What were the effects of this intervention?*

From these suggestions, the following related secondary research questions were developed:

- What is the level of mathematics anxiety in the year 7 cohort?
- What intervention would help individual students to manage and overcome their mathematics anxiety?
- What is the impact of the intervention on individual learners?
- How might this intervention be improved?

These secondary research question meet the Design-Based Research structure as follows:

Table 4.4 Research Questions aligned with Design-Based Research structure

Design-Based Research structure	**Resulting Secondary Research Questions**
Based on the literature and expert opinion what would be a suitable learning goal for a particular group of learnings?	To help learners manage and overcome their mathematics anxiety – so first need to establish presence and level of mathematics anxiety. Hence: **What is the level of mathematics anxiety in the year 7 cohort?**
What is a teaching-learning strategy that would help students to achieve this goal?	**What intervention would help individual students to manage and overcome their mathematics anxiety?**
How well was this strategy implemented?	**How might the intervention be improved?**
What were the effects of this intervention?	**What is the impact of the intervention on individual learners?**

Bakker (2018) recommends that the first stage of a Design-Based Research plan is the identification of a suitable learning goal. The learning goal for this research is to increase the ability of year 7 learners to actively manage their mathematics anxiety in order to learn mathematics more productively. The second stage of a Design-Based Research plan (Bakker, 2018) is to identify a teaching and/or learning strategy that enables learners to achieve the goal in question. The teaching-learning strategy that would help students to achieve this goal as indicated by the literature on mathematics anxiety takes the form of interventions and is described in detail below. The third stage is to evaluate the strengths and weaknesses of the implementation of the intervention (as distinct from the intervention itself). The process is examined to extract learning points for future Design-Based Research studies. If ways in which the implementation of the intervention could be improved are identified, then future research practices can be improved. The manner in which the implementation was evaluated is described in detail below. The fourth stage of DBR (Bakker, 2018) is to identify the effects of this intervention, whilst remaining aware of the possibility of there being detrimental as well as beneficial effects. The specific question is: what improvement can be observed in the management of mathematics anxiety of the participants? This is where the impact of the intervention is identified.

I have added an extra stage to the DBR process. This stage was not explicitly identified by Bakker (2018) but is suggested by one of the key principles of Design-Based Research, which is the intention to inform the literature. Therefore, the final stage in my research should be to identify any recommendations for other schools.

4.2.6 Section summary

This section has outlined the paradigmatic stance which underpins this thesis, and indicated the adoption of a pragmatic paradigm, with the caveat of my intention to consistently aim towards alignment of assumptions and methods, and transparency in recording and reporting. The decision of selecting a mixed methods approach has been described, with an explanation that the majority of the data was expected to be qualitative in nature. The rationale and justification of a Design-Based Research framework followed, and the application of the various DBR stages explained. The next section presents the research plan in detail.

4.3 PLANNING THE RESEARCH

4.3.0 Introduction

In order to answer the research questions explained in the section above, three distinct stages of research were identified. The first stage concerned the quantitative elements of the research and addressed the first secondary research question, the second stage concerned the main research where the intervention was developed and refined, and the third stage concerned data processing, analysis and the emergence of recommendations for other schools. These stages will be explored in detail below.

4.3.1 Research Participants

As identified in chapter 3, the target group for this research is learners in their secondary school stage of education. For all stages I chose to involve a local secondary comprehensive school. I reached out to my contacts and received a recommendation for a secondary school where the headteacher was open to new initiatives. The school was recruited and access to their learners granted by the headteacher acting as a gatekeeper, on the condition that a report summarising the research was shared with them. The headteacher was very aware of the need to address mathematics anxiety, as they had personal experience of it in the family. Involvement in the research was further secured through initial meetings with the headteacher, and subsequent meetings with the link mathematics teacher. The intended participants were in their first year of secondary full-time education, in other words, they were aged eleven and twelve. I contacted the headteacher and met with them and a mathematics teacher who would be my main contact.

4.3.2 Research Instruments

A variety of mathematics anxiety rating scales are available to the researcher (e.g., Dreger & Aiken, 1957; Wigfield & Meece, 1988) of which the Mathematics Anxiety Rating Scale (MARS), designed by Richardson and Suinn in 1972, is perhaps the most commonly recognised. Because it is widely used and the resulting data have been published, MARS has excellent levels of reliability and validity (Plake & Parker, 1982). The MARS was originally developed with 98 questions that explore the participant's response to typical mathematical learning contexts. It focuses on numbers and mathematical concepts, rather than test anxiety. However, the practicality of asking year 7 learners to complete a 98-question scale seemed dubious. Betz (1978) developed another mathematics anxiety measurement scale with a similar wide usage and a comparable level of reliability and validity. This was designed from the start as a much more manageable ten-question format, with answers recorded on a 5-point Likert scale ranging from 'strongly agree' through 'agree; and 'undecided' to disagree 'and finally 'strongly disagree'.

Finding participants to take part in studies of mathematics anxiety is very challenging, so it is perhaps not surprising that this scale, like many others, was developed with American college students who are a conveniently captive audience for university academics. 652 students studying mathematics or psychology were asked to provide their responses in a bidimensional task, so some questions were written positively and some negatively, necessitating a reversal of the scores when calculating the final total score. As Betz had used a large sample, calculated thorough statistics, and the scale itself was well recognised and had stood the test of time (including being cited by 676 other authors) I decided that it was robust enough for my needs. The practical implementation of the test appeared to be both manageable and straightforward. However, I was concerned that the scale had been developed for American college students rather than young British secondary school pupils, and so the questions may not be entirely appropriate.

Researchers who have adapted the Betz MAS include Pajares and Urdan (1996), who expanded it in a thorough research study involving over a thousand participants. Pajares and Urdan added three questions and used it with American high school students, students in eighth grade at middle school and college students. They also split their sample by gender, resulting in six distinct subgroups. High school in America relates to pupils aged from 14 to 18 years old, higher than the 11 and 12-year-old age range I targeted. I therefore had to adapt the scale for younger participants. Pajares and Urdan confirmed the reliability of the Betz scale in their research and recommended that their adaptation of the scale could be used with high school students. They advised caution with grade eight middle school students however (13 to 14 years) as there was less variance. However, these younger students recruited for the research were all studying algebra courses, and so were possibly those who had a higher level of successful experiences with mathematics., Pajares and Urdan found two factors that consistently applied to all their subgroups. These were a general sense of worry when mathematical teaching, tasks or tests were anticipated, and the stronger ‘negative affective reaction’ which refers to how the participants reported mathematics affected them physiologically. Bai et al. (2009) took the Betz scale and adapted it to address some problems in the presentation of positive affect.

They made it bidirectional, in that some questions were phrased positively and some negatively, which protected against unreliable completion of the scale, and also included the situation of maths tests.

The Betz mathematics anxiety scale has further been reliably adapted to meet the needs of secondary school students by Mahmood and Khatoon (2011) in India. They added four questions but adapted the language to make it more accessible for younger readers. This scale was again evaluated as robust and reliable.

I adapted the scale still further and made sure that it could be understood by an eleven-year-old pupil in England by using the readability analytic tools in Microsoft Word. I designed a layout that had two parts; the first part gathered contextual information such as age, teaching group and register number. When asking participants for information about their gender, I made sure that I gave them the opportunity to either identify as male or female, or to choose the additional option of 'prefer not to say'. I have come to realise the importance of this third option through the different stages of a transgender journey of a close family member, and so felt strongly that I wanted to recognise the possibility that some of my young participants would appreciate the opportunity to opt out of this question.

Once I had decided on the scale, I then had to decide how I would encourage the participants to reply honestly. I looked at several options including lines with numbers ranging from 1 to 5. However, I felt that this format was too abstract and separate from an eleven-year old's understanding to make it relatable. Another option would be to have faces ranging from smiling to frowning but I felt that this approach was too patronising and childish. Eventually I decided to write the words 'always agree', 'sometimes agree', 'uncertain', 'sometimes disagree' and 'always disagree' out for each question as then the flow of conceptual understanding would be supported (Chyung et al., 2017). I asked the participants to 'read the sentence and then circle the words that describe how you feel'. This instruction is very similar in sentence construction to the instructions they would have experienced in the end of year assessments in year 6. The scale was then piloted with 30 year-6 students from a primary school in Kent, where the headteacher is a family member who was happy to help with my research. There were no reported issues with the scale, and the results were found to be as expected, inferring that the pupils were able to read, understand and complete the scale reliably. The returned scripts demonstrated involvement and understanding, so I was happy to proceed with their use with year-7 pupils. The scale can be seen in Appendix 4.1. Resilience data was also gathered through an additional questionnaire, but this will be published elsewhere as the scope of the thesis did not permit this extra level of depth.

After some confusion about what I could call the intervention sessions, I found the description of 'clinical interview' to be the most applicable. The use of the clinical interview format to both gather and present information was first developed by Piaget (Ginsburg, 1981) and is used in mathematics and science education (Clement, 2000) to offer a window into cognitive processes through observing the responses of the learner. It involves presenting the learner with information to consider and tasks to complete, and thus offers a different experience to the standard interview format. The intervention sessions in this research would involve presenting the learners with new information and gathering their responses. They would also involve asking the learners to try out certain strategies and report back on progress in a subsequent meeting. I also hoped to expand the scope of the interview to include the emotional processes of the learner using the Growth Zone Model (Johnston-Wilder & Lee, 2010).

4.3.3 Stages of research

An overview of the stages of research and their corresponding research question is shown in table 5.1 and described fully below.

Table 5. 1 Aligning the Research Questions to the Research Stages and Processes

Research Stage	**Research Question**		**Evaluated through**	**Reported in**
1	1	What is the level of mathematics anxiety in the year 7 cohort?	Mathematics Anxiety Scale	Chapter 5 – Quantitative Findings
2	2	What is the impact of the intervention on individual learners?’	Thematic analysis on transcriptions of clinical interviews, and field notes.	Chapter 7 – Qualitative Findings
2	3	How well was this intervention implemented?	All Design-Based Research Cycle Reviews	Chapter 6 – Design-Based Research Findings
2	4	‘How might the intervention be improved?’	All Design-Based Research Cycle Reviews	Chapter 6 – Design-Based Research Findings

The first stage of the research was to assess mathematics anxiety through a rating scale specifically adapted for young learners. These rating scales were completed by each learner in a timetabled mathematics lesson without the researcher being present, so that the teachers could deliver them at their convenience. A4 envelopes were provided for each teaching group so that the scales could be safely stored. A period of one week was suggested for the completion of the rating scales, after which they were collected directly from the school by the researcher. In order to maintain anonymity, the returned scripts did not include the names of the learners, instead being identified by the teaching group and the learners' register numbers.

The second stage of the research involved qualitative data gathering in the form of recorded one-to-one intervention sessions. The participants were selected by identifying the year-7 learners with highest levels of mathematics anxiety with the additional criteria of having a representative number from each teaching group. Three iterative cycles of Design-Based Research were planned, as this would provide an opportunity for improvement between cycles within the limited time frame of the school term. The intervention consisted of three clinical interviews, lasting around 30 minutes, with each learner (see Appendix 4.2 for the Clinical Interview Plan). I planned to work with six learners in each cycle, as this number of pupils could be seen within one school day, an arrangement which made data collection manageable for me. I planned to evaluate through ongoing reflection in my fieldnotes, with a more formal reflection between each cycle and the next. This formal reflection involved the use of a prompt sheet which I developed from Collins, (2004) (see Appendix 4.3). The sessions were recorded for transcription and analysis at a later date. Therefore, 18 children were expected to be involved, each having three clinical interviews. Due to issues of recruiting participants within specific teaching groups, 13 children were actually involved, some of whom received three clinical interviews while others received two.

Table 4. 5 Cycles and clinical interview structure, with reflection points.

Cycle 1	First clinical interview for 6 learners	Reflection in fieldnotes
	Second clinical interview for same 6 learners	Reflection in fieldnotes
	Third clinical interview for same 6 learners	Reflection in fieldnotes
	Reflection and discussion with supervisor	
Cycle Review - Revise intervention, informed by reflection and discussion		
Cycle 2	First clinical interview for 6 new learners	Reflection in fieldnotes
	Second clinical interview for same 6 learners	Reflection in fieldnotes
	Third clinical interview for same 6 learners	Reflection in fieldnotes
	Reflection and discussion with supervisor	
Cycle review - Revise intervention, informed by reflection and discussion		
Cycle 3	First clinical interview for 6 new learners	Reflection in fieldnotes
	Second clinical interview for same 6 learners	Reflection in fieldnotes
	Third clinical interview for same 6 learners	Reflection in fieldnotes
	Reflection and discussion with supervisor	

The clinical interviews were carefully designed to introduce the learner to the different zones of the Growth Zone Model (Johnston-Wilder & Lee, 2010, explained in section 2 of chapter 3), and the associated feelings and emotional tools required to manage movement to the growth zone, which is the optimal zone for learning (see Appendix 4.2 for the Clinical Interview plan). The Growth Zone Model was to be shared with the learners though the use of an application on an iPad (see Appendix 4.4 for a detailed description of the grOwth app).

The first clinical interview focused on supporting the learner to recognise when they were in the anxiety zone and providing suggested strategies for managing those emotions and recovering from them. I felt that it was most important to start the clinical interview suite with a focus on the anxiety zone, as that is the area where most harm can be caused. The first clinical interview began by setting the scene to create a comfortable environment, by sharing the purpose of my research, and by gathering how the learner felt about learning mathematics. The interview then addressed the management of unpleasant emotions and self-safeguarding by introducing the Hand Model of the Brain (Siegel, 2010). It continued by showing the learner how to reset their parasympathetic nervous system through recovery breathing (Benson, 1975). The learner then was encouraged to recognise their emotions through identification with the Growth Zone Model (GZM, Johnston-Wilder & Lee, 2010) and demarcation of their position on the GZM with an app. The interview ended by reviewing the session and agreeing actions for the following interview.

The second clinical interview focused on supporting the learner to persevere in the growth zone. It began by gathering more data about the learner's recognition and management of their emotions following reflection on the information shared in the previous session. This learning was consolidated, any misconceptions were addressed, and the continued use of the Growth Zone Model was encouraged. Next the learner's assumptions about the benefits or otherwise of making mistakes when learning were addressed (Boaler, 2016; Moser et al., 2011). The characteristics of self-efficacy

(Bandura, 1994), perseverance (Williams, 2014) and optimistic struggling (Seligman, 1991) were encouraged. The interview ended by reviewing progress and agreeing actions for the following interview.

The third clinical interview aimed to support the learner in the process of moving out of the comfort zone, a process I called 'creeping out of comfort'. It also aimed to build mathematical resilience by focusing on the four elements of Mathematical Resilience (Johnston-Wilder & Lee, 2010), namely having a growth mindset, valuing mathematics, optimistic struggle and recruiting support. The session began by gathering more data about the learner's recognition and management of their emotions experienced whilst learning mathematics. It continued by consolidating learning on mathematical resilience, particularly the growth aspect, addressing misconceptions, and encouraging continued use of the Growth Zone Model. The possible need to support the process of recovering from learned helplessness (Peterson, Maier & Seligman, 1993) was supported by developing an appreciation of the value of mathematical learning. The session also addressed the need for the learners to recognise that mathematical learning would be worth a little discomfort. An image from Circles of Relationship (Walker-Hirsch & Champagne, 1991) was shown to the learners to raise awareness of the different kinds of support available to them (see Appendix 4.5). As with the other sessions, data was gathered for the next iteration of the research. The suite of sessions ended by ensuring that the participant was ready to finish the sessions.

The second and third cycles of the suite of clinical interviews were expected to develop and refine this intervention. The final stage of the research drew from the outcomes and learnings of the main stage (stage 2) and identified the messages that should be disseminated to schools, and the wider mathematical education field.

The importance of consistently matching the paradigmatic nature of the research and the identified purpose of the research (Baskarada & Koronios, 2018) has been noted above. This research aims to maintain an alignment between the underlying pragmatic assumptions and the research methods employed (Hathcoat & Meixner, 2017). Through endeavouring to transparently disseminate my decision-making process, I aimed to match the research methods to the pragmatic assumptions which underlie the research.

The purpose of the research was to support learners, by maintaining a balance between scaffolding and allowing learner autonomy. I conducted this research from the position of understanding how some learners would have a tendency towards anxiety and knowing first-hand the importance of having autonomy. A key strength of Design-Based Research is that it is based on and feeds back to theory, so I hoped that the research would enable me to persuade others of the importance of balancing learner support and enabling learner autonomy. Therefore, in order to maintain realistic and achievable outcomes that would be workable for pupils, I decided to conduct the research in a school setting.

4.3.4 Analysis

Using the levels of mathematics anxiety identified by Mahmood and Khatoon (2011), namely, high, medium and low, the scales were marked and levelled. The information was then inputted into Excel and SPSS. Patterns and trends were established around the prevalence of mathematics anxiety in gender, previous mathematics qualification and teaching group. Statistical significance of differences was sought. The findings are presented in the next chapter.

For the second stage of the research, the iterations involved in Design-Based Research were deployed, examined, and regularly discussed with my supervisor. The outcomes were recorded on a template and further information was gathered in a fieldnotes diary. The audio elements of the clinical interviews were recorded on an app on a mobile phone, and an iPad was used to provide a second, back-up recording for each case. The audio files were transcribed, ensuring that the participants were identified by their pseudonyms.

The themes evident in the transcriptions were established through thematic analysis. Braun and Clarke's (2006) approach was initially selected, as they describe a systematic, robust and flexible way of analysing qualitative data through coding and network analysis. However, further research revealed that the approach of Nowell et al. (2017) provided a further level of transparency and checking to establish trustworthiness, and so this process involving six phases was rigorously followed instead of the approach recommended by Braun and Clarke (see Table 4.3 below for details about each phase).

Table 4.6 Nowell et al.'s (2017: 4) phases of thematic analysis

Phases of Thematic Analysis	**Means of Establishing Trustworthiness**
Phase 1: Familiarizing yourself with your data	Prolong engagement with data Triangulate different data collection modes Document theoretical and reflective thoughts Document thoughts about potential codes/themes Store raw data in well-organized archives Keep records of all data field notes, transcripts, and reflexive journals
Phase 2: Generating initial codes	Peer debriefing Researcher triangulation Reflexive journaling Use of a coding framework Audit trail of code generation Documentation of all team meeting and peer debriefings
Phase 3: Searching for themes	Researcher triangulation Diagramming to make sense of theme connections Keep detailed notes about development and hierarchies of concepts and themes
Phase 4: Reviewing themes	Researcher triangulation Themes and subthemes vetted by team members Test for referential adequacy by returning to raw data
Phase 5: Defining and naming themes	Researcher triangulation Peer debriefing Team consensus on themes Documentation of team meetings regarding themes Documentation of theme naming
Phase 6: Producing the report	Member checking Peer debriefing Describing process of coding and analysis in sufficient details Thick descriptions of context Description of the audit trail Report on reasons for theoretical, methodological, and analytical choices throughout the entire study

The instruction to ‘triangulate with other researchers’ is notably frequent in Nowell et al.’s phases. This would be hard for an independent researcher at doctoral level, but I was fortunate to have a very supportive supervisor who was always available to triangulate each stage of the process. I therefore tailored this aspect of Nowell et al.’s guidance to my requirements by discussing my progress, justifying and reconsidering my decisions, and sharing and solving my problems with my doctoral supervisor. In order to manage the coding process which involved a substantial amount of qualitative data, a software package which was available to me as a university student was used. This was NVivo version 11. The software was downloaded to my personal computer and the data generated was stored on my personal files on the university memory drive.

4.3.5 Section summary

This section has outlined the research plans for each of the three stages of the research. A quantitative approach was taken to establish the levels of mathematics anxiety in the cohort. From that data, possible participants were identified. The participants who chose to take part in the study were involved in three clinical interviews each, which were iteratively arranged to allow for developmental alterations. The interviews were recorded, transcribed, and uploaded to NVivo software. Additional information was gathered through the reflections and discussions from the Design-Based Research stages and a fieldnotes diary. The outcomes were analysed thematically.

4.4 ETHICAL CONSIDERATIONS

When conducting educational research, a comprehensive review of the ethical implications involved is of great importance (Robson, 2002; Thomas, 2013) to ensure that research integrity is maintained (UKRIO, 2009). Additionally, as doctoral research is supervised by an awarding institution, the approval of said institution is a necessity. When conducting primary research on vulnerable participants, such as Y7 pupils who are both young and in a relatively powerless position in a new school, detailed reflection is required on both: the ethical requirements of obtaining consent, maintaining confidentiality, ensuring transparency, and safeguarding the participants; and the impact of the selected research methods on these requirements.

Ethical approval was applied for, and permission was granted by the Centre for Education Studies, Warwick University (Appendix 4.6). Ethical approval was initially sought and granted for year-6 and year-7 pupils. When it became clear that additional valuable information could be gained from the teachers at the participating secondary school, a subsequent ethical approval process was followed, and permission granted (Appendix 4.6).

For the first stage of the research, consent from the headteacher acting as gatekeeper was secured for the anonymised data from the year-7 cohort. An information sheet was given to the headteacher and the maths teacher involved (see Appendix 4.8) and an explanatory letter that outlined the process of securing informal consent was provided for the teachers administering the scale (see Appendix 4.9). Confidentiality was assured through the use of a coding structure that identified the school, class and register identity of each learner. Therefore, the students could not be identified by anyone outside the school.

For the second stage, as the learners were underage, I secured consent from their parents by sending likely participants an information letter and consent form to return if they and their children were happy to participate in the research. They indicated their willingness to participate to their mathematics teacher by returning the signed consent form (see Appendix 4.10). Respect for the rights and dignity of the participants was recognised by explaining participants' right to withdraw involvement at the start of every session, and reminders of this right whenever I felt they were necessary. I was aware of the power imbalance between myself and the learners, in that I was an adult in their school environment, and so I took extra steps to enable the learners to opt out if they felt uncomfortable. This involved sharing laminated cards with them at the beginning of each session. The cards had various self-care messages, such as 'don't forget to breathe' and 'let your troubles float away '(Elsa Support, 2018). Rather than expecting the learners to voice their feelings, which may have been challenging, I encouraged them to touch their card if they wanted me to pause or stop. This was particularly important in the one-to-one discussions about mathematics anxiety, which is a distressing subject (Dowker, Sarkar & Looi, 2016). Confidentiality was assured in the one-to-one sessions by allocating a pseudonym to each learner, and removing identifiers such as learner name, any mention of names of friends, teachers' names and names of primary schools from the transcriptions.

The need for the research to involve transparency in all areas was addressed in various ways. Participants at both stages were explicitly informed of my status as a doctoral student at Warwick University. I emphasised this point at the start of the one-to-one sessions, explaining that I was finding out about mathematics anxiety and asked for their help. I hoped that this would shift the power balance from researcher – participant towards one of co-researchers. Information sheets were prepared for pupils, parents, and staff which explained the purpose of research and my contact details should additional information be required. Additionally, the purpose of the research was explained at the start of the sessions. The intention to feed back to staff, parents and pupils about the research was given for both stages. This involved both written reports and the offer of staff and parents' meetings.

I considered measures to promote the safeguarding of the participants. I hold a current Disclosure and Barring Service enhanced check, which was shared with the school. An additional form to allow independent access to the school as indicated by a particularly coloured lanyard was requested by the school and completed by my supervisor. The participants were treated with respect and dignity at all times. Admittedly I had less control over this aspect in the first stage, when I was not present, and the mathematics teachers were managing a class of learners. For each of the one-to-one sessions I took time to smile at the learner, respond to their line of discussion respectfully, and demonstrate that I was interested in their opinions. Alongside this however I made it clear that any safeguarding issues would be reported.

As previously mentioned, when asking questions about mathematical learning and mathematics anxiety, participants can get distressed. I ensured that tissues, chocolate, and water were available and visible at each session. Additionally, as mentioned above, the participants were informed that they could stop at any time and given a card to touch in case they struggled to voice their wishes.

The final area to consider in terms of my ethical responsibilities was the privacy and confidentiality of participants. In the first stage of the research, the register number and teaching group of each participant were the only identifying pieces of information held, and as mentioned above, no-one outside the school, including myself, would be able to identify an individual learner from this data. In the second stage, which involved transcribed audio recordings, pseudonyms were used for all documentation. The resulting data was stored securely, with the hard copy data stored in a locked filing cabinet and the electronic data stored on an external hard drive, which was held in a locked filing cabinet. The identifying information such as learner name and teaching group was deleted and shredded as soon as it was no longer needed.

Additionally, I planned to explain to the participants that I would not divulge any information to their mathematics teachers, and in fact would not necessarily know who their mathematics teacher was. However, I was concerned that I may inadvertently contradict the mathematics teachers with a contrary or confusing message about mathematics. I therefore planned to take every opportunity to communicate my intentions to the mathematics teachers as a whole and note any possible areas of conflict.

In this section I have demonstrated my consideration of the ethical requirements when conducting primary research with vulnerable participants. For the areas of obtaining consent, maintaining confidentiality, ensuring transparency, and safeguarding the participants, I have detailed my planned actions and explored the impact of my selected research methods on these requirements. The message that underlines all of this ethical aspect is that, whilst I feel I have something to offer these learners, nevertheless I am expecting them to open up about their emotions, which puts them in a vulnerable position. I planned to be very mindful of the responsibility to tread carefully with these young people.

4.5 LIMITATIONS

There were various limitations to this research. The first limitation is in the first stage of the research, where a mathematics anxiety scale was to be administered to all the year 7 pupils. This approach involved a threat to the validity of the research in that the pupils were self-reporting their levels of mathematics anxiety in the very situation where they would experience such anxiety, namely their mathematics class. This incurred the possibility of pupils reporting lower than actual levels of mathematics anxiety because they did not feel safe enough to be honest about their experiences, being surrounded by their fellow pupils. Additionally, in the presence of their mathematics teacher, they may have felt the need to portray a more positive version of their true feelings.

The second limitation of the research was another aspect of the involvement of the teacher, in that the approach relied upon the teachers' assistance in administering the scales to their pupils. I have already indicated my concerns about the teachers' understanding and implementation of the rights of the pupils to participate or not as they would wish. Additionally, I relied upon the teachers to actually do what was required. As it turned out, the mathematics anxiety scales for one of the nine teaching groups were not returned. This may have been because I asked the school to administer a mathematical resilience scale at the same time as the mathematics anxiety scale, a move that later became redundant for this particular research. Giving the teachers just one scale to administer may have reduced the possibility of teachers not finding the time to cooperate with the research.

The third limitation was the number of Design-Based Research cycles, which was set to 3 as a pragmatic decision to fit the fieldwork and analysis schedule into one school year. If 4 or 5 Design-Based Research cycles were possible, this may have provided insight into the usefulness of the intervention for those learners with moderate rather than high levels of mathematics anxiety.

4.6 CHAPTER SUMMARY

This chapter has outlined the specific research questions I arrived at following careful consideration of the relevant literature, in the fields of mathematics education and psychology. From those research questions, my research principles and approaches emerged. The details of the research plan were then explained, and the chapter concluded by explaining my consideration of my ethical responsibilities. This plan was then deployed. The quantitative findings (from the first stage) are shared in the next chapter, the findings from the Design-Based Research aspect of the second stage are shared in chapter 6 and the qualitative findings from the thematic coding process are presented in chapter 7.

CHAPTER 5 QUANTITATIVE FINDINGS

5.0 INTRODUCTION

This chapter presents a description and analysis of the quantitative findings gathered from the first stage of the research. The outcomes from the contextual data are described, followed by presentations of the mathematics anxiety scores grouped for gender, prior attainment and teaching group. Mathematics anxiety was measured through a paper-based questionnaire, herewith referred to as the MA scale, in two parts. The first part gathered contextual information such as gender, age and Key Stage 2 Standard Assessment Test score. The second part was adapted for upper primary and lower secondary pupils (10- to 12-year-olds) from the Betz (1978) Mathematics Anxiety Scale (see section 4.3.1 in chapter 4 for details). This part asked the students to report their feelings in various mathematical situations (see Appendix 4.1 for the questionnaire).

As the scale was bidirectional, the mathematics anxiety score for each pupil was calculated by firstly reversing the scores for items that had been negatively phrased, and then summing the item scores. The data were entered into SPSS version 25 (IBM, 2017) manually and then analysed within SPSS. The data were analysed in two main ways, through description and through comparison (Hinton, 2008). The frequency, graphs and charts functions were used to explore the data descriptively, and the analysis of variance (ANOVA) and linear regression functions used to compare and test the differences between different sub-groups. Mathematics anxiety scores were used to assess the level of mathematics anxiety in the whole cohort, then by gender, by reported previous mathematics attainment, and by teaching group. It is thereby possible to compare the findings with those of other studies reported in the research literature from cohorts around the world, both at the level of individual questions and of group means, which will be discussed in chapter eight. The data collected were then examined through linear and multivariate regression to see whether mathematics anxiety levels in the sample were associated with gender, reported Key Stage 2 mathematics test score and teaching group.

5. 1 CONTEXTUAL INFORMATION

5.1.0 Introduction

This section of the chapter describes the contextual information of the qualitative data, including information about the participants, the Key Stage 2 mathematics scores that they reported and their gender.

5.1.1 Participant information

Following agreement from the headteacher, the MA scale and instruction letters were distributed to the mathematics staff. The participation rate for the study was high, as students were asked to complete the MA scale as part of a mathematics lesson. The total number of year 7 pupils in the school is 290, and 223 MA Scales were returned. I did not receive the MA scales from one teaching group, and there were some absences in the rest of the cohort, which resulted in the non-completion and return of some scales. However, to perform an unrelated two-tailed test with a 0.05 level of significance, a medium effect with a power of 0.8, then 128 participants are required (Hinton, 2014). This sample size is therefore more than adequate to indicate significant trends and reliable conclusions.

A total of 223 year-7 pupils took part in the survey, from eight out of nine teaching groups in year 7 in the participating school. The teaching groups had a broadly similar history of mathematical attainment, apart from two groups which just contained those pupils who had achieved above a certain level in their key stage 2 test, undertaken the previous year whilst they were at primary school. However, the labelling of the teaching groups did not necessarily reflect this equality of expectation.

Table 5. 2 Labels of Year 7 Mathematics Teaching Sets

Higher attainment only	**Mixed attainment**
Set 1	Set 2a
Set Y1	Set Y2a
	Set 2b
	Set Y-Ma2b
	Set 2c
	Set 2d

5.1.2 Reported Key Stage 2 mathematics test scores

The students were asked to recall their Key Stage 2 mathematics Standard Assessment Test score as assessed whilst they were at primary school. These are national tests with possible scores ranging from 80 to 120. It was not possible to establish the reliability of the students' recall, but the range of scores was checked and found to be within the possible boundaries, so therefore the recalled scores were viewed as plausible. The national average score is 100. All but 10 students provided a score.

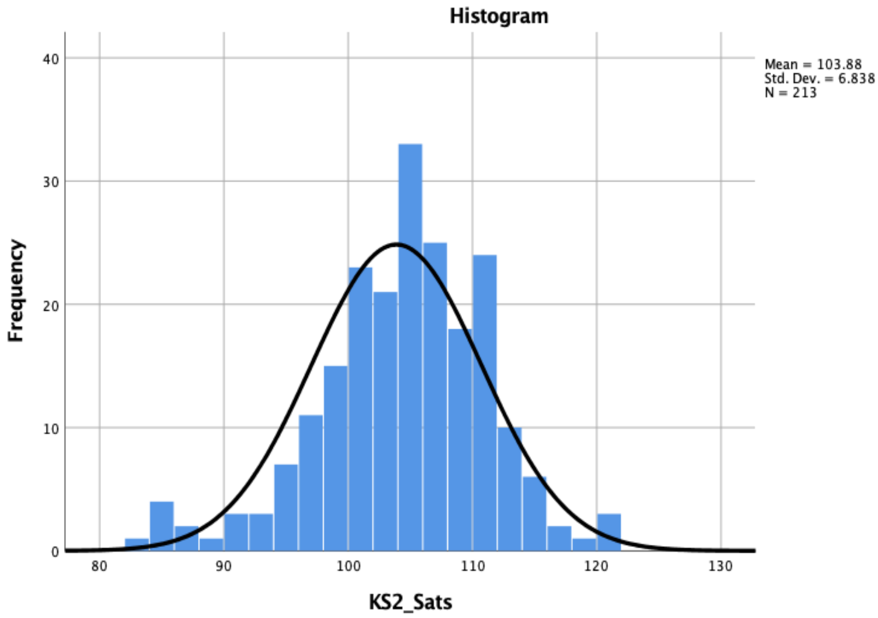


Figure 5.1 Recalled KS2 mathematics test scores

The data sample was evaluated using the Kolmogorov-Smirnov test, a test for normality (Hinton, 2004) and found to be within the limits of a normal distribution. It must be noted, however, that Field (2013) warns against the use of such tests for normal distribution for either large or small samples. Given the purpose of the statistical analysis though, it can be observed that there is no significant level of skewness or kurtosis. The reported Key Stage 2 mathematics test scores fall within the shape of a normal distribution curve with a mean of 104, which is slightly above the national average of 100.

5.1.3 Gender

The gender distribution of the sample is as expected in a co-educational institution. Slightly more learners identified as female (49%) than as male (44%), with 7% of the sample indicating that they preferred not to identify with a specific gender. As explained in section 4.3.1 of the previous chapter, I took this approach because personal experiences had increased my awareness of the possibility that pupils as young as eleven-years old might feel uncomfortable identifying as either male or female. This is an unusual feature of my data, which is not represented in the general mathematics anxiety literature (see for example, Akbayir, 2019, and Wang et al., 2020). However, there is an adequate number of learners who identify as either male or female to allow comparison to findings in the literature.

For the purposes of statistical analysis, the 7% of the sample who did not identify themselves as a specific gender were positioned in between the male and female groups. There are two reasons for this decision, The first is that the learners could be either male or female. The second is that the participants may view themselves as non-binary, in other words not fitting into either end of a perceived gender spectrum (Losty & O'Connor, 2017).

Table 5. 3 Students by Gender

Gender	Count	%
Female	110	49
Prefer not to say	14	7
Male	99	44
Total	223	100

5.1.4 Subsection summary

To summarise this subsection, the participating learners were distributed across eight teaching sets, with two of those sets containing only the higher achievers. The achievement levels of the sample were slightly above the national average. The gender distribution was broadly representative but 7% of the sample took the opportunity to identify as neither male nor female.

5.2 MATHEMATICS ANXIETY SCORES

5.2.0 Section Introduction

Mathematics anxiety (MA) was measured using a version of the Mathematics Anxiety Scale (Betz, 1978) adapted for upper primary and lower secondary pupils (10- to 12-year-olds). 5 questions were positively worded and 5 were negatively worded (see Appendix 4.1). The total MA score was calculated by hand, inputted to an excel spreadsheet and then uploaded to IBM SPSS version 25, a statistical software package. The results were used as an indicator of level of mathematics anxiety in the cohort in order to compare groups with the findings and theories in the mathematics anxiety literature.

The section then explores the possible relationships between the different data groups and mathematics anxiety. The literature indicates that mathematics anxiety is associated with mathematics achievement (Namkung, Peng & Lin, 2019), gender (OECD, 2013) and teacher attitudes (Maloney, Schaeffer & Beilock, 2013) and teaching styles (Nardi & Steward, 2003). Therefore these data groups were explored through regression analysis.

5.2.1 Frequency of mathematics anxiety

The possible scores resulting from the MA scale ranged from 10 to 50, with 10 representing the lowest level of reported anxiety and 50 representing the highest level of reported anxiety. MA scores above 32 are recognised as likely to represent a tendency towards visibly high anxiety (Mahmood & Khatoon, 2011). MA scores above 27 but below 33 are recognised as likely to represent a tendency to be anxious without necessarily demonstrating visible effects (ibid, 2011). MA scores up to 27 represent a low level of mathematics anxiety. The MA scores ranged from the lowest possible score of 10 to a high score of 44, so the pupils reported MA scores from the absolute lowest point to quite near the top of the range. The mean MA score was 26.7, just below the threshold from low levels of anxiety into a tendency to be anxious. The standard deviation was 7.5, and the data were normally distributed, shown by the Shapiro-Wilk test, (p = .062).

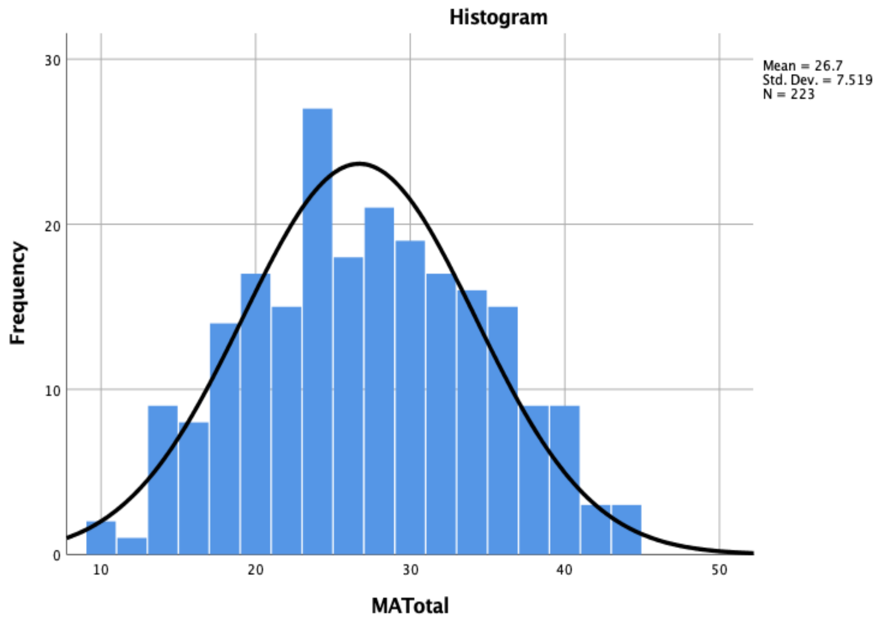


Figure 5.2 Frequency of MA scores

Over half of the cohort, 123 pupils or 55%, demonstrated low levels of mathematics anxiety, recording MA scores of 27 or below. Some 45 pupils, a proportion of 20%, demonstrated moderate levels of anxiety, with scores falling into the range of 28 to 32 inclusive. A quarter of the cohort, 56 pupils, demonstrated high levels of anxiety. Therefore 45% of the cohort demonstrated either moderate or high levels of mathematics anxiety.

Table 5. 3 Levels of Reported Mathematics Anxiety

123, or 55%, of the year 7 students surveyed demonstrated low levels of maths anxiety.
45, or 20%, of the year 7 students surveyed demonstrated moderate levels of maths anxiety.
56, or 25%, of the year 7 students surveyed demonstrated high levels of maths anxiety.

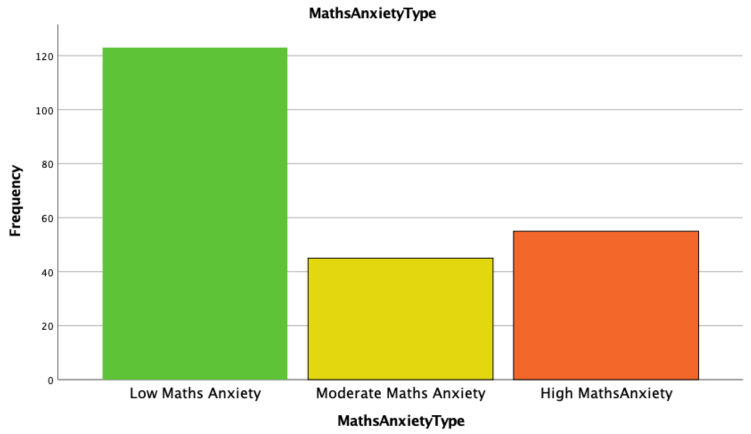


Figure 5.3 Bar Chart of grouped MA levels

5.2.2 Frequency of mathematics anxiety by previous mathematical attainment

In order to establish if there was a relationship between previous mathematics achievement and level of reported mathematics anxiety, as is indicated by the literature (Namkung, Peng & Lin, 2019), SPSS version 25 (IBM, 2017) was used to draw a scatterplot with a line of best fit (Figure 5.2).

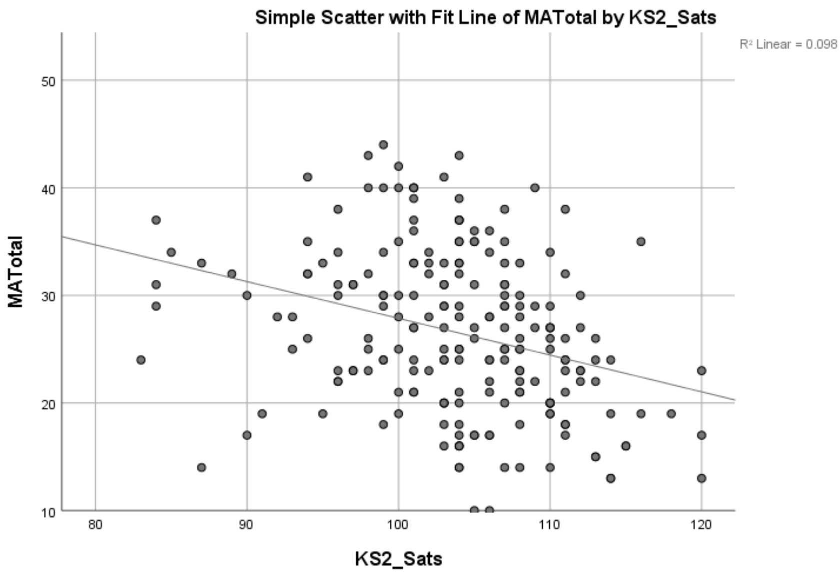


Figure 5. 4 Scatterplot with Fit Line - MA against Previous Attainment

The graph shown in figure 5.2 indicates that a negative relationship exists, in that higher levels of previous attainment, as measured by learner-reported Y6 SATs score, tend to be related to lower levels of mathematics anxiety. However, the level of previous attainment does not offer a strong indicator of mathematics anxiety, as some learners reported high levels of previous attainment and high anxiety, and some reported low levels of previous attainment and low anxiety.

To pursue this further, a linear regression was calculated using SPSS.

Table 5.4 SPSS Output of linear regression MA to previous attainment

ANOVA						
Model		Sum of Squares	df	Mean Square	F	Sig.
	Regression	1155.918	1	1155.918	22.744	.000[b]
	Residual	10672.780	210	50.823		
	Total	11828.698	211			
a. Dependent Variable: MATotal						
b. Predictors: (Constant), KS2_Sats						

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.313[a]	.098	.093	7.129
a. Predictors: (Constant), KS2_Sats				

Table 5.4 shows that the correlation indicated in Figure 5.2 is significantly different from zero. However, the adjusted R^2 value indicates (Field, 2013) that previous mathematical attainment can only account for 9.3% of the variation in mathematics anxiety within the sample. This finding will be further explored in the discussion chapter. The relationship according to SPSS can be expressed as follows:

MA = 62.02 – (0.093 × Previous Attainment)

5.2.3 Frequency of mathematics anxiety by gender

Next, in order to establish if there was a relationship between gender and level of reported mathematics anxiety, as is indicated by the literature (Hill et al., 2016), SPSS version 25 (IBM, 2017) was used to draw a scatterplot with a line of best fit (Figure 5.3).

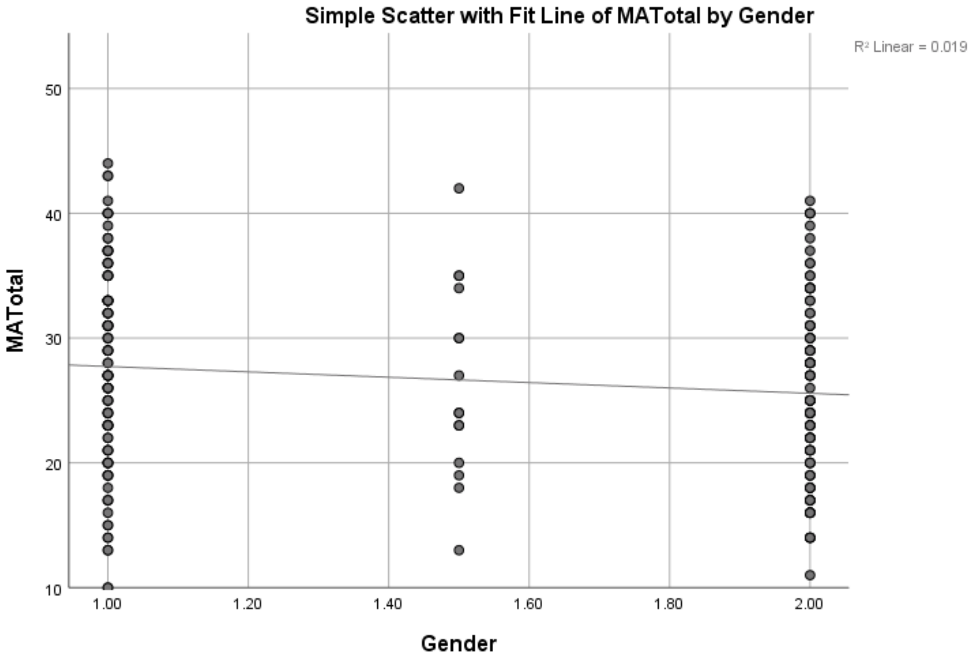


Figure 5. 5 Scatterplot of mathematics anxiety and gender

This graph, along with the table and chart shown below in table 5.5 and figure 5.6, shows that a relationship exists in that on average female participants (coded as 1) have higher levels of Maths Anxiety than those who prefer not to report a gender (coded as 1.5) and male participants (coded as 2).

Table 5.5 Levels of Reported Mathematics Anxiety by Gender

Female pupils
48, or 44% of the female pupils surveyed demonstrated low levels of maths anxiety.
28, or 25% of the female pupils surveyed demonstrated moderate levels of maths anxiety.
25, or 23% of the female pupils surveyed demonstrated high levels of maths anxiety.
Male pupils
55, or 56% of the male pupils surveyed demonstrated low levels of maths anxiety.
26, or 26% of the female pupils surveyed demonstrated moderate levels of maths anxiety.
16, or 16% of the female pupils surveyed demonstrated high levels of maths anxiety.

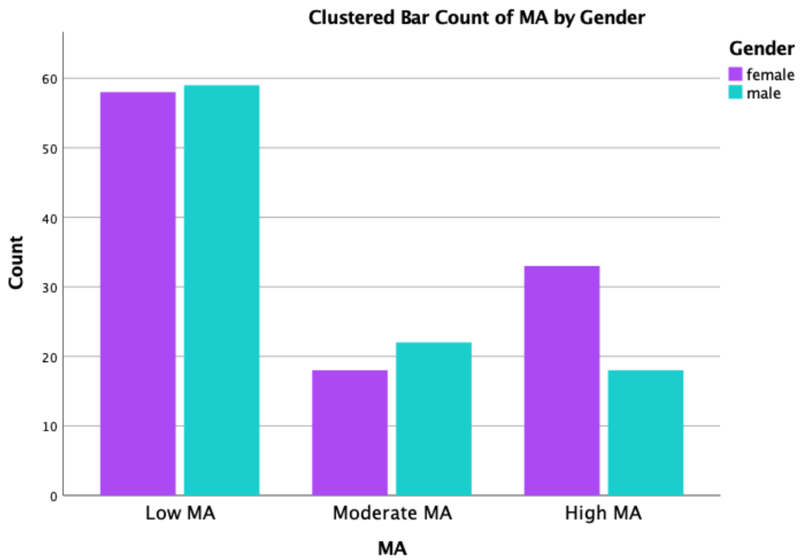


Figure 5.6 Bar chart of grouped MA levels by gender

To pursue this further, a linear regression was conducted in SPSS.

Table 5. 6 SPSS Output of linear regression -mathematics anxiety and gender

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
	Regression	239.704	1	239.704	4.304	.039[b]
	Residual	12309.560	221	55.699		
	Total	12549.265	222			
a. Dependent Variable: MATotal						
b. Predictors: (Constant), Gender						

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
	.138[a]	.019	.015	7.463	.019	4.304	1	221	.039

a. Predictors: (Constant), Gender

Table 5.6 shows that mathematics anxiety and gender were negatively correlated, $R^2 = .019$, $F (1, 210) = 4.30$, $p< .05$. However, the adjusted R^2 value indicates (Field, 2013) that gender can only account for 1.5% of the variation in mathematics anxiety within the sample. This finding will be further explored in the discussion chapter. The relationship can be expressed as follows:

$$MA = 29.87 – (0.015 \times Gender)$$

5.2.4 Frequency of mathematics anxiety by teaching group

Lastly, I wanted to find out if the teaching group was related to mathematics anxiety. The school had informed me that there was an element of setting with the groups, in that two of them contained only students with higher KS2 SATs scores (Table 5.5 and Figure 5.4).

Table 5. 7 Year 7 Class Grouping

Higher attainment only	Mixed attainment
Set 1	Set 2a
Set Y1	Set Y2a
	Set 2b
	Set Y-Ma2b
	Set 2c
	Set 2d

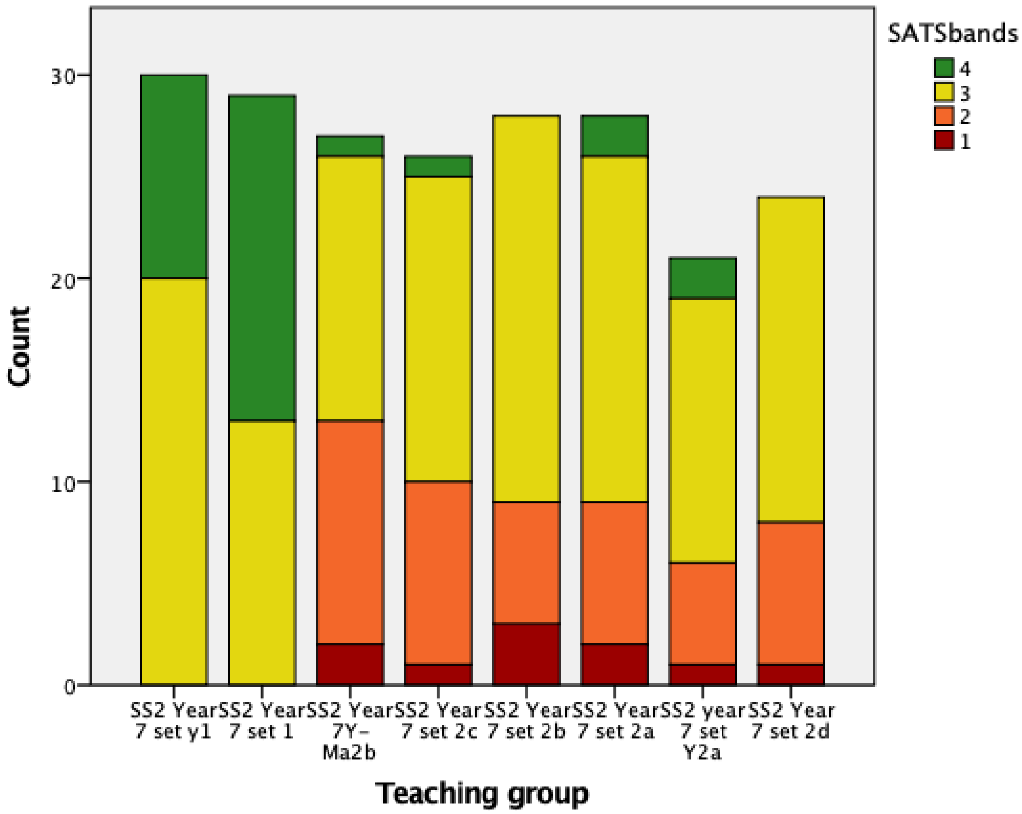


Figure 5. 7 Year 7 Class grouping

I removed set 1 and set Y1 from this particular analysis as otherwise there would be a confounding variable from the previous attainment of the students. Carrying out the analysis on the groups which were mixed attainment enabled a clearer finding.

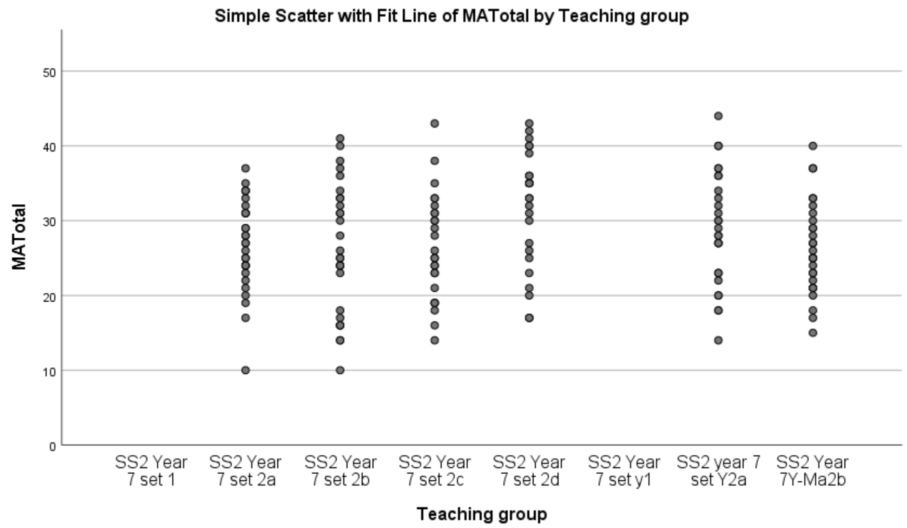


Figure 5. 8 Scatter Plot of Teaching group with mathematics anxiety

Figure 5.8 seems to indicate that a relationship exists between teaching group and mathematics anxiety. The groups were then ordered in terms of the mean, the medians and the ranges in terms of levels of mathematics anxiety.

Table 5. 8 Mixed Attainment Groups ordered by mean, median and range.

Mixed attainment	**Mean**	**Median**	**Range**
Set 2b	26.29	25.5	31
Set Y-Ma2b	26.39	25.5	25
Set 2c	26.50	25.5	29
Set 2a	26.90	27	27
Set Y2a	29.04	29	30
Set 2d	31.68	33	26

Which gives the following scatterplot:

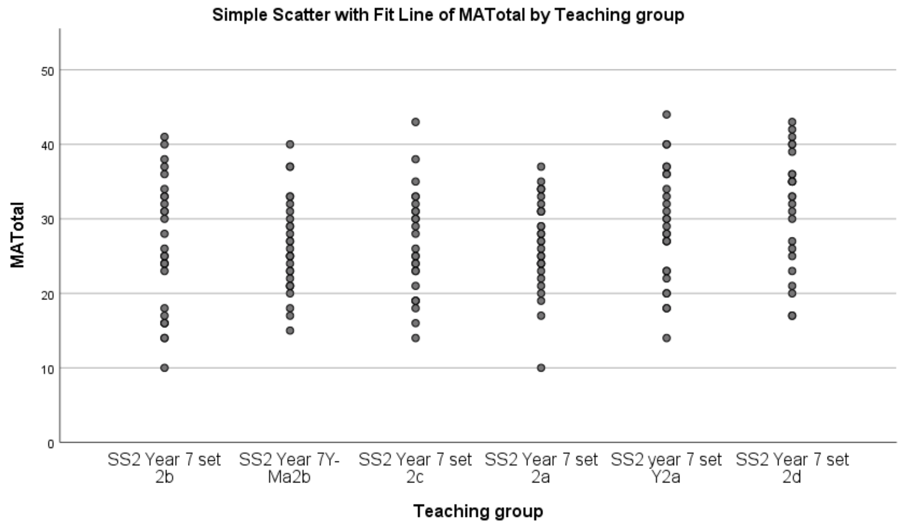


Figure 5. 9 Mathematics anxiety by teaching group (revised)

Although a relationship was suggested between teaching group and mathematics anxiety, a simple linear regression found the relationship not to be significant.

5.2.5 Section Summary

There is a significant relationship between the levels of mathematics anxiety in the participants and both their previous attainment and their gender, but not their teaching group. Previous attainment accounts for 9.3% of the variation and gender accounts for 1.5% of the variation in mathematics anxiety. To find out how these two factors combine in accounting for mathematics anxiety, it is necessary to conduct a multiple regression.

5.3 Multiple Regression Analysis

It was established that there is no relationship between teaching group and mathematics anxiety, so this grouping was omitted from the multiple regression analysis. The multiple regression was conducted using previous attainment and gender as the related factors. The analysis was conducted on all participants, as omitting teaching groups because of setting confounders was not required. KS2 SATs was entered before Gender.

Table 5. 8 Multiple Regression Output

Correlations				
		MATotal	KS2_Sats	Gender
Pearson Correlation	MATotal	1.000	-.313	-.135
	KS2_Sats	-.313	1.000	-.008
	Gender	-.135	-.008	1.000
Sig. (1-tailed)	MATotal	.	.000	.025
	KS2_Sats	.000	.	.455
	Gender	.025	.455	.
N	MATotal	212	212	212
	KS2_Sats	212	212	212
	Gender	212	212	212

Table 5.8 shows that mathematics anxiety is negatively correlated with both previous attainment, $p<.001$, and gender, $p<.05$.

Table 5. 9 Multiple Regression SPSS Output

Coefficients						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
	(Constant)	65.299	7.555		8.643	.000
	KS2_Sats	-.343	.071	-.314	-4.825	.000
	Gender	-2.135	1.009	-.138	-2.117	.035
a. Dependent Variable: MATotal						

Table 5.9 suggests that the variance in mathematics anxiety predicted by previous attainment is -0.31 and the variance in mathematics anxiety predicted by gender is -0.14. The relationship between mathematics anxiety, previous attainment and gender can be expressed as follows:

Table 5. 9 Change statistics

				Change Statistics				
R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
.343[a]	.118	.109	7.034	.118	13.688	2	205	.000

$MA = 65.23 – (0.31 \times PA) - (0.14 \times G)$, where MA represents mathematics anxiety, PA represents previous attainment (KS2 SATs score) and G represents gender.

5.4 Implications

Whilst the findings are significant, they only account for a relatively small amount of variation. In other words, using previous attainment as a measure as a proxy for current mathematical ability, it cannot be assumed that mathematical ability heavily influences, or causes mathematics anxiety. Equally, it cannot be assumed that girls are much more prone to mathematics anxiety than boys, as this has a relatively small correlation with mathematics anxiety at this age.

5.5 CHAPTER SUMMARY

The cohort involved in the research can be regarded as representative of year-7 pupils in a typical English secondary school. They reported an expected range and distribution of Key Stage 2 mathematics test scores, with an average that was slightly higher than the national average.

Whilst 55% of the group demonstrated low levels of mathematics anxiety, 20% demonstrated moderate levels and 25% demonstrated high levels of mathematics anxiety. More female pupils reported higher levels of mathematics anxiety than their male counterparts, a finding that was statistically significant. A negative correlation was found between reported attainment and mathematics anxiety level, a relationship that was found to be statistically significant. However, it was noted that it cannot be assumed that mathematical ability heavily influences, or causes mathematics anxiety, or that girls are much more prone to mathematics anxiety than boys, as this has a relatively small correlation with mathematics anxiety at this age.

The next chapter will display the findings from the second stage of the research, where qualitative findings were gathered. The subsequent chapter will discuss both qualitative and quantitative findings, comparing them to expectations from the literature, evaluating them and identifying gaps.

CHAPTER 6 DESIGN-BASED RESEARCH FINDINGS

6.0 INTRODUCTION

This chapter reports on the Design-Based Research (DBR) aspect of the thesis. It proved to be challenging to report on the DBR process, as I felt that there were so many stories to tell. McKenney and Reeves (2012) recommend a focus on the scope of the research to be reported, then refining the message, and finally illustrating the report with ‘inspiring examples’ (2012: 207). This contrasts with Collins’ advice (2004: 39) that it is ‘necessary to describe each phase’. I began by attempting to follow Collins by describing each iteration, identifying the critical elements, describing the settings, stating the changes I made, the reasons behind those changes, the effects of the changes, the general outcomes and the lessons learned. However, this proved to be indigestible reading. I have therefore chosen an account that is more in line with McKenney and Reeves (ibid.), with the intention to provide interesting reading whilst still meeting the standards of the thesis for transparent research. Where possible, I add information about the process without disrupting the flow of the narrative.

The scope of this chapter is a description of the development of self-efficacy, the awareness of emotions and then management of emotions in the learners through an intervention which was progressively revised through three iterations. I refine the message by addressing each of these three aspects in separate sections. Each section describes the Design-Based Research process for that particular aspect, provides examples which both inspire and demonstrate impact and analyses the process. The original conception of the intervention proved to be relatively successful, and the adaptations which ensued throughout the process were fewer than expected. These adaptations were generated through the reflection which was guided by the Design-based Research – Cycle Review template which I created for this purpose (see Appendix 4.3). These reviews generated the outcomes which are described and explained in this chapter and are evidenced through reference to my field notes and transcriptions of specific clinical interviews. Table 6.1 describes the changes I made in cycles two and three. These changes will be explained in more detail in later sections of this chapter.

Table 6. 1 Changes Made in Cycles Two and Three

Cycle	**Changes made from previous cycle**	**References**
2	Terminology of HMB changed from 'brain flip' to 'freeze', 'blank' and 'un-blank'	Section 6.1.5, page 143
	Maths Toolkit provided to all learners in the first clinical interview	Section 6.2.5, page 153
	Refinement of clinical interview to 20-30 minutes	Section 6.5.1, page 171
3	Number of sessions reduced from 3 to 2	Section 6.5.1, page 170
Future interventions	Consider timings in the school year – avoid late summer term.	Section 6.5.1, page 172
	Be prepared to provide more than two clinical interviews to those learners who need it	Section 6.5.2, page 176

6.1 DEVELOPING SELF-EFFICACY

6.1.0 Introduction

A lack of self-efficacy (Bandura,1994) is recognised as a causal factor in mathematics anxiety, as noted in chapter three. To recap, self-efficacy is the perception of the learner around their ability to succeed at a particular challenge. In the context of learning mathematics, if the learner compares the challenge of completing a task, or understanding a concept, against their perception of how able they are to succeed, and the result is that their perceived ability does not meet the needs of the activity, then their self-efficacy will be low. I predicted that the self-efficacy of my learners in terms of learning mathematics would be low.

I assessed the self-efficacy of the learners by asking them about their feelings around previous mathematical experiences in the first clinical interview. As self-efficacy is the perceived ability of the individual to complete a specific task rather than a general feeling of competence around a subject, it can be argued that it would have been better to give the learners a specific task to attempt and ask them about their feelings regarding that task. However, as I was asking them about their feelings around previous mathematical experiences, and those mathematical experiences would have been specifically delineated, I argue that I can describe levels of self-efficacy though their descriptions. It is also arguably less distressing to describe previous feelings of anxiety than to experience fresh feelings of anxiety. However, in future iterations of the intervention, I will reconsider the possibility of presenting a specific task and gathering learner reactions in a manner that would minimise distress.

This section describes my findings about the apparent self-efficacy of the learners towards mathematics. It then describes the process of addressing low self-efficacy and the attempt to develop self- efficacy through the introduction of Siegel's (2010) Hand Model of the Brain (HMB). The section then describes some unexpected outcomes of the HMB before summarising the section.

6.1.1 Did the learners have low self-efficacy in mathematics?

All my learners apart from one (Jack) reported feeling unable to learn at some stage in their mathematical education. However, the learners attributed this inability to learn to various factors. Some learners saw the problem as to do with themselves. Adam described the problem as one of confidence, rather than self-efficacy. The relationship between confidence and self-efficacy is further discussed in chapter eight, but it is worth noting here that learners such as Adam will be familiar with the term 'confidence' and unfamiliar with the term 'self-efficacy'. My interpretation is that Adam means self-efficacy as he is specifically referring to mathematics learning when he says: *'well, I never had, really much confidence in myself even in primary school'* (Adam, Cycle 1, Clinical Interview 1, Line 30 – in future references as C1, CI1, L30)

while Chris described communal confusion during primary school mathematics: *'but then other people in my classes were getting confused as well. So that was kind of like, almost, a queue asking the teacher to help'* (Chris, C1, CI1, L35). Erin also described feeling confused: *'well, in primary school, I, like, didn't get it at all, and I was really confused with everything'* (Erin, C1, CI1, L19). Devon assumed that she lacked ability: *'I was really down, thinking I was really dumb, and I was always like, I'm really dumb'* (Devon, C1, CI3, L192).

Oher learners saw the problem as to do with other factors. Blake described the problem as not having enough time: *'it takes me time to process one method and then by the time I've processed that, I've got another two methods to process. And I just, can't, really, get it in my mind'* (Blake, C1, CI1, L29). Hayden also reported being left behind: *'in primary school I found it, like, hard to catch up'* (Hayden, C2, CI1, L34). Finley was affected by her peers: *'who you're around affects like your maths and stuff'* (Finley, C1, CI1, L39). George also reported being negatively affected by peers because the teacher would: *'explain it in a way only my classmates would understand it, and I don't really understand it because I'm not really like them' (George, C2, CI1, L44)*. Indigo compared her achievements to others and found herself wanting, which made her feel a *'bit annoyed cause I couldn't do as well as the other people'* (Indigo, C2, CI1, L69).

Two learners saw the problem as to do with the nature of mathematics itself. Max had strong feelings about mathematics: *'I don't really like maths. Cause it's like really difficult.'* (Max, C3, CI1, L32). Lynden perhaps described his feeling about mathematics most eloquently when he said: *'I don't really, uh, like how difficult it is and why and who, whoever made maths or thought of it had to think of it as such a difficult specimen … why they had to make it so hard… and give me a living hell.'* (Lynden, C3, CI1, L35).

Although the learners (apart from Jack) all described feelings of low self-efficacy when learning mathematics, they variously attributed this low self-efficacy to their personal characteristics, their circumstances or the nature of mathematics itself.

Having established the presence of low self-efficacy for mathematics learning in these particular learners, the next step was to attempt to increase their self-efficacy.

6.1.2 Process of developing self-efficacy

I began the process of developing self-efficacy in the learners by re-educating them about the way the brain learns. I explained that recent developments in medical technology such as functional magnetic resonance imagining (fMRI) has enabled scientists to challenge previously held beliefs about how the brain learns. I hoped that the process of sharing these new understandings with learners would help them appreciate that mathematics is not a talent of the elite but a subject open to all learners. I emphasised that everyone can learn mathematics, albeit in different ways and speeds. This view is explained in chapters two and three.

I shared Siegel's (2010) Hand Model of the Brain with the learners to explain that the brain responds automatically to protect against perceived threat with the fight, flight or freeze response (Dhabhar, 2018). To make this automatic response more understandable to learners, Siegal describes each hand formed as a fist as representing one half of a brain. The thumb folded over the palm represents the limbic system, the emotional centre, which takes over in fight, flight or freeze situations. When the fingers are folded over the thumb, they represent the cortex, the cognitive centre, which becomes disconnected in fight, flight or freeze responses. I shared this model with the learners and explained that learning mathematics can trigger a fight, flight or freeze response, as the possibility of failing, being left behind the rest of the class or being ridiculed or reprimanded presents as a very real threat to emotional well-being (Foley et al., 2017). Once the cognitive centre has disconnected and the emotional centre has taken control, the individual will stop thinking clearly, and can feel ‘dumb’ or confused. These are experiences that Devon, Chris and Erin described above.

The Hand Model of the Brain is a very portable and effective reminder that the cognitive centre, or ‘thinking brain’ as Siegel describes it, can be reconnected through the recovery response, which is explored below.

6.1.3 Did it work?

The Hand Model of the Brain proved to be effective in changing learner preconceptions about their mathematics ability, although the terminology involved changed in cycle two, as will be discussed below. The learners found the Hand Model of the Brain to be a helpful reminder that the feeling of being confused, or not being able to think, was a temporary state and that they could reconnect their thinking brain. Hayden explained that *‘it helps me understand what goes on inside my brain. And like, um, like what happens when you get, like, anxious.’ (Hayden, C2, CI2, L165)* whilst Chris explained the process of disconnection, adding that she now knew how to reconnect her thinking brain: *‘cause when I don’t understand it, that’s when my brain freezes’ – and ‘when my brain freezes, I now know how to get it back, and be able to carry on with my work’.* (Chris, C1, CI3, L199).

Erin appreciated the convenience of the model. After explaining the model to her, I asked if the Hand Model of the Brain would help, and she replied: *‘yeah, because my hand’s right in front of me’.* (Erin, C1, CI1, L170). Blake also appreciated the convenience of the model. He described how he used it in mathematics lessons by repeating the representation of the brain ‘flipping’. He explained that he *‘knew in my* *head it was flipping back and forth* [whilst flipping his hand underneath the table] *and I was just reminding myself that it's just the brain'* (Blake, C1, CI2, L63).

Devon described the change in her perceptions of her ability: *'the hand model of the brain, cause then it sort of made more sense and you could like, understand why you get anxious, so then you could think about it and think, oh no, it's not because I'm dumb, and like everyone is like it sometimes, but it's just that, like some people would be like it in English, but I'm not like it in English. Some people won't be like it in maths but I'm like it in maths. So like everyone has it in some subject or something. So like it helps you, like think that you're not dumb, you just need like, more help to like, encourage you and, like, get you like going and like on maths… if that makes sense.'* (Devon, C1, CI3, L260). Devon shared the model with her mother and explained that they both felt that they understood what was happening inside Devon's brain. Interestingly, her language changed. Initially when describing her feelings about mathematics, she had used terminology such as 'dumb' that implied a permanent state of being. However, once she had been introduced to the hand model of the brain and had learned that her feelings of inadequacy were a temporary protective response, her chosen words reflected implications of impermanence and reversibility. Her new terminology contained words such as '*blank and freak out'*. This is very different from the permanent label of being 'dumb': *'And I said about that you said that the brain flips and about the emotions and stuff. I think it sort of made more sense why I do blank and freak out a bit.'* (Devon, C1, CI2, L88).

6.1.4 Surprising Outcomes of the Hand Model of the Brain

Many of the learners moved from terminology which described the response as a brain 'flip' to a brain 'freeze', or in Chris's case, 'semi-frozen': '*So last lesson, whenever it was, … it was like semi frozen' (Chris, C1, CI2, L61)*. Other learners described the disconnection as their brains going 'blank'. *'You think that's why you blank sometimes, and you get scared, when you see the big number. [Then you can] un-blank your brain and carry on doing it, like understand that it's not that hard'* (Devon, C1, CI2, L98). I decided to adopt these terms in the later cycles as they seemed to be more meaningful to the learners.

One of the learners saw the HMB as a useful tool to counteract negative internal narratives: *'My brain's trying to sabotage me, thinking you're doing it wrong or the teacher's staring at you. He's like 'oh, she's definitely getting them all wrong', all this badness, and yeah…it's just like, saying, oh you're gonna get it wrong, oh, you're gonna get it wrong, and then that breathing thing and the, [Erin demonstrates the HMB] …Yeah, kind of just like, maybe think oh, he's probably looking at the person next to me that's talking to everyone, like, he's probably thinking, oh, she looks worried I'll see if she's ok'* (Erin, C1, CI2, L131).

6.1.5 Section Summary

I therefore concluded that the Hand Model of the Brain was an effective tool in addressing the self-efficacy of the learners. The tool was refined for cycles two and three by adapting the terminology of 'brain flip' to 'blank/un-blank' and 'freeze', terms which the learners themselves used. This tool represented the explanations I had given which described the process of the brain.

6.2 DEVELOPING EMOTIONAL AWARENESS

6.2.0 Introduction

Once I had addressed the self-efficacy of the learners and encouraged them to believe that they were capable of learning mathematics, I then wanted to help the learners develop the ability to evaluate their emotional state. I used the Growth Zone Model (Johnston-Wilder & Lee, 2010), as described in chapter 3. The first step in introducing the model was to explain the different zones to the learners. I described the comfort zone as a state where the learners might feel safe and secure and would not encounter challenges. I then described the growth zone as a state where learners might feel a little unsure and nervous, but that they could also feel challenged, interested and excited. Finally, I described the anxiety zone as a state where learners might feel panic and fear.

In this section I will explain the process of informing the learners of the Growth Zone Model, and how I checked that they understood. I then explain the technology I used to allow the learners to share their experiences of the Growth Zone Model, which was an application on an iPad, described in Appendix 4.4. I then present data pertaining to each zone. At the end of the section, I introduce an alternative method of recording which zone the learner is in, before summarising the section. The two alternative methods of identifying learner zone will be explored in more detail in a later section of this chapter.

6.2.1 Learners describe the zones and how they feel in them

In order to ensure that my explanations had been meaningful for the learners, in each phase of the design, I asked them to describe the three different zones involved in the

Growth Zone Model in the second clinical interview, a week after they had first been introduced to it. They all remembered the key elements of the model: *'Well comfort zone is if you're… easy but it's boring. The growth is if you're learning, but you're challenging yourself a bit, anxiety is if your brain flips and you don't understand it'.* (Adam, C1, CI2, L30), *'the green bit's where you like… you don't find it challenging, it's like really easy, and then the growth is where you like, learning, like it's challenging but not too challenging, and not too easy. And then the anxiety is where you, like, you don't get it and it's completely challenging. You don't get it'* (Devon, C1, CI2, L18), *'comfort is where it's like, comfortable, and then growth's where you're comfortable but also learning and anxiety's like, don't understand it'* (Erin, C1, CI2, L56).

When faced with the Growth Zone Model, an understandable initial assumption would be that the comfort zone is the most advantageous zone to be in. However as was explained in chapter three, the comfort zone is not the best zone for learning, as it does not encourage the challenging stretch that is required for optimal learning (Johnson-Wilder & Lee, 2017). I wanted to make sure that the learners understood this and realised that the optimal zone for learning was the growth zone. I also wanted to ensure that the learners understood that the growth zone was not necessarily a comfortable place to be, but that that was not necessarily a bad thing. From their descriptions of the comfort zone and the growth zone, I felt that the learners had a good enough understanding of the characteristics of the zone to proceed. The approach of explaining the Growth Zone Model remained consistent throughout all three cycles, although I became more proficient at explaining the model as I became more experienced through assessing the responses of the learners.

The fact that some learners such as Erin described the comfort zone as 'comfortable' did not necessarily indicate that that they understood that it was not the best place for learning, however as she then described the growth zone as 'comfortable but also learning' indicated to me that she understood enough to proceed. I will now share evidence of the learners describing themselves in each of the zones.

6.2.2 Emotions Experienced in the comfort zone

When asked in their first clinical interview about their usual experience of learning mathematics in terms of the Growth Zone Model, two of the learners described themselves as being mainly in the comfort zone. They both justified this in terms of a lack of challenge. Finley describes 'going over the things I've already done' and Jack explained that 'if it's easy, it's just writing down the same thing, not actually learning'.

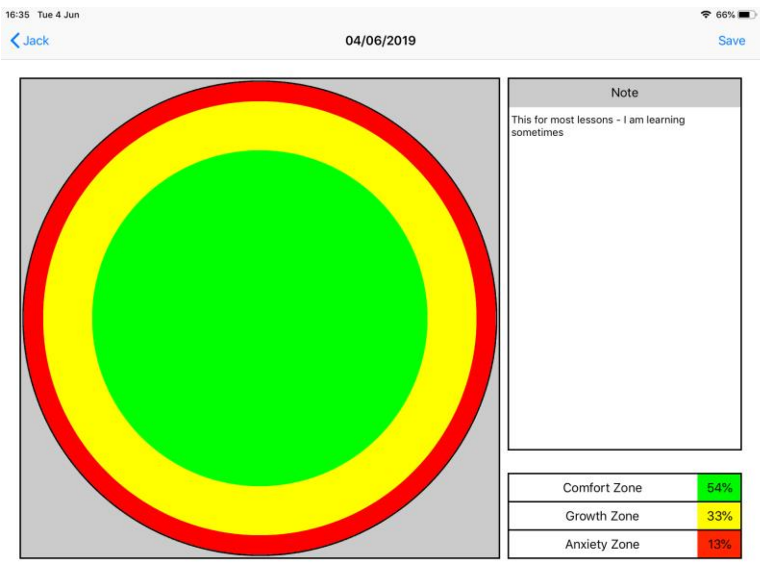


Figure 6. 1 Jack, Cycle 2, Clinical Interview 1

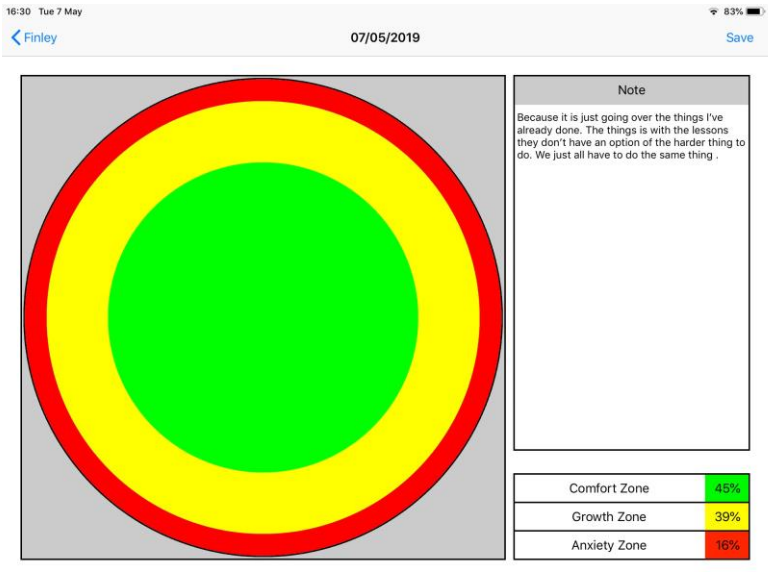


Figure 6. 2 Finley, Cycle 1, Clinical Interview 1

These learners showed a good understanding of the intended meaning of the comfort zone, although arguably not a very satisfactory or challenging experience of learning mathematics. Other learners described feeling mostly in the comfort zone, when they possibly meant the growth zone. Erin describes the pressure she felt in a mathematics test declining, to the point where she felt that she could still proceed with the test. This is not the intended meaning of the comfort zone, although there is a difference between performing in a test and practising to learn.

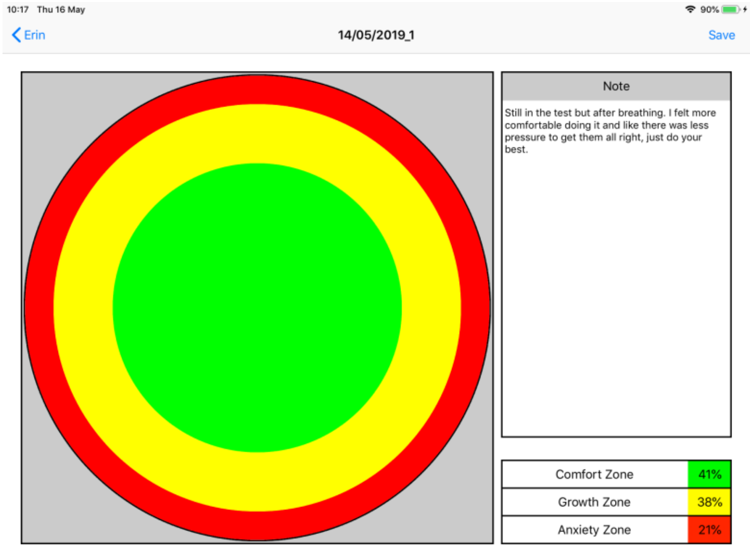


Figure 6. 3 Erin, Cycle 1, Clinical Interview 2

Here Blake explains that he could understand the mathematics, and as he therefore felt comfortable about the learning situation, he described himself as mainly in the comfort zone.

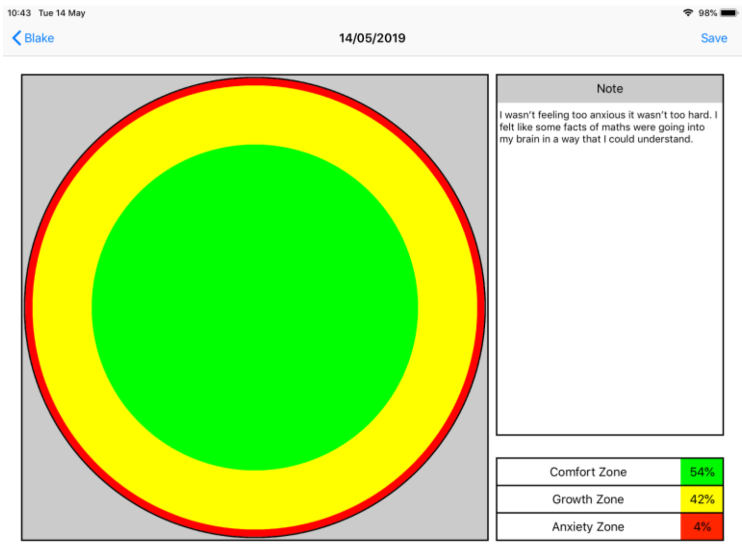


Figure 6. 4 Blake, Cycle 1, Clinical Interview 2

Devon explains how she felt after a test. She had time to check her answers and she felt confident because she felt that she had got them mostly right.

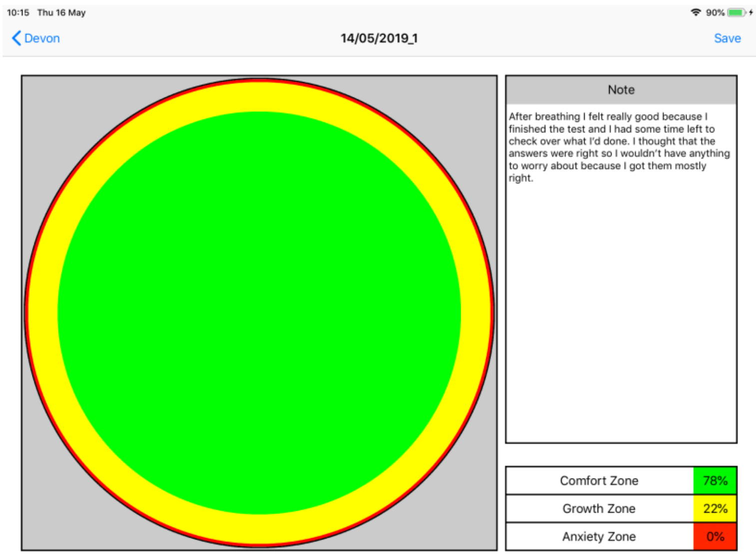


Figure 6. 5 Devon, Cycle 1, Clinical Interview 2

6.2.3 Emotions Experienced in the growth zone

Adam shows that he understands the definition of the growth zone because he describes himself as mostly learning.

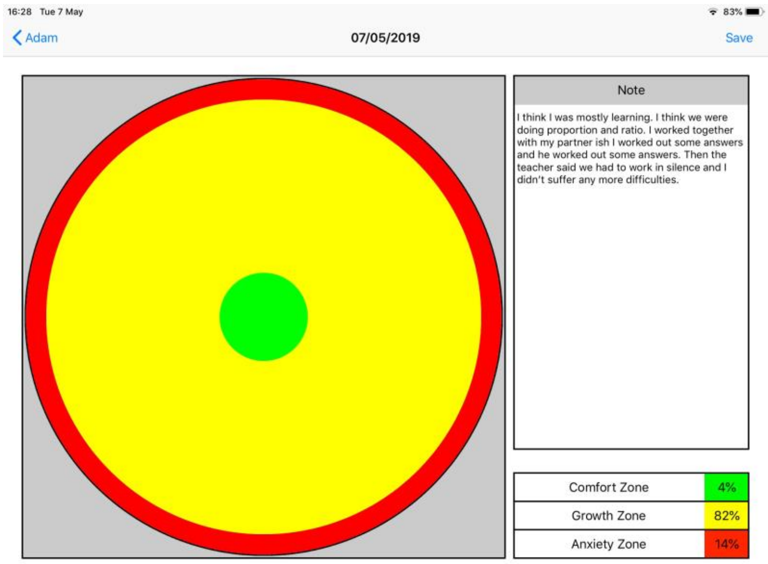


Figure 6. 6 Adam, Cycle 1, Clinical Interview 1

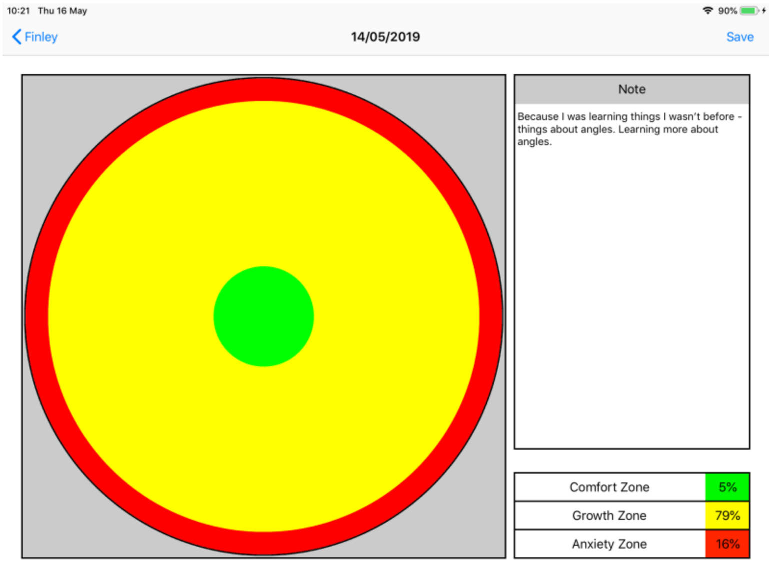


Figure 6. 7 Finley, Cycle 1, Clinical Interview 2

The week after her comments about not being challenged in the comfort zone, Finley now describes the experience of being in the growth zone as 'learning things I wasn't before'. This further supports the conclusion that Finley understands the zones.

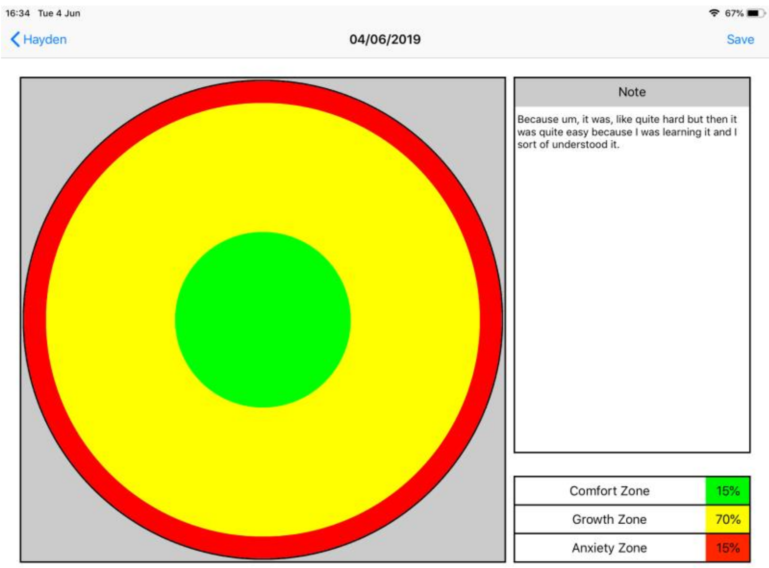


Figure 6. 8 Hayden, Cycle 2, Clinical Interview 1

Hayden's comments about being in the growth zone are very interesting. She explains that she felt she was learning, and that she understood the concepts. Additionally, she explains that while the challenge appeared to initially be 'quite hard', once she had grasped the concept it then appeared to be 'quite easy'.

6.2.4 Emotions Experienced in the anxiety zone

The images which follow clearly show that the learners understand the nature of the anxiety zone. Indeed, their justifications are distressing to read. Blake describes feeling anxious because he felt he 'couldn't process it'.

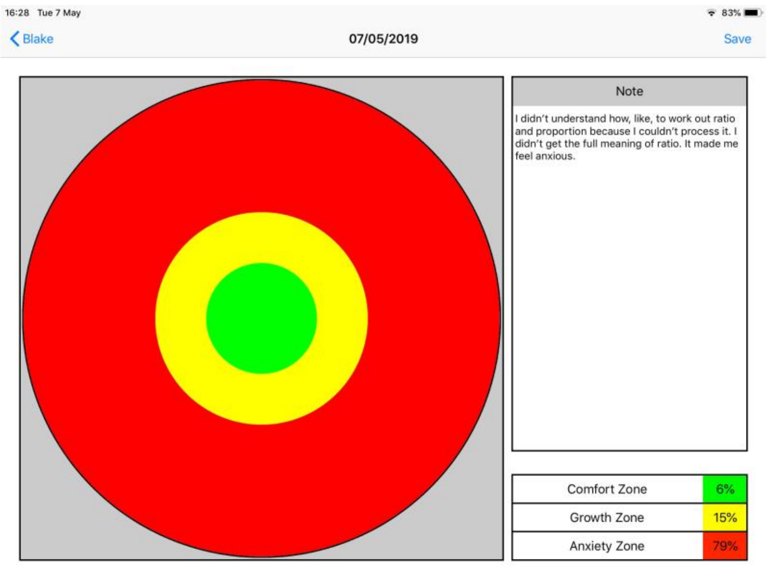


Figure 6. 9 Blake, Cycle 1, Clinical Interview 1

Erin describes feeling angry, both at the homework task and at herself for not understanding.

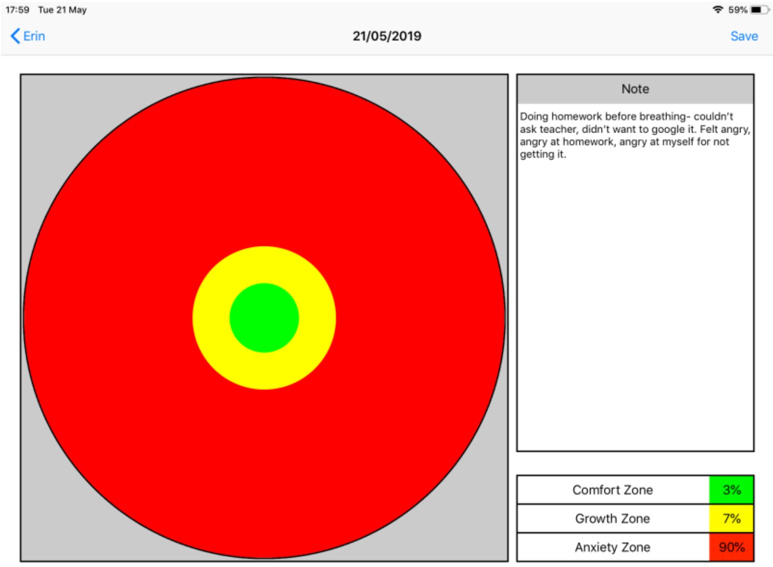


Figure 6. 10 Erin, Cycle 1, Clinical Interview 3

And George describes feeling frustrated, being told off for not understanding, and ending up being stuck.

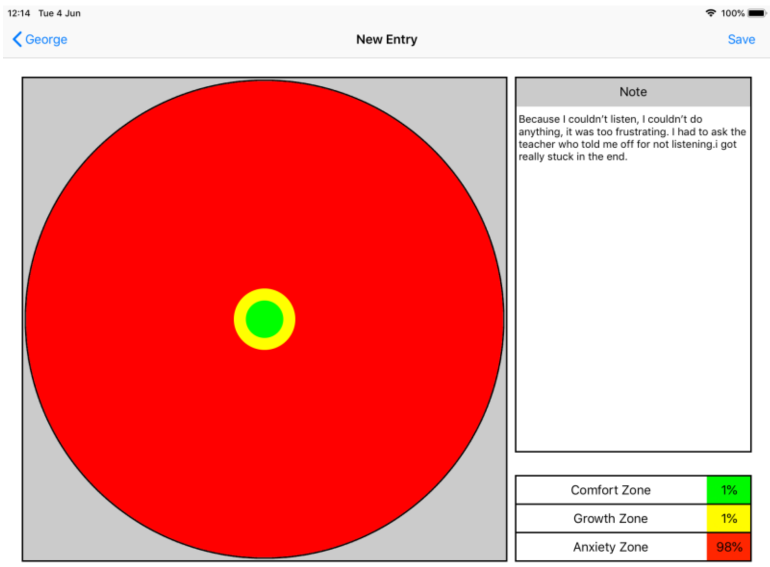


Figure 6. 11 George, Cycle 2, Clinical Interview 1

6.2.5 Developing the Mathematics Anxiety Toolkit

The app was a very helpful tool to allow the learners to share descriptions around their awareness of emotional state. It was particularly valuable as a review tool to be used with a coach or researcher. However, the learners could not use the app in lessons as their school has a ‘no mobile’ policy. Additionally, the needs for emotional awareness in the process of the lesson rather than as a review are rather different. After discussion with the learners, and prompted by my noticing that several of the learners carried papers from previous clinical interviews around with them and seemed to find that useful, in the second cycle of the DBR process I provided the learners with a physical toolkit that included a representation of the Growth Zone Model. This consisted of a small, zipped plastic pouch that would fit in a blazer pocket.

Figure 6. 12 Pouch for the Maths Toolkit

Inside the pouch I put four laminated cards, and a glass pebble. The first card contained a reminder of the Hand Model of the Brain and was intended to remind the learners that brain freeze or the brain going blank was temporary, and that they could reconnect their thinking brain.

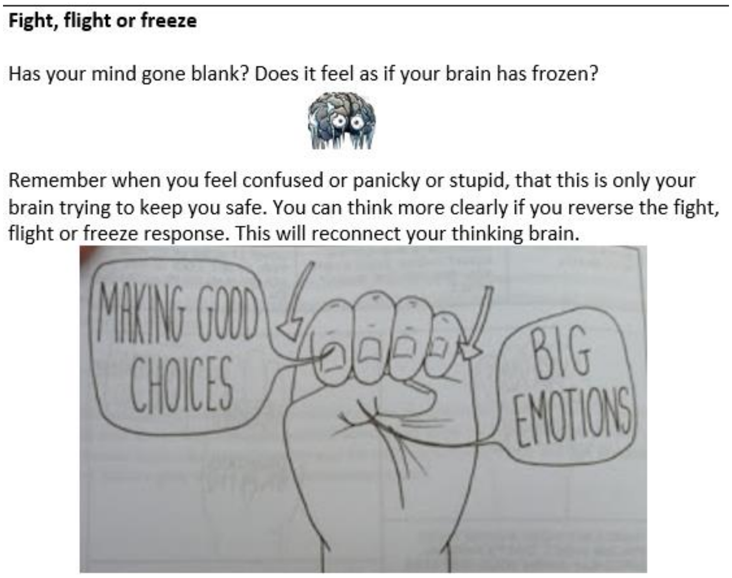


Figure 6. 13 HMB Card in Maths Toolkit

The glass pebble could be used with the GZM card, to allow the learner to indicate their current emotional zone placement to themselves (and possibly to a teacher, as Lynden did).

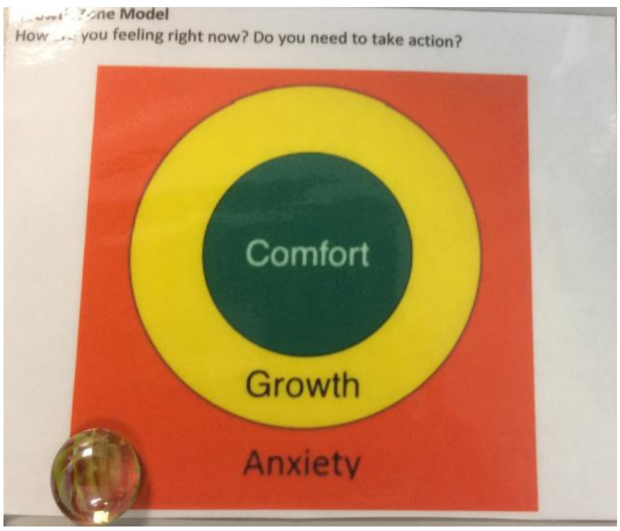


Figure 6. 14 GZM and pebble - Maths Toolkit

'the way I use it is I put this on the table. I've told Miss about it. And I put the pebble wherever I am in the lesson, and so she can analyse it and give me the correct … treatment, can I say?' (Lynden, C3, CI2, L35).

6.2.6 Section summary

This section has described the tools developed and used in the intervention to support the learners in their development of emotional awareness. All the learners found the Growth Zone Model as mediated through the app and the maths toolkit to be accessible and helpful, as demonstrated through their understanding of each of the zones. The growth app was a useful tool for the clinical interviews but did not transfer to the classroom. The maths Toolkit was therefore developed, with the intention that learners would keep it in their blazer pocket and refer to it when they needed it. The learners were now in a position to recognise their emotions, so the next stage of the clinical interview was to support them to take appropriate action to manage their emotions when needed.

6.3 DEVELOPING EMOTIONAL REGULATION

6.3.0 Introduction

In this section, the role of the Growth Zone Model in the process of regulating the emotions are further explored. Then, the active involvement in the learner in the process of moving from the anxiety zone to the growth zone is explored, in order to show learners how to reconnect their thinking brains. This process can be achieved in various ways, and so the tools which were shared with the learners in the clinical interviews are explained and evaluated. The main tool for recovering from the anxiety zone and moving into the growth zone used was Benson's (1975) recovery response.

This is described, and the learners' responses evaluated. As not all learners feel comfortable when focusing on breathing, alternative methods emerged during the DBR process, and these are also described.

6.3.1 How the Growth Zone Model helps

The first and necessary stage of emotional regulation is for the learners to become aware of the need for emotional regulation. This is achieved through the Growth Zone Model, where learners are prompted to take time to self-evaluate and identify their current emotional state. Lynden was very proactive in finding a way to both evaluate his emotional state and share it with his teacher, as has been shown in the previous section. Lynden gave a further example of a lesson that placed him in the anxiety zone: *'We were doing, uh, graphs, stuff with like y equals something and, um, we're doing symmetry… uh, reflection, but I didn't… but miss… miss explained that has something to do with reflection. I was like, whoa! I had no idea.' (Lynden, C3, CI2, L218).*

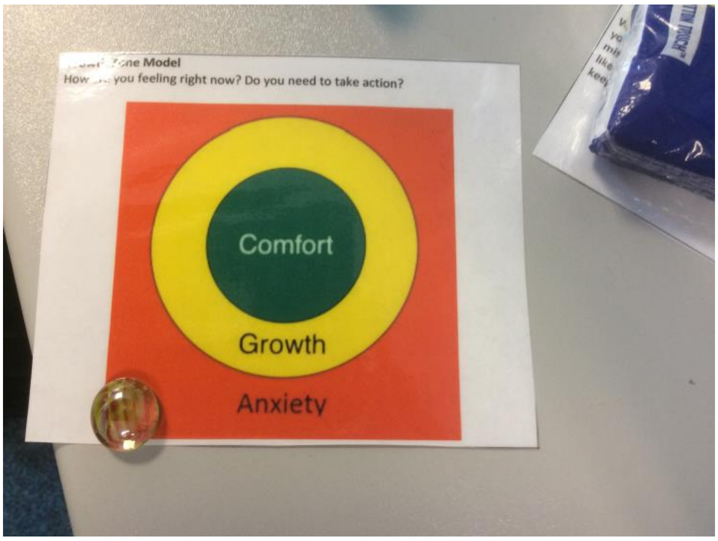


Figure 6. 15 Lynden's representation of his emotional state on the GZM.

And he used the Growth Zone Model to demonstrate his feelings by placing the pebble at the edge of the zone. Max describes a lesson and her subsequent emotional state:

Max: *We had like a double lesson and we have a lesson [one] after the other but with a different teacher. And we're like learning about different things and it just makes me really confused.*

Janet: *If you're the pebble, where would you put yourself on the growth zone [model] for that maths lesson?*

Max: *Probably in like the anxiety zone.* (Max, C3, CI1, L165)

Kelsey used the grOwth app to variously describe being in first the anxiety zone, and then the growth zone: *'Well sometimes, um, I don't know really. It just… just sometimes I feel like, that I can't do it. And I stress. And make myself upset. But sometimes I feel like there's something in my brain that will switch. So I will know when to learn'* (Kelsey, C2, CI, L170).

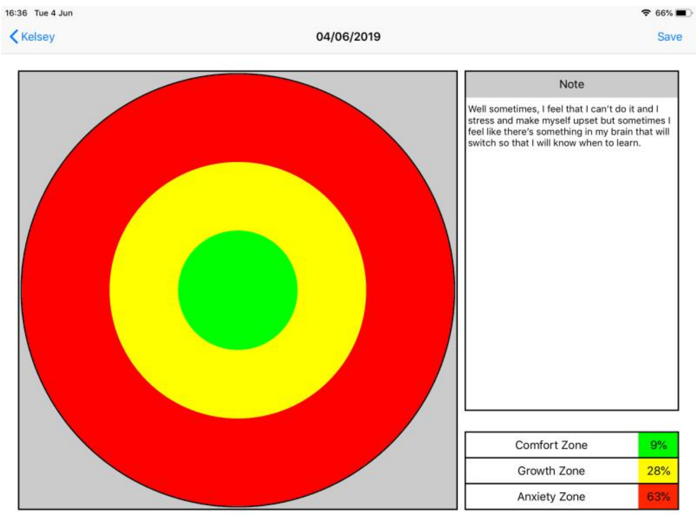


Figure 6. 16 Kelsey's emotional state on the grOwth app.

For all these learners, once the red zone was recognised, they could then take action. However, the ability to take action depends on various factors, as will be explored in the next sub section.

6.3.2 Moving from Anxiety to Growth

In order to move from the anxiety zone to the growth zone, the intervention assumed the importance of the learners taking the appropriate action from their own volition rather than depending on the 'treatment' of others. However, the ability to do this depends on the learner having agency and a growth mindset, as described in chapter 2. A sense of agency will give the learner the opportunity and permission to take action, while a growth mindset will enable their belief that the action will have a beneficial impact on their learning. Taking action to regulate their emotions may also require perseverance, as, like many skills, the benefits of emotional regulation may not be immediately apparent. The process of encouraging agency, a growth mindset and perseverance were included in the clinical interviews and described above. Once this was judged to be in place for each learner, then the next stage of sharing the tolls to regulate emotions could be delivered.

Benson (1975) developed a strategy to reduce tension and anxiety. The description of how he found this strategy, originally a way to reduce high blood pressure, can be found in chapter two. I shared this strategy with the learners as a tool to reduce anxiety once they had realised that they were in the anxiety zone; for the purposes of the intervention, I called it 5/7 breathing. To move back from the anxiety zone to the growth zone, or to the comfort zone to recover, I asked the learners to breathe in steadily for a count of 5 then breathe out to a count of 7. I then asked them to repeat this as many times as needed, but typically for between five and ten breaths, which would take no more than a minute or two. I emphasised the classroom-friendly nature of this strategy by explaining to the learners that no one would notice them taking a minute to focus on their breathing. My intention was to encourage their sense of agency so that they would feel more able to take responsibility for the management of their emotions.

To remind them of the strategy, a 'Rest and Recover' card was included in their Maths Toolkit (see below).

Rest and Recover

To reconnect your thinking brain, try 5/7 breathing. Breathe in while you count to 5, and out while you count to 7. Do this again and again until you start to feel calm.

Figure 6. 17 Rest and Recover Card

Most of the learners found this breathing strategy to be beneficial: *'I did the breathing, and that helped'* (Chris, C1, CI2, L34). *'I didn't understand this question, I was like, 'I'm feeling a bit…' and I was thinking 'ok, so I think the anxiety bit's like massive, so I should start breathing'. Well, it like calmed me down, and then I was kind of like trying to look out the window and ignore the maths for like a couple of minutes and then I was like… I felt like calm enough to work but not calm enough that I'm about to fall asleep, I went back'* (Erin, C1, CI2, L31). *'I probably, well, to breathe in and out. Kept myself calm'* (Kelsey, C2, CI2, L72).

Here Chris, Erin and Kelsey describe effective deployment of the 5/7 breathing strategy. Importantly, they are able to do so as they have the agency to take proactive action, rather than depending on an adult such as their teacher or me to do it. Therefore the 5/7 breathing strategy proved to be efficacious in adjusting (as Erin describes) and maintaining (as Kelsey describes) emotional regulation.

Erin also reported that the 5/7 breathing strategy was useful in out-of-school situations: *'Well, I was doing my homework like, I don't know, a couple of days ago and I got really confused. I had like a little panic attack. I was like, I can't do it. And then I did like the breathing thing and, like, cause normally it's just a little bit I don't understand, and it helps, but I was like, wow, it really really works. Cause I was like so confused I was like crying and I was having a fit and I was throwing things and I was like, oh, I could do the breathing thing. And then it worked, and I was like, ok.'* (Erin, C1, CI3, L16). Having the presence of mind to remember to 'do the breathing thing' in the middle of a 'little panic attack', whilst at home rather than in a school setting, was an unexpectedly high level of emotional awareness and agency.

The learners identified that the strategy could be useful in other situations. Erin described how she would use the tool more widely: *'if I just feel like I don't want to do something, or I'm worried that people will stare at me, because on non-school uniform days I hate it, because everyone is wearing different things, and I'm like 'they're going to judge you for what you're wearing' and then, in school I'm like 'I should have worn this or worn that' that will probably help then because I can think [breathing out heavily] it doesn't matter'* (Erin, C1, CI1, L182).

The 5/7 breathing response proved to be manageable in classroom settings, efficacious to reduce anxiety and transferable to other situations. However not all learners were comfortable with focusing on their breathing, so other strategies were developed, as will be described next.

Some learners don't like focusing on their breath – prior to the research, I had become aware of this through my neurodiverse daughter becoming very uncomfortable when focusing on her breathing. So I was determined to allow and even encourage other calming tools. I suggested similar micro-mindfulness techniques, such as focusing on the senses (close eyes and listen for 5 things, look out of the window, feel the tension draining through your feet, etc) but the most helpful alternative calming technique serendipitously presented itself in the first DBR cycle as part of a task I adapted from one designed by Boaler (2016) to encourage learners to understand that mistakes are beneficial. I called this the 'Scrumple task'.

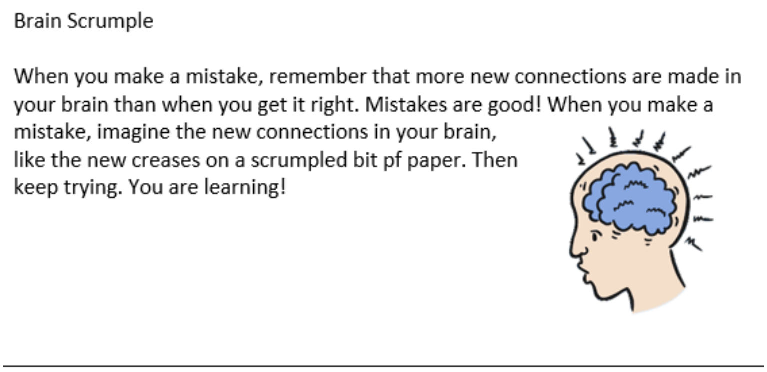


Figure 6. 18 Scrumple Task Instructions

Several of the learners, including Blake, independently decided to continue filling in the lines, as they found this to be a calming activity: *'I used the scrunched-up paper and I managed to do every crease after a few lessons, so I put it in the bin. And then after a few lessons I started getting nervous again, so I scrunched up* *another piece of paper. It was kind of like, in my mind, I was saying to myself, draw something, and then I tried to draw a reindeer with all the cracks, and it took my mind of it and then it like… kept me calm.'* (Blake, C1, CI3, L14).

Although a focus on the breathing has been found to be clinically effective, (Park et al., 2013) as some learners may not be comfortable with focusing on their breathing, other, classroom appropriate, options need to be available. To encourage the agency of the learners, they could be offered a choice of recovery tools and then select the tool that most appeals to their individual tastes and needs.

6.3.3 Section summary

Once they had become familiar with the Growth Zone Model and were able to identify when they were feeling debilitatingly anxious, the learners needed to have a mechanism for reducing that anxiety. Most of the learners found the breathing strategy to be efficacious, but a few others developed an alternative calming technique for themselves from the brain scrumple task. My approach here was a combination of research-informed information sharing and participant involvement.

6.4 EFFECTIVENESS OF INTERVENTION

6.4.0 Introduction

This section considers the effectiveness of the whole intervention rather than any specific strategy or tool. Section 2 of this chapter detailed the effectiveness of the development of self-efficacy in the learners, and section 3 detailed the effectiveness of sharing the Growth Zone Model. This section is informed by the conversation with each learner in the last clinical interview of their intervention, where I asked them to provide feedback on the most helpful and least helpful aspects of the intervention as a whole.

The section first considers the two main artefacts which were developed and refined as part of the Design Based Research process. These are the Growth Zone Model app, which was initially presented to the learners as a tool for their personal use, but which proved to be unsuitable for classroom use, and the Maths Toolkit, which was developed in place of the app, specifically for personal use in the classroom. The section then presents the outcomes of the overall feedback about the intervention gathered from the learners.

6.4.1 App versus Toolkit

The app and toolkit have been described in previous sections. This section will explore their differing characteristics, to indicate their strengths and weaknesses, and suggest how each tool might be used in the future. The advantages of the toolkit were that it was very portable and convenient, so it could be taken into the classroom and used as part of the learner's desk equipment, as Lynden did: *'I can lay it down and actually physically show the teacher my emotions without having to like say them out loud'* (Lynden, C3, CI2, L210). Here Lynden indicates that a visible indication of his current emotions means that he does not have to voice them, which presumably would be embarrassing. Additionally, the toolkit was relatively cheap to produce, as it consisted of a small pouch and laminated paper. The toolkit was also adaptable, as the learners could add different, helpful additions, as Chris suggested: *'you can just… even put a few fresh pieces of paper and just scrumple them up as well. I think that would help'* (Chris, C1, CI3, L77).

The physical nature of the toolkit, the tangibility, was appreciated by some: *'Because you can mainly, like, pick it up and, like, think and see what you think'* (Kelsey, C2, CI2, L160). Perhaps the best aspect of the toolkit was convenience, in that it was available when required. Learners could carry it in their pocket and, if they realised that they needed it, could access it quickly and without fuss: *'Because I've got it folded up in my pocket'* (Erin, C1, CI3, L136).

However, not all learners found the toolkit helpful. Displaying their current emotional state on their table was a little too obvious for some. Max explained that she would not be happy to display the GZM on the group table, as it was draw attention to her and her emotional state: *'if I got it out, like, whenever I have something, like, everyone on my table, if I have something different, they always say like, oh why have you got that, like what is that, and it just makes me kind of like annoyed'* (Max, C3, CI2, L34). Max also reported that the pack was helpful, but that she preferred to keep it out of sight in her pocket. This was very interesting, as it suggested that Max had quickly internalised the model (Bruner, 1967) and was finding it beneficial without having to display it.

George was the only learner who did not find the toolkit helpful at all. He may have been too anxious to give it a try: *'I had a look at it, but it never really seemed to help me. Because even if I… if something's gonna help me, I wouldn't expect it just to make all those mean people just go away. What I'd expect it to do is that I'd expect it to try and calm me down and make me more confident against those mean people and not make… not enough to make me like fight them or something'* (George, C2, CI3, L89).

George’s words suggest that he needed subsequent clinical interviews to explore the use of the toolkit and more generally, to address his mathematics, and social, anxiety. I arranged further interviews with the school, but when I offered them to George, he declined. It may be that a longer sequence of interviews arranged from the beginning would have been better for him.

Other disadvantages of the toolkit are that it does not record previous data points, so the learners cannot review their overall emotional state. Also, as it is a relatively small piece of equipment, it can be forgotten or lost, as in the case of one learner whose parent washed their blazer and the toolkit was forgotten and left by the washing machine.

In contrast to the maths toolkit, the app has the ability to both capture the emotional state of the learners over a series of data points and record their comments. This means that the learner can view the relative increase in area of their growth zone, as in Finley’s case. Here Finley increased her growth zone by moving out of the comfort zone.

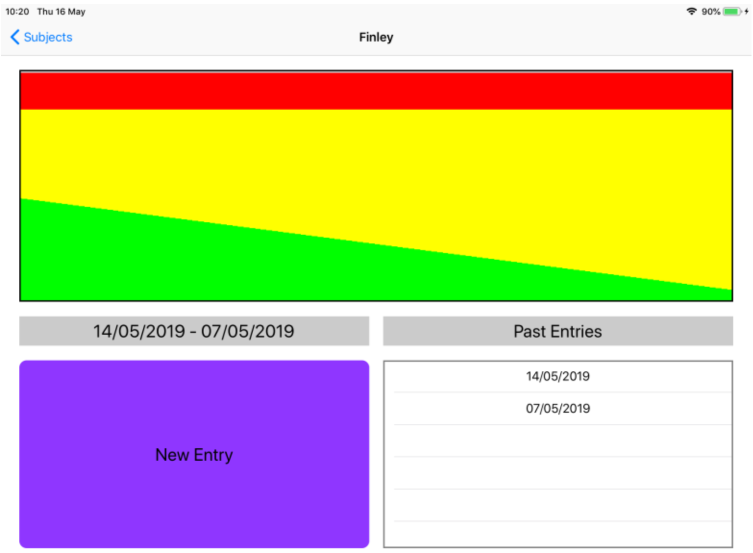


Figure 6. 19 Finley, Cycle 1, Clinical Interview 2

Whereas Blake worked on decreasing the anxiety zone, which as is visible was not a linear route.

Figure 6. 20 Blake, Cycle 1, Clinical Interview 3

Another advantage of the app was that I could retrieve data from a previous clinical interview and share this with the learners, so that they could compare their recent emotional experiences with their previous ones. Additionally, as the app was moveable, the learners could adjust the zones until they were a close representation of their experience, and the visual feedback assisted in this. I could then discuss their representation with them and ask them to justify their decisions.

There were several drawbacks with the app, however. The main drawback was that the school had a ‘no mobile phone’ policy, which meant that my original plan of sharing the app with the learners was not possible. Interestingly, even if a special dispensation could be arranged for the learners, they felt that this would be difficult, as it would single them out form the other pupils in the class: *‘But then it would be just more complicated for them because the other students would moan’* (Hayden, C2, CI2, L179).

Following the experiences of using the app and developing the toolkit, I came to the realisation that both tools had potential benefits. The app would be useful in future research interviews, and potentially in mathematics anxiety coaching interviews, while the toolkit would be beneficial as a personal aid for the learners to use in classrooms and at home, wherever they are faced with mathematical learning situations. As Indigo points out: *‘You can’t really, like, get your phone out and have a look at it. But you can just take a piece of paper out’* (Indigo, C2, CI2, L188).

6.4.2 Overall Outcomes of the Intervention

Once all three Design-Based Research cycles were completed, I was able to identify the benefits of the intervention for the learners. There were seven key benefits, which mirror the intentions of the clinical interviews.

The first benefit is that the learners were able to understand why they might become anxious when learning mathematics, or in mathematics tests. This benefit can be observed in the comments which follow: *'it helps me understand what goes on inside my brain, and what happens when you get anxious'* (Hayden, C2, CI2, L165), *'it helps you think that you're not dumb'* (Devon, C1, CI3, L260). The Hand Model of the Brain (Siegel, 2010) was instrumental in this process: *'they're not just in my head, the back of my mind thinking about it. It's actually in front of me so it's easier'* (Erin, C1, CI3, L126).

The second benefit of the intervention was that the learners were able to increase their awareness of their emotional state, as can be observed by the comments which follow. The Growth Zone Model was instrumental in this process: *'just thought to myself about what zone I'm in a couple of times. I thought a couple of times, well, that's a neuron in my brain connected'* (Adam, C1, CI3, L32), *'you can think about how big the anxiety bit is, how big the growth is, am I learning a lot, or do I need to calm down'* (Erin, C1, CI3, L149),*'it makes me understand more what I'm feeling when I do maths'* (Hayden, C2, CI2, L162).

This increased awareness of emotional state enabled an increase in autonomy, the third benefit, as in the example below where Jack realises what he needs to learn and is then able to request it. *'Cause then you like… say if like you know you're confused … you can ask the teacher'* (Jack, C2, CI2, L284).

Although not all learners found the 5/7 breathing strategy helpful, a fourth benefit was that it was beneficial to many: *'after I'd done the breathing and I was fine again'* (Erin, C1, CI3, L61). Interestingly, it became a backup plan for some, to be held in reserve for when it was needed, or perhaps as a safety net to give extra confidence, as in Devon's case: *'I sort of thought, I don't need to do it anymore'* (Devon, C1, CI3, L298).

The fifth benefit of the intervention was significant in that the mathematics achievement of the learners increased. Hayden and Blake explained what this meant for them: *'I felt like I got onto a lot more questions, by taking my time and trying not to worry as much'* (Hayden, C2, CI2, L26), *'I managed to get onto question… I usually get onto question four or five. I think I got onto question eight or nine'* (Blake, C1, CI3, L32).

The sixth benefit of the intervention was unexpected. I sensed that many learners appreciated the opportunity to share their experiences and feelings about mathematics on a personal basis. This was exemplified by Kelsey: *'Feeling OK, that I've let out what I probably needed to let out what I felt about the test'* (Kelsey, C2, CI2, L186).

The seventh benefit was that the intervention as a whole gave learners an increase in their general level of confidence. Perhaps George expressed this best: *'I feel like I have the courage now to do whatever'* (George, C2, CI3, L283).

These seven benefits were all evaluated as short-term effects, as a limitation of the research design was that a longer-term measure of the impact of the intervention on the mathematics anxiety of the learners was not in place. Thus the data does not provide any evidence about any long-term effects on mathematics anxiety, although this is recommended as a future direction for research.

6.4.3 Section Summary

This section compared the two methods of sharing the Growth Zone Model with the learners and concluded that both the app and the maths toolkit had value, albeit for differing purposes. Used in tandem, with the toolkit for the learner's personal use and the app for clinical interviews, they resulted in an increase in confidence, awareness of emotions and management of emotions by the learners. The future deployment of these tools offers various possibilities, as will be explored in the next section.

6.5 REFINING THE CLINICAL INTERVIEWS AND FUTURE ROLL OUT

6.5.0 Introduction

This section describes the process of refining the clinical interviews, following a Design-Based Research approach. As I explained in the introduction to this chapter, my attempts to follow through the various phases of research, as recommended by Collins, proved rather indigestible. Instead, I have attempted to guide the reader through the main aspects and outcomes of the research. However, some reference should be made to the Design-Based Research process, and I do so here. I explain how the design of the clinical interview structure, the interviews themselves and the tools I used evolved. The second part of the section explores possibilities for future roll-out of the intervention. Any research report may include a possible next steps section, but the difference here is that I consulted the learners and gathered their views about future possible roll-out, so this subsection is placed in this chapter reporting the outcomes of the Design-Based Research.

6.5.1 Refining the Clinical Interviews

The design of the clinical interviews as a unit evolved over time by reducing from three interviews in the first cycle to two. The first cycle involved a series of three clinical interviews. I planned to replicate this in the second cycle but had to cancel the middle interview of the three due to ill-health; unfortunately, I was unwell for the planned date of the second interview and could not deliver it on the date planned. This resulted in a gap of a fortnight between interviews. This demonstrated to me that a gap of a fortnight between interviews is too long; I felt that the momentum had been lost between interviews, and the learners did not remember the strategies I had taught them as well as the first group did. When I met with the learners for their rescheduled second interview, I realised that while a gap of a fortnight was not as beneficial as a gap of a week between interviews, in the second interview itself I was able to cover all the elements originally involved in the third interview. I then decided to try just two interviews in the third cycle and confirm my instinct that two interviews would be adequate for many learners.

The exception to this was George, who had so much to say about his feelings for mathematics, learning in general, the school organisation and his fellow learners, that I needed three clinical interviews to cover the key elements. At the end of the third interview, I still felt that George would benefit from further interviews and arranged with his teacher to release him. However, George declined the offer. On reflection, George may have needed an intervention around wider mental health issues other than just mathematics.

Regarding the timings of the clinical interviews, I felt that I had enough time to talk though all elements of introduction, set the scene, begin to build a relationship in a gentle way and introduce the emotional management tools. I was initially concerned about how the timings would work out, as interviews that were too short would be a waste of everyone's time, and interviews that were too long would not achieve everything I wanted to achieve. I worked out that there will be some variability in timings, as learners respond in more or less detail. For the second cycle, I decided to aim for a interview lasting between 20 and 30 minutes, and to be clear about the essential elements of the interview, as compared to the interesting extras.

Another element of clinical interview design that evolved was recruiting the support and involvement of the learners, I found myself explaining my role as a doctoral researcher and asking the learners to help me in my research. Although this was not in my script, it felt like a natural approach to take from the start, and the learners responded well to it. I decided to add this to the script. In cycles two and three, taking time to recruit the support of the learners as fellow researchers became an integral part of the first interview. I explained that, as I am not in year 7, I can't really do the research in their classes, and ask for their help. It was consistently well received, and their involvement has been enthusiastically given.

The timing of the cycles in terms of the school year is important, as the cycle that I delivered in the second half of the summer term was not as satisfactory. The learners did not seem to be faced with challenging mathematical learning situations so much – when asked about her last maths lesson, for example, Kelsey said that she didn't actually do any maths in the lesson. Perhaps this is not the best time to be delivering this intervention. The third aspect of the interview plan was the emergent need for a physical maths toolkit, which has been fully described above

6.5.2 Future Roll out

When considering the long-term possibilities for implementation of the intervention, I identified three aspects that were key aspects of any future iterations. These were the possible applicability of the interviews to all learners, independently of their current levels of mathematics anxiety, the wider application of the tools outside mathematical learning, and the possibility of delivering the intervention to small groups or class groups.

Regarding the applicability of the interviews to all learners, I felt that the intervention was most useful to those learners who were most anxious, although I strongly felt that '*there was something here for everyone to learn from'* (Field Notes, p40). Adam in particular described an apparent lack of need for the strategies as he felt competent enough and identified as having English as a strength rather than mathematics. By contrast, George was the one learner who, I felt, would benefit from further interviews. This conclusion must however be mediated by the consideration that George may have had other needs that were clouding the efficacy of the intervention. None the less, an extended suite of five or six weekly interviews may have benefited George. Future interventions should consider this possibility and plan to meet the needs of learners who, for various reasons, need more time to embed the tools. George did benefit from the three interviews he received and said that he felt much more confident at the end. I just was not convinced that, amongst all his other concerns, the tools to address mathematics anxiety would be retained by him. These two extremes of need indicate that future iterations of the intervention should consider whether the intervention should be delivered to all learners, or just those with evident levels of mathematics anxiety, and whether the number of interviews should be tailored to the needs of the learners. This would probably require a triage stage before the main implementation.

The second aspect that should be considered in any future implementation is that of the applicability of the intervention to learning other than mathematics, and possibly outside learning situations. Finley applied the tools to a difficult ongoing situation at home (Finley, Cycle 1, Interview 2). This made me think about the wider applicability of the tools, and whether there were possible benefits outside mathematical learning. The scope of this thesis does not permit this exploration, but it is suggested as a possible direction for development in the future. However, the experience of working with George, who possibly had wider mental health issues, and the research by Johnson-Wilder and Mackrell (in press) who describe Jackie being mindful but not able to apply this mindfulness to mathematics without a specific intervention suggests that a focus on mathematical learning may be more efficacious in the short term.

The third aspect to be considered in future iterations is whether the intervention could be delivered to whole class groups, or small groups, or whether it should remain as a one-to-one delivery. From consulting the learners on how they saw the intervention working best, a clear picture emerged. The learners preferred the one-to-one interview and thought that they would feel more restricted and less comfortable in a group of learners. Chris explains this well: *'I think it would be… I* *think it's better one to one, cause I think… I know I would definitely be too shy to, like, put my hand up and ask stuff'* (Chris, C1, CI3, L239). However, when asked if she could see the intervention working in a small class group, Chris explained that it would depend on the individuals in the group: *'I think I'd feel less shy [in a small group vs a whole class] but it almost depends on the person. Like if it's one of those really judge-y people then no. Like, if you don't understand something, and they do, then like, they almost judge you for not knowing, and they think you're really stupid and stuff'* (Chris, C1, CI3, L247).

Devon could imagine gaining benefits from an interview with a small group of like-minded learners: *' I sort of find it easier when it's a one to one, cause then I think you wouldn't like, be able to say all that you want to say if it was in, like, a group, and stuff because then you'd be scared to say some stuff, cause other people might be like, oh, why you get like that, and stuff. So I think it's almost better like, just like one to one or something. Or like in a small group or something. I don't know you could do it in a class but, like, you wouldn't, like, ask questions so much cause then not everyone could answer. So you need the people who get really anxious in a little group'* (Devon, C1, CI3, L274).

6.5.3 Section Summary

The intervention was refined and developed in various ways. The default offer was two interviews, although this was extended when necessary. The app was used within the interviews, and the maths toolkit was provided for use by each learner in their mathematics lessons and whenever else they needed it. These refinements and developments were very helpfully informed by the contributions of the learners, who were very insightful and honest. The framework of Design-Based Research helped in that it encouraged continuous reflection and improvement but did not help with the reporting.

It is hoped that there will be further trials of the intervention. These trials should consider the criteria for selecting participants / learners, the structure of the interview suite and the applicability to other areas. These issues will be discussed further in the next chapter.

6.6 CHAPTER SUMMARY

This chapter described the creating of an intervention that effectively addressed mathematics anxiety in young learners. Once I had established the need to address mathematics anxiety in year 7, I could then progress to supporting the learners directly on a one-to-one basis. I reduced the number of interviews in the intervention from three to two interviews, although my experience with one learner suggested that some learners will need more than 2 interviews. As the learner in question did not want to appear atypical to their classmates, they accepted one extra interview but refused further interviews. In future trials of the intervention, it may be beneficial to operate a triage system to identify other learners who would need similar consideration and offer four interviews as a starting point for them.

The intervention sought to build self-efficacy in the learner, chiefly through the introduction of the Hand Model of Brain (Siegel, 2010). The learners were then supported to increase their awareness of their emotions through the Growth Zone Model, (Johnston-Wilder & Lee, 2010). Learners were then taught a version of the Recovery response (Benson, 1975) to enable them to regulate their emotions. Two artefacts to support the intervention were developed. The grOwth app was found to be beneficial in the interviews, but not appropriate for learners to use outside the interview. The Mathematics Toolkit was subsequently co-created with the learners and was found to be beneficial for the personal use of the learners. The next steps of the development could be to establish the relative permanence of the intervention, whether it would work with small groups or whole classes, and whether it would be beneficial to apply to other subjects and situations.

The next chapter will examine the data through a different lens. As I have indicated, whilst the process of Design-Based Research was helpful, it did not offer enough scope to develop theory. I therefore conducted a thematic analysis on the recordings of the interviews. The outcomes of this analysis will be presented in the next chapter, and the following chapter (Chapter 8) will discuss the findings, including the quantitative findings in the previous chapter, as a whole.

CHAPTER 7 QUALITATIVE FINDINGS

7.0 INTRODUCTION

This chapter describes the findings which emerged from a thematic analysis of the transcribed recordings of the clinical interviews which took place in the second stage of the research. The first section of the chapter describes the analytic process which was adopted and justifies the rationale behind the adoption of this particular approach. The second section describes the first main theme which emerged from analysis of the data, namely the causes of mathematics anxiety observed in the learners. I expected to see personal and environmental causes of mathematics anxiety, but learners also report strong concerns about falling behind other learners. The third section describes the second main theme, namely the use of the Growth Zone Model and other tools. The findings reported in this chapter cannot be described as forming grounded theory, as they are based on transcriptions of clinical interviews where I had very clear objectives. As the findings are necessarily focused on particular areas, the approach is inductive in nature, as the data is gathered and then considered in the light of the relevant literature.

7.1 DESCRIPTION OF THE PHASES OF ANALYSIS

7.1.0 Introduction

My approach towards the thematic analysis of my data drew from the constant comparative approach of Thomas (2013), the process of identifying these from theoretical constructs of Leech and Onwuegbuzie (2007) and the emphasis on establishment of trustworthiness of Nowell et al., (2017). I based my analytic process on Nowell et al.'s (2017) six phases of thematic analysis (see Table 7.1). This

Table 7. 1 Establishing Trustworthiness During Each Phase of Thematic Analysis, From Nowell et al., (2017)

Phases of Thematic Analysis	**Means of Establishing Trustworthiness**
Phase 1: Familiarizing yourself with your data	Prolong engagement with data Triangulate different data collection modes Document theoretical and reflective thoughts Document thoughts about potential codes/themes Store raw data in well-organized archives Keep records of all data field notes, transcripts, and reflexive journals
Phase 2: Generating initial codes	Peer debriefing Researcher triangulation Reflexive journaling Use of a coding framework Audit trail of code generation Documentation of all team meeting and peer debriefings
Phase 3: Searching for themes	Researcher triangulation Diagramming to make sense of theme connections Keep detailed notes about development and hierarchies of concepts and themes
Phase 4: Reviewing themes	Researcher triangulation Themes and subthemes vetted by team members Test for referential adequacy by returning to raw data
Phase 5: Defining and naming themes	Researcher triangulation Peer debriefing Team consensus on themes Documentation of team meetings regarding themes Documentation of theme naming
Phase 6: Producing the report	Member checking Peer debriefing Describing process of coding and analysis in sufficient details Thick descriptions of context Description of the audit trail Report on reasons for theoretical, methodological, and analytical choices throughout the entire study

appeared suitably systematic, and the instructions were detailed so I felt confident that I would be adopting a thorough approach. In the absence of relatively little experience, this promised to be a scaffolded way of conducting the research.

7.1.1 Phase 1 – Data Familiarisation

The first stage suggested by Nowell et al. (2017) is for the researcher to familiarise themselves with the data and organise it. I had transcribed some of the data so was fairly familiar with it, but had much of the interview data professionally transcribed due to personal time constraints, so I subsequently read through these as Braun and Clarke recommend reading all through the data. I also recorded field notes. The data in its various forms was filed in labelled folders in an external disc drive, as stipulated in the ethical approval documentation. The process of reading through and then coding the data was almost visceral. As I had conducted the interviews, reading them through again was often an emotional experience, as I was reminded of the often-visible mathematics anxiety of the learners (Field Notes, p73). The triangulation of different data collection modes did not appear to be either important or possible to me as a novice researcher, although I now realise that triangulation was possible between my field notes, the Design-Based Research cycle notes and the transcriptions themselves. However, I did document my theoretical and reflective thoughts, and my thoughts about potential codes and themes. As I mentioned above, my main reflection on reading through the transcriptions was that they were 'hard to experience again' (Field notes, p73) as I was putting myself back in to the situation of hearing about the experiences of the learners and feeling their remembered pain. Revisiting these experiences was harder as I was able to fully engage with the emotions described by the learners rather than viewing them from the more objective role of managing the clinical interviews.

I carefully organised the data in folders. Surprisingly, as it felt like unnecessary fussiness at the time, this turned out to be time well spent, as I was able to locate specific data easily. I chose against creating an excel spreadsheet, as Nowell et al. (2017) suggest, as I felt I did not have enough data to manage to warrant this step. This may have been a mistake as I was buried in the detail rather than having an overview of how many interviews were conducted altogether. I realise now that I rushed through this section, probably because I was anxious to make sense of NVivo. In future research, I will spend more time thinking about and organising my data.

7.1.2 Phase 2 – Generate initial codes

The initial coding framework revealed that I had a wealth of data concerned with the causes of mathematics anxiety for the learners. Following discussion with my supervisor, who adopted the role of a peer researcher for the study, I realised that I needed to separate the codes which concerned the feelings of the learners from the codes for personal causes of mathematics anxiety, as the feelings of the learners were evidence of mathematics anxiety rather than causes. I also was able to identify at this early stage of analysis that whilst I had gathered a lot of data around the causal factors of mathematics anxiety, I had not gathered data around the relationship between working memory and learning. This was not a problem, rather I was able to establish the boundaries of my research. My notes also record my realisation that I needed to code for the valence of feelings. In doing so it became apparent that I had expected to hear only negative feelings and was surprised at the positive feelings shared by the learners. In this phase I explored these feelings in detail, a focus that would be broadened in the later phases.

7.1.3 Phase 3 – Searching for themes

Further researcher triangulation in the form of discussions clarified possible themes. I used mind mapping software to diagram possible connections within and between the themes. Two main themes emerged, namely ‘Causes of mathematics anxiety’ and ‘Using the growth zone model’. For ‘Causes of mathematics anxiety ‘, the initial stage of diagramming the themes reveals that I had divided the theme into two subthemes of ‘personal’ and environmental’.

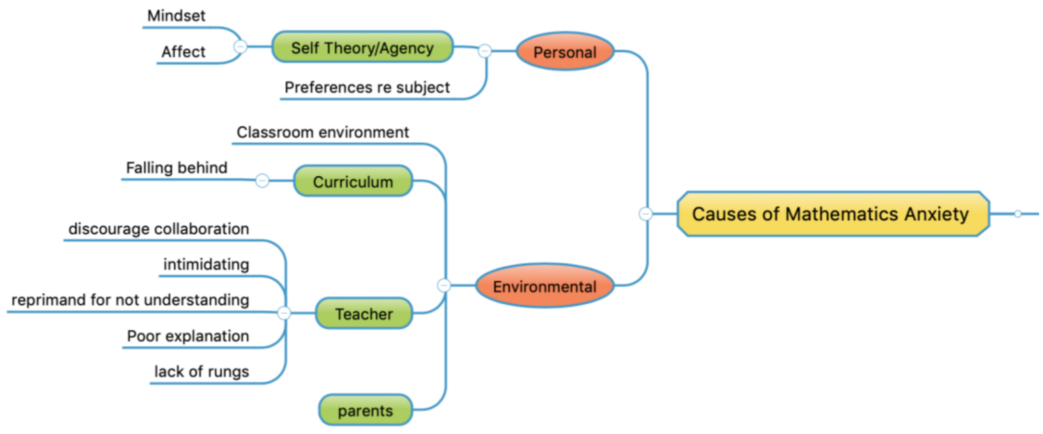


Figure 7. 1 Excerpt from Diagram of Themes, 11/02/20

However, as can be seen from a later iteration of the diagram, a new subtheme entitled ‘Falling Behind’ was created. This subtheme is closely linked to both subthemes of personal and environmental. It was created as a separate entity as there was enough data to warrant this step.

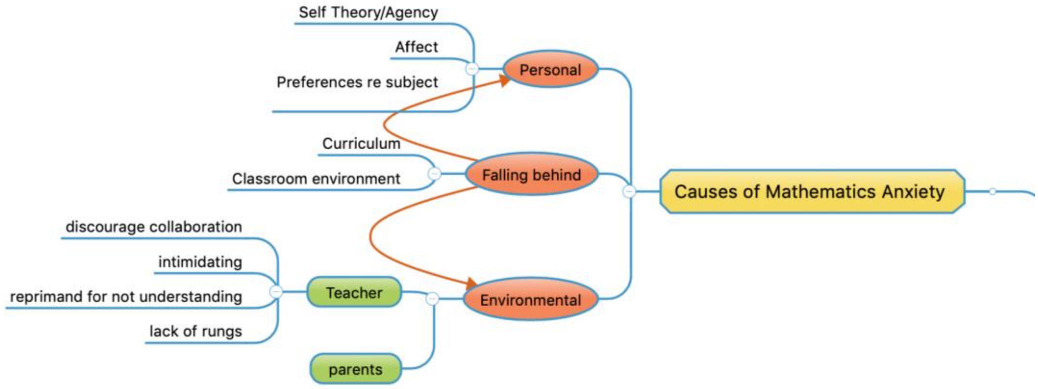


Figure 7. 2 Excerpt from Diagram of Themes, 03/04/20

The other theme of 'Using the Growth Zone Model' revealed a distinction between awareness of feelings and their subsequent management. Further reflection on the 'Taking action' subtheme revealed the dynamic possibilities of the Growth Zone Model, where the process of recovering from anxiety, blossoming in growth and creeping out of comfort requires active management of emotions by the learner.

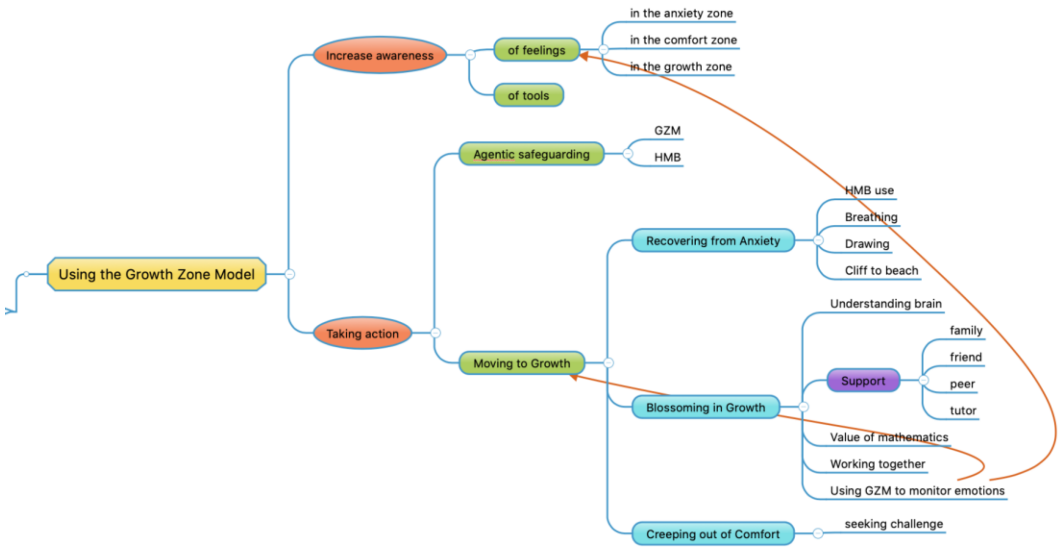


Figure 7. 3 Excerpt from Diagram of Themes, 03/04/20

7.1.4 Phase 4 – Reviewing themes

Further discussions with my supervisor supported the process of refining and developing the themes and subthemes, to produce the diagrams shown above. Nowell et al. (2017) also suggest that this phase involves a test for referential adequacy by returning to the raw data. In order to do this, I created a framework document for each subtheme that noted the subtheme, noted the specific codes that contributed to that theme, and gathered quotes to support and exemplify the categorisation (see for example Appendix 7.1). This process supported the further refinement of the themes and subthemes. These documents were discussed and developed with my supervisor.

7.1.5 Phase 5 – Defining and naming themes

In order to define and name the themes and subthemes, I created another framework document which developed the previous document for each subtheme. These documents included an excerpt of the diagram pertinent to that subtheme, the subtheme name, with a prompt to check if the name was punchy and whether the words of the learners could be used (Nowell et al., 2017) , a description of the subtheme, a rationale of the subtheme, and including annotated quotes to support the inclusion of the subtheme (see, for example, Appendix 7.2)

7.1.6 Phase 6 – Producing the report

The report for this analysis comprises of this chapter and has been checked and confirmed by my supervisor who was involved throughout. I have tried to 'describe the process of coding and analysis in sufficient detail' and add 'thick descriptions of context' (Nowell et al., 2017). In this way I hope to establish the trustworthiness of the data.

7.1.7 Section Summary

The adoption of Nowell et al.'s (2017) phases of analysis proved to be both systematic and supportive, as I had hoped. The process guided me to engage with the raw data in a meaningful and thorough way and prompted me to develop my thoughts and conclusions through productive discussions with my supervisor. The rest of this chapter will detail the findings in two main sections as they emerged from the data, namely the causes of mathematics anxiety and the use of the Growth Zone Model.

7.2 Causes of Mathematics Anxiety

7.2.0 Introduction

I originally expected the data in this area to separate into the themes of 'personal' and 'environmental' causes, as was indicated from the literature. However, the analysis indicated the need for an extra theme that linked both personal and environmental causes, namely 'falling behind'.

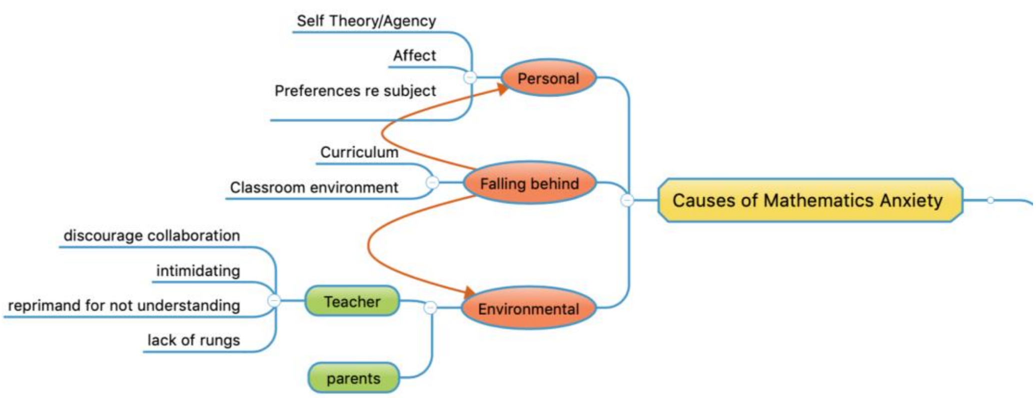


Figure 7. 4 Causes of Mathematical Anxiety

7.2.1 Personal causes of anxiety

This section describes the data which supports the process of developing mathematics anxiety through internal thoughts and attitudes, feelings and preferences rather than external environments. Self-theory includes the learners' sense of self-efficacy, and their mindset towards learning. These factors contribute to how able the learner feels to learn. The subsection on affect involves the learner's feelings about mathematics.

7.2.1.1 Affect

The learners described a range of emotions when recounting their experiences of learning mathematics. Some of these experiences were positive. Hayden described feeling confident: *'I feel confident doing bar charts more than fractions, because I find bar charts, like, a lot easier.'* (Hayden, Cycle 2, Clinical Interview 1, Line 47, referred to in future as C2, CI1, L47) while Indigo described a recent mathematics lesson where she understood the concepts and felt *'good'*, *'proud'* and *'happy'* (Indigo, C 2, CI1). However, most of the learners ascribed negative emotions to their previous experiences of learning mathematics, as is shown in Table 7.2.

These emotions encompass anxiety (nervous, anxious, worried), anger (annoyed), sadness (sad) and fear (scared) as well as a general feeling of a lack of comfort (not comfortable). Putting aside the research evidence that shows that emotions such as these inhibit learning, as a teacher, I would not be satisfied with my pupils experiencing these emotions in my classes without me being aware of them.

Table 7. 2 Negative emotions associated with previous mathematical learning

Emotion	**Reference**
nervous	Blake Cycle 1, Session 1
anxious	Blake Cycle 1, Session 1 Kelsey, Cycle 2, Session1 Lynden, Cycle 3, Session 1
annoyed	Chris, Cycle 1, Session 1 Indigo, Cycle 2, Session 1
confused	Hayden, Cycle 2, Session1 Max, Cycle 3, Session1
worried	Indigo, Cycle 2, Session 1
not comfortable	Lynden, Cycle 3, Session 1
sad	Max, Cycle 3, Session1
scared	Lynden, Cycle 3, Session 1

7.2.1.2 Mindset

Analysis of the data supports the theory of fixed and growth mindsets (Dweck, 2000). Erin describes her mother's mathematical ability and describes it as an inherited talent rather than a developed ability. *'Well, my mum is like, really good at maths. Like, I didn't expect that she'd be that good. She like really understands it. Like, why didn't I get that gene?'* (Erin, C1, CI3, L 181). Devon also displays a fixed mindset in that she sees mathematics as something to be understood or not straight away rather than something that can be understood after engagement and effort. '*And there's certain parts that you understand and certain parts that you don't understand, and that's one of the parts that I didn't understand, so then you get like, anxious about it, cause you* *think 'this is one of the parts I'm gonna fail at', and you don't understand so you're not gonna be good at it.'* (Devon, C1, CI2, L171).

George demonstrates a slightly different problem in that he exemplifies limitations with growth mindset teaching. Some learners misinterpret the construct as necessitating more pressure on the learner as, in order to succeed, they just need to try harder. Therefore, a lack of success is doubly their fault as they feel expected to achieve at mathematics and also expected to have a growth mindset: *'So basically, that proves that if you try, you can actually get good marks. And if you don't try, well that's your fault'* (George, C2, CI2, L 96), *'When I was back in year six when I did maths, basically I asked for help, and I didn't get… I didn't really understand it even if the teacher helped me. So then I just put down a guess of what I thought it was. Or just somehow worked it in my brain for ages and then just put it down. But I always thought if I got a question right, then that meant that I just didn't have to stress. Or I could miss it out and then go onto the next one but the teacher would be questioning me for that. But then I soon learnt that if I tried a lot harder then I'd be able to do that and that's what I did'* (George, C2, CI2, L 107). Here George describes a focus on getting the 'question right' rather than understanding the mathematics involved.

7.2.1.3 Self-Theory and Agency

Bandura describes the development of self-efficacy as depending on four factors, namely mastery, vicarious, social persuasions and emotional state (Usher & Pajares, 2009). Devon describes the third of these, social persuasions, when I asked her what her teacher says that encourages her with the mathematics: *'…at the start I was really down, thinking I was really dumb, and I was always like, I'm really dumb, and my* *hand was literally always up on every question. And then he [her teacher] came over and I was like, sorry I'm really dumb. And then the teacher, was like, no, you're not, you just need to have faith in yourself. But now like I understand it more so it's like, just more like, he's saying… telling me how it works now, and I can do the rest on my own. So, it's like, really helped'* (Devon, C1, CI3, L192). Devon describes her teacher building her self-efficacy through persuasion. Adam provides another example of a teacher building self-efficacy in their pupil, this time in primary school: *'well I never had, really much confidence in myself even in primary school, but I had a teacher that helped me, um, she believed in me and then, made me a better, made me more confident in maths'* (Adam, C1, CI1, L30). Here Adam uses the word 'confidence', but I have interpreted it as self-efficacy as it is improved by persuasion and is particularly focused on mathematics. The distinction between confidence and self-efficacy was explored in the first literature review chapter on the psychological perspective and will be further discussed in the discussion chapter.

The learners describe a range of negative emotions encompassing anger, sadness, anxiety and fear. These emotions partly arise from either instances of a fixed mindset, where mathematical learning is seen to be a talent only granted to a few, or a misunderstanding of the construct of growth mindset, where the learner believes that they lack effort rather than mathematical ability. However, two learners report that their sense of self-efficacy has been developed through encouragement by their teachers. In contrast to this positive message from teachers, the next section describes reports of negative message from teachers.

7.2.2 Environmental Causes of Anxiety

The environmental causes of mathematics anxiety identified through the data were either from the learner's teachers, or from their parents. The learners described learning environments where teachers discouraged collaboration: *'cause like, when I don't get it, I just start talking to [friend] and we both get into trouble for talking'* (Erin, C1, CI1, L149). Admittedly it is difficult to identify with this quote whether the conversation, had it been allowed, would have enhanced Erin's learning process. However, Erin also reported being reprimanded for not understanding the subject content: *'well, in primary school, I, like, didn't get it at all, and I was really confused with everything. And like, my teachers sort of told me off for not getting it. I'm pretty sure that they thought at one point I was pretending not to get it for attention or something. So, I don't really like it, because I basically got told off for not getting it'* (Erin, C1, CI1, L19).

George reported being reprimanded for not listening: *'Because I couldn't listen, I couldn't do anything. It was too frustrating, and I eventually needed help doing it and the teacher told me off for not listening, when I really needed to, I just couldn't pull my brain together'* (George, C2, CI1, L253). Here George's teacher seems to misinterpret his non-compliance as wilful disobedience rather than non-compliance due to brain flip. In addition to describing teachers who were generally lacking in empathy, the learners described situations where the teachers did not support the learning process adequately: *'it's been awful. At the start of the year I was ok cause we were doing stuff that I knew and we kept expanding that little bit. But, um, all of a sudden, we're jumping out of nowhere like, y equals something on a grid, or stuff that I never even actually did in primary school and it's just that massive* *jump that made me feel uncomfortable. And it makes me anxious'* (Lynden, C3, CI1, L66). *'The teacher explains it to me. But I don't exactly get it cause she's a bit complex the way she explains it'* (Blake, C1, CI2, L138).

Although I did not explicitly ask the learners about the messages given by their parents about mathematics, Lynden's voluntarily offered experience deserves inclusion: *'Uh, when I'm anxious, I think of the consequences of when a letter goes home saying I've done no work because I'm anxious, and how my parents are gonna punish me. The way I respond when I get anxious is, I tend to just shake and just lose my mind. Like my mind is just blank. Cause it's too much work piling on. And it's also really stressful. And sometimes it can even get depressing, having that much stress on you, in maths as well'* (Lynden, C3, CI 1, L75).

The learners describe teachers reprimanding them for not listening to them and for not understanding the mathematics being taught. They also describe teachers failing to structure the learning appropriately so that the learners could progress with their learning. This aspect of progressing with the learning will be explored further in the next section.

7.2.3 Falling Behind

This theme is an unexpected one. It seems to involve both environmental and personal causes. The learner's self-efficacy, or lack of it, is fundamental to the theme. However, the interface between the learner's perceived capability (their self-efficacy) and the expectations of the learning situation is also involved. The learners provide vivid descriptions of situations where the expectations presented to them appear unreasonable. The theme involved several aspects, namely a lack of understanding, concern over appearing different to other learners, and striving to catch up. The data for each of these aspects will be presented in turn.

Chris explained that, because she failed to understand the mathematics and then did not manage to produce the expected work, she expected a reprimand from the teacher: *'I just didn't want to get told off for not doing enough work because I can't help not doing enough work when I don't understand it'* (Chris, C1, CI1, L66). Erin and Indigo expressed concern over appearing to be different to their peers: *'well, I still don't, really, ask for help, because everyone else in the class is like 'oh yeah I get it' so I don't really want … to get up and be different from everyone else and ask for help'* (Erin, C1, CI1, L38), *'Bit annoyed cause I couldn't do as well as the other people'* (Indigo, C2, CI1, L69).

Every learner apart from Finley (whose main concern at the time of the clinical interviews was issues at home) seems to have some experience of negative feelings surrounding the experience of not understanding the content of the lessons. Many learners described experiences of striving to catch up with the learning in some form. This could be to do with the speed of delivery of the curriculum, as in Blake's case: *'like, even when Miss tries to explain it, in like, stats, I just can't, 'cause it takes me time to process one method and then by the time I've processed that, I've got another two methods to process. And I just, can't really, get it in my mind'* (Blake, C1, CI1, L29).

George felt that he did not have enough time to consolidate his learning: *'… she explains one thing and I just can't… seems like I can't get it the first day, but the second day I just get it all and I can do it really easy. But then my teacher moves on to* *another subject so it's like I never get the chance to improve, and I never get the chance to learn or anything'* (George, C2, CI1, L63).

Lynden and Max identified that the mathematics had got harder in the transition from primary to secondary school: *'I thought that it would only like a little bit get harder. At the start of the year I was ok cause we were doing stuff that I knew and we kept expanding that little bit. But, um, all of a sudden, we're jumping out of nowhere like, y equals something on a grid, or stuff that I never even actually did in primary school and it's just that massive jump that made me feel uncomfortable'* (Lynden, C3, CI1, L68), *'it's got harder, but like some of the stuff I don't really understand that much'* (Max, C3, CI1, L43).

Hayden described the theme of falling behind as simply finding it hard to catch up with the other learners: *'Well, in primary school I found it, like, hard to catch up, and I did ask for help a bit. Here [secondary school], I'm asking for help a bit still, and finding it hard to catch up still'* (Hayden, C2, CI1, L34).

This subtheme has been included in the section of causes of mathematics anxiety but could equally be included in a section on the impact of mathematics anxiety, as there is a vicious circle effect of mathematics anxiety in play here (Carey et al., 2019). This will be discussed further in the next chapter.

7.2.4 Section Summary

This section presented data to exemplify the theme of 'causes of mathematics anxiety' which were divided into the subthemes of personal causes, environmental causes, and an unexpected subtheme which combined aspects of personal and environmental causes into a new subtheme of ‘falling behind’. These subthemes will be compared to existing literature and discussed in the next chapter.

7.3 USING THE GROWTH ZONE MODEL AND OTHER TOOLS

7.3.0 Introduction

The themes that emerged concerning the use of the Growth Zone Model separated into two subthemes, namely the learner’s increased awareness of their feelings in the different zones and of the model itself, and the instances where they took action to manage those feelings. As a result, a new insight into the nature of the model became clear, which was that the best use of the model comes from the learner having the autonomy to move from either comfort or anxiety to the growth zone.

7.3.1 Increasing Awareness of Emotions

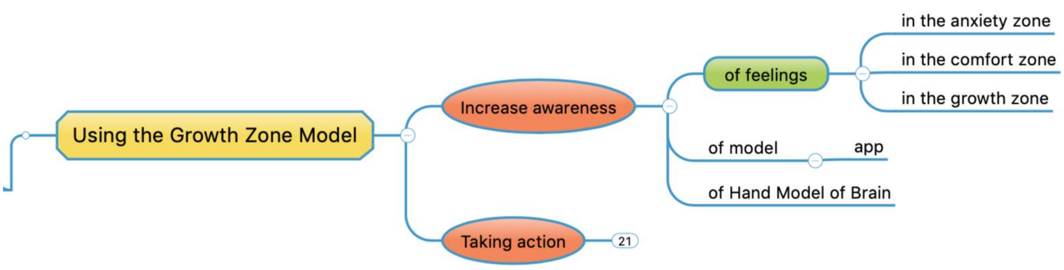


Figure 7. 5 Thematic Structure of 'Increasing Awareness of the Growth Zone'

Once I had introduced the Growth Zone Model to the learners, they were able to describe their feelings in each of the zones. This data can also be seen in section 6.2 of the previous chapter.

7.3.1.1 Awareness of Emotions in the Anxiety Zone

This subtheme recounts instances where the learners describe their feelings when in the anxiety zone as a manageable brain flip rather than a disastrous event. The subtheme supports the conjecture that the first step of managing feelings is becoming aware of them. I therefore evidence the learners using the Growth Zone Model and Hand Model of the Brain to become more aware of their feelings as a first step. The following examples show learners describing feelings from the anxiety zone by using either the app or the Maths Toolkit.

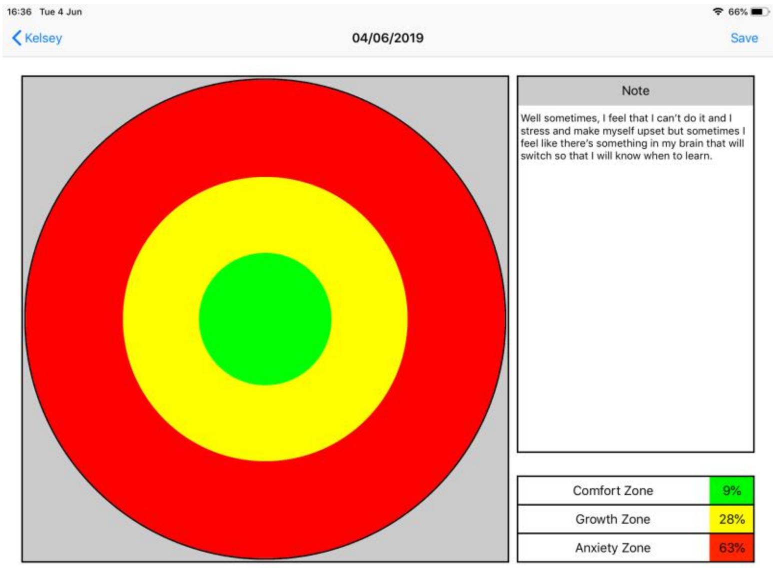


Figure 7. 6 Kelsey, Cycle 2, Clinical Interview 2

Kelsey described her feelings about mathematics in general as mostly ones of anxiety: *'Well sometimes, um, I don't know really. It just… just sometimes I feel like, that I can't do it. And I stress. And make myself upset'* (Kelsey, C2, CI1, L 170).

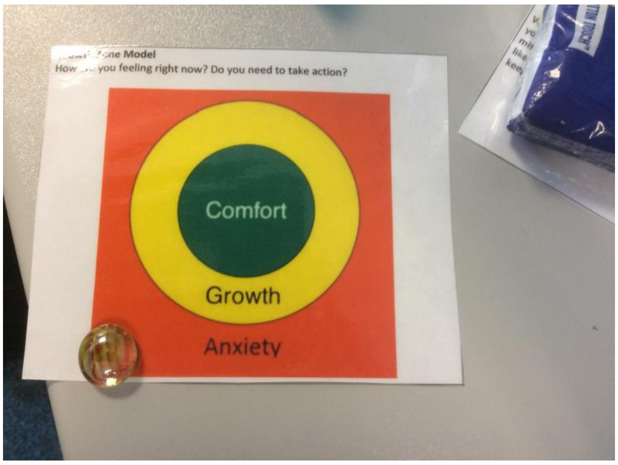


Figure 7. 7 Lynden, Cycle 3, Session 1

Lynden placed his pebble at the extreme edge of the anxiety zone when describing his lack of understanding: *'We were doing, uh, graphs, stuff with like y equals something and, um, we're doing symmetry… uh, reflection, but I didn't… but miss… miss explained that has something to do with reflection. I was like, whoa! I had no idea'* (Lynden, C3, CI1, L218). However Max did not need the physical diagram as she could internalise the Growth Zone Model and describe her emotional state verbally when prompted with a question such as 'If you're the pebble, where would you put yourself on the growth zone for that maths lesson?': *'Probably in like the anxiety zone' (Max, C3, CI1, L 165).*

7.3.1.2 Awareness of Emotions in the Comfort Zone

I predicted that learners would become aware of their feelings when in the anxiety zone, as these can often be overwhelming (literally in that they inhibit normal learning behaviour). The following subtheme presents evidence that learners can also describe how they feel in the comfort zone. I also predicted the need for extra vigilance in my analysis and evaluations, as I wanted to hear the voice of the students but was aware of the danger of hearing a repeat of my own words.

Adam recognises the possibility of staying in the comfort zone at primary school: *'I think I may have done, at primary school, because we had the choice to go for easy, middle or hard and I'd usually go middle, but I was capable of going for hard, but I just played it safe'* (Adam, C1, CI1, L 150).

Devon associates the comfort zone with a feeling of confidence: *'After breathing I felt really good because I finished the test and I had some time left to check over what I had done. I thought that the answers were right so I wouldn't have anything to worry about because I got them mostly right'* (Devon, C1, CI2, L214).

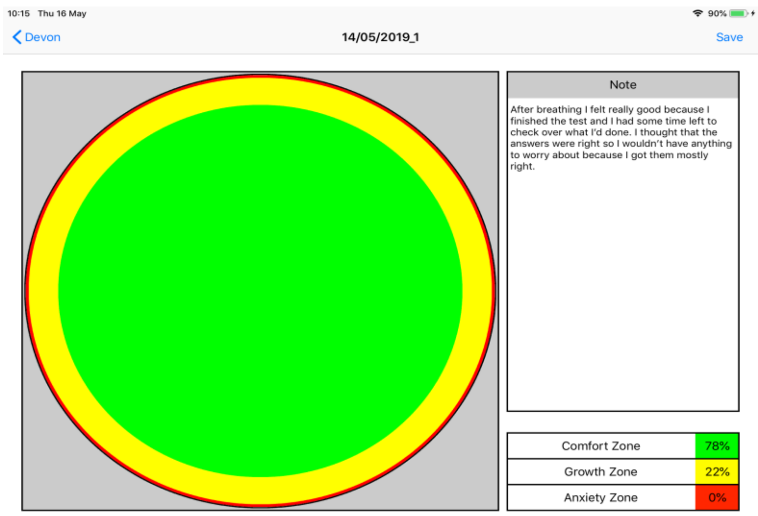


Figure 7. 8 Devon, Cycle 1, Session 2

Jack realised that the comfort zone is not the optimal state for learning: *'If it's just easy, it's just writing down the same thing, not actually learning. Just doing the same thing that you already know'* (Jack, C2, CI2, L 76).

<u>7.3.1.3 Awareness of Emotions in the Growth Zone</u>

When analysing the data, I was interested to see if there would be anything of value for the growth zone. I suspect that I had a preconception that this would be the hardest one (I said to one learner that we will leave the growth zone until last, as it is the hardest). This preconception may well have affected the data, both in nature and in quantity. Adam captures the essence of the growth zone when he describes 'tackling' the mathematical challenges and feeling better about making mistakes. He explained that he was usually in the growth zone: *'Because ... the questions were challenging but I did get most of them correct. It felt ok. Yeah. I just felt like I was learning, and with the neurons thing*' (Adam, C1, CI3, L 24).

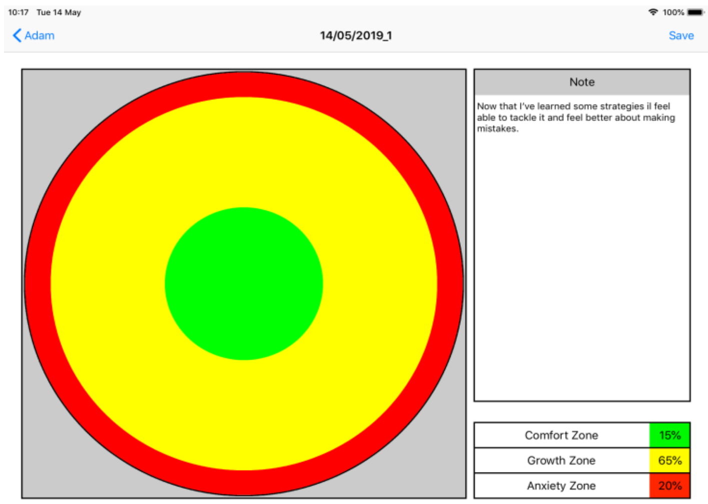


Figure 7. 9 Adam, Cycle 1, Clinical Interview 3

In his first session, I asked Blake if he could remember times when he was in the growth zone and he shook his head and became visibly distressed. However, by the next week, he could recognise being in the growth zone: *'Because I wasn't feeling too anxious, and…it wasn't too hard. I felt like… some facts about maths were going into my brain in a way that I could understand'* (Blake, C1, CI2 L200). Finley felt that she was in the growth zone '*because I was learning things I didn't before'* (Finley, C1, CI2, L131). Devon described being in the growth zone as: *'Like, not really easy but, probably in like the growth zone. Like, it's challenging but I can manage it anyway.' (Devon, C1, CI 3, L32).* This description of the growth zone as a place of manageable challenge is both very descriptive and an accurate representation of the meaning of the zone.

7.3.2 Taking Action to Address Emotions

7.3.2.1 Recovering from anxiety

The subtheme entitled 'Moving to Growth – Recovering from Anxiety' describes any instances in the data where the learners manage to recover their equanimity from a state of anxiety. This subtheme does not include instances where the learner safeguarded themselves by staying in the comfort zone. The subtheme gathered many similar coding instances, so the quotes shared here will be a comprehensive representation rather than a full recount.

Many learners found that the 5/7 breathing tool helped them to recover from anxiety. In terms of the tool itself, several learners found it calming, as in Adam's case: *'it is calming me, yes, it's kind of round my chest'* (Adam, C1, CI1, L88). Others described it as relaxing, as in Erin's case, having done the breathing: *'hmm, I already feel relaxed'* (Erin, C1, CI 1, L106). Devon described the effect of the breathing tool on her cognitive processes: *'you feel like you got rid of some of the stuff you thought you were like, worrying about, like in maths'* (Devon, C1, CI1, L100).

The process of recovering from anxiety involves knowing when to use the 5/7 breathing tool. Erin explained that she intended to use the breathing tool *'when the* *anxiety bit's massive'* (Erin, C1, CI1, L160). Blake described the process of using the breathing tool: *'Well when I got stuck on a question I would just get out the paper [the 5/7 breathing prompt sheet in the Maths Toolkit], look at it and go right, I'm gonna do that [5/7 breathing] for this long, and I wrote it down on the paper how long I did it for'* (Blake, C1, CI2, L33), and the beneficial result after only five breaths*: 'I felt a little bit calmer'* (Blake, C1, CI2, L42).

Chris also recognised that the 5/7 breathing tool could be helpful:

'I had a maths lesson last lesson, and we were doing proportion, but yesterday I was on the border of anxiety… I was really stuck on what to do, and … I just had no idea and I was really confused, and so then I realised that I felt like I was about to go into brain freeze, and then I did the breathing… I did the breathing, and that helped.' (Chris, C1, CI2, L26).

Some learners described situations that recreated strong emotions through retelling, and still managed to use the 5/7 breathing tool:

'Janet: How did you know that you were in the anxiety zone?

Indigo: Cause I felt panicky.

Janet: [Indigo shows visible signs of distress]. I'm sorry. Do you not want to talk about it in here?

Indigo: No, it's fine. [extended pause] I kind of just went quite blank. Like I didn't know what was… just forgot stuff. And I just thought I couldn't really answer the questions well…I did the five seven, and it helped. It was just a couple of times and then I felt a bit better.' (Indigo, C2, CI2, L57).

Devon describes being able to learn more effectively after 5/7 breathing:

'[I was] able to concentrate on the question and then sort of try and work it out better. Like you didn't really know what to do and then you do the breathing and it's like… you sort of think 'oh right that's what I have to do', and then you sort of see it differently once you calm down' (Devon, C1, CI2, L59). The last phrase of this quote typifies the message I wanted the learners to hear – that they could learn mathematics once they learned to manage their emotions – to such an extent that I have chosen it as the title of this thesis. This is the message I want all learners to hear.

Learners used the 5/7 breathing tool at home as well as at school. *'Yeah. Well I was doing my homework a couple of days ago and I got really confused. I had like a little panic attack. I was like, I can't do it. And then I did like the breathing thing and, like, cause normally it's just a little bit I don't understand, and it helps, but I was like, wow, it really, really works. Cause I was like so confused I was like crying and I was having a fit and I was throwing things and I was like, oh, I could do the breathing thing. And then it worked, and I was like, ok. [Before] I was really angry. I was like, I can't do it. [Afterwards] I felt really, like, calm. And I just felt really, like, more comfortable doing the homework'* (Erin, C1, CI3, L16).

One learner used the 5/7 breathing tool to manage her emotions in a difficult personal situation which did not involve learning mathematics: *'on Thursday I got like a bit like almost nervous. Like… And I was just thinking about it. [Afterwards] I just felt calmer'* (Finley, C1, CI2, L19). Others planned to use the tool in other subject lessons: *'when I'm like confused in other lessons I'll just think and start doing the breathing'* (Erin, C1, CI2, L92).

However, two learners did not find the 5/7 breathing tool helpful, preferring to use the brain scrumple as a calming technique: *'I mean, the breathing doesn't help that much cause um, even if I do try and breathe slowly it doesn't wear off the stress that's still on my mind'* (Lynden, C3, CI2, L71).

Interestingly, once they had mastered the 5/7 breathing technique, some learners realised that they did not need it anymore as it had served its purpose.

'Probably like the breathing as well. Because I did use that, like, the first week. But I think after I'd used it, I sort of thought, I don't need to do it anymore' (Devon, C1, CI3, L298).

This subsection has described the ways in which the learners took action to recover from being in the anxiety zone. In the next subsection, the ways in which the learners took action to stay in the growth zone will be described.

<u>7.3.2.2 Blossoming in growth</u>

Once the learners understood the importance of being in the growth zone, they were in a position to take proactive steps to stay there: 'Well this last week I've been understanding what we're doing in maths a lot more, so I've not been able… not been having to do the breathing as much. But I'm still in the growth zone' *(Chris, C1, CI3, L16).* They described the value of mathematics: *'I think it's helpful any time, because something could pop up every day and you just need to know the answer something and because you've learnt it in maths you know how to go about working it out.'* (Adam, C1, CI3, L91). Learners also described the value of mathematical qualifications: *'I don't really care about what mark I get in my tests. I do care about* *what marks I get in my GCSEs though. GCSEs are important. I know I'm gonna need it [mathematics] in my life. To apply for something [a job], you have to have learnt what you need to learn in order to do this. So say if I need mathematics to become a builder, like angles, they would ask me stuff about angles and I would show them, oh, here's my angle stuff. To prove that you didn't just copy it down, he would say, tell me something only a person that's good at geometry would tell me. Then, you have officially applied for the job. Well done'* (George, C2, CI1, L332).

Learners realised that they could learn from their mistakes: *'because I just know … if I make mistakes it doesn't matter. I need to learn from them'* (Adam, C1, CI1, L169), and became more comfortable when unsure: *'Well, I was still a bit worried that I got it wrong, but I was more ok with getting it wrong. More comfortable with not knowing'* (Erin, C1, CI3, L 89).

7.3.2.3 Creeping out of comfort

Two learners described an awareness of the comfort zone being, and described that depends on mathematics learning being seen as characterised by interesting wrestling with conceptions and struggling to work out efficient and effective procedures rather than getting the answer right most or all of the time. Adam is aware that he chose the less challenging option: *'at primary school we had the choice to go for easy, middle or hard and I'd usually go middle. I was capable of going for hard, but I just played it safe … just because I knew I'd do well'* (Adam, C1, CI 1, L150). He then experienced the encouragement of a teacher at primary school, and also began to change his attitude towards making mistakes: *'Because my primary school teacher, you know, believed in me a bit more, I did go for the hard for a couple of years after that. I just* *know I'm more capable of it and if I make mistakes it doesn't matter. I need to learn from them'* (Adam, C1, CI1, L159).

Jack describes the comfort zone as a less than satisfactory state in terms of learning: *'What, like, want a challenge? Yeah, sometimes. If it's just easy, it's just writing down the same thing, not actually learning. Just doing the same thing that you already know. Which can sometimes happen in my maths. Cause I'm ahead of the class, above average, so…'* (Jack, C2 CI2, L72).

The difference in Adam and Jack's descriptions seems to depend on a difference in self -efficacy, which may in turn reflect a difference in the relative agency afforded to each learner. While Adam describes having a choice to attempt questions in varying levels of difficulty, Jack describes the occurrence of situations where there is a lack of challenge. This data highlights the importance of learner agency.

7.3.3 Section Summary

An important distinction in the thematic analysis of the data is that before the learners can take action to address their emotional state, they first need to be aware of it. The data presented in this section shows that the learners could recognise their emotional states. When in the anxiety zone, they could then take action in various ways to recover their equanimity and reengage with the learning process. This therefore involved a balance of prerequisite knowledge and positive action.

7.4 CHAPTER SUMMARY

This chapter has presented the qualitative data and described how it was analysed thematically. The next chapter will draw together the findings as presented in the three previous chapters and consider them in the light of the relevant literature as explored in chapters two and three.

CHAPTER 8 DISCUSSION

8.0 INTRODUCTION

This chapter draws together the findings from chapters 5 (Quantitative Findings), 6 (Design-Based Research Findings) and 7 (Qualitative Findings) in the context of chapters 2 (First Literature Review: The Psychological Perspective) and 3 (Second Literature Review – The Mathematics Education Perspective). The data revealed significant levels of mathematics anxiety, higher than expected by the literature in this relatively young age group. The existing literature primed me to see personal and environmental causes of mathematics anxiety in the learners, but the data also revealed an additional cause which I named ‘falling behind’, where the mathematics anxiety of the learners was exacerbated by an expectation to learn at the same rate and in the same way as their peers. The intervention being developed through Design-Based Research was found to be efficacious through qualitative feedback, and insight was gained regarding the use of an app versus a physical artefact to help mitigate mathematics anxiety. The findings regarding the use of the Growth Zone Model (Johnston-Wilder & Lee, 2010) and other tools are of main interest in terms of adding knowledge and will be explained by a model shared in the last section of this chapter.

The structure of this chapter is based on the sections which make up the two literature review chapters, to ensure that the psychological perspective and the mathematics education perspective are both considered. Thus, the chapter begins by discussing the data as they relate to positive psychology and anxiety in general. The chapter continues by discussing the data as they relate to the literature on mathematics anxiety. The chapter concludes by exploring and extending the understanding of mathematical resilience and explains the main contribution to knowledge of the thesis.

8.1 POSITIVE PSYCHOLOGY

8.1.0 Introduction

This subsection considers the literature presented in the first section of chapter 2 (First Literature Review – The Psychological Perspective) which concerns the field of positive psychology. In particular, the constructs of growth mindset, agency and self-efficacy are re-evaluated in the light of data generated from the study. A particular focus is then trained on Self-Determination Theory. The subsection ends by considering the area of mathematical well-being and how it is informed by the data.

8.1.1 Growth Mindset, Agency and Self-efficacy

Chapter two of this thesis defined agency as the learner's actual ability to 'exercise control over events' (Bandura, 1990b:128), self-efficacy as 'people's beliefs about their capabilities to exercise control over events that affect their lives' (ibid., 1990:128) and autonomy as the individual's motivation to exercise control over events which is influenced by their psychological needs of competence and relatedness (Ryan and Deci, 2017). Thus 'agency' describes actual ability to control, 'self-efficacy' describes perceived ability to control, and 'autonomy' relates to the individual motivation of the learner. The construct of growth mindset is based on Bandura's constructs of agency and self-efficacy (Dweck, 2000). The importance of autonomy, agency, self-efficacy and growth mindset to overcoming mathematics anxiety was confirmed through data, as will be explained below. The mindset of the learner acted as a gatekeeper to autonomy, agency and self-efficacy, with a fixed mindset acting as a barrier to the learner being autonomous, agentic and efficacious, and a growth mindset acting as an enabler. The data revealed much evidence of fixed mindsets in the learners. This was best typified by Erin who perceived mathematics ability as a genetic trait when she bemoaned' '*why didn't I get that gene?*' These learners viewed a lack of understanding to be a problem rather than a challenge, with mathematics as something to be understood, or not, straight away, rather than something that can be understood after engagement and effort (Boaler, 2009).

The clinical interviews challenged this fixed mindset by using the Hand Model of the Brain (HMB, Siegel, 2010) to help the learners understand that the experience of their brains 'freezing' or going 'blank' was not a permanent reflection of their ability to learn mathematics, and the scrumple task (Boaler, 2016) to introduce the understanding that mistakes are not to be avoided at all costs, but rather that mistakes can be valuable steps in the learning process. Once the learners understood these two aspects of effective learning, they could then become more agentic and efficacious.

I came to realise experientially that the level of learner agency and self-efficacy in the classroom will vary (Wagner, 2007). This is demonstrated in the data by the differing abilities to deploy the mathematics toolkit. Lynden reported his approach of placing the mathematics toolkit, particularly the Growth Zone Model, on his table in the classroom, thus making his emotional state visible to both himself and his teacher. In contrast, Max did not feel able to use the toolkit in this way, as she did not want to draw attention to herself and did not want to appear different to her peers. She therefore kept the toolkit in her pocket, whilst still managing to monitor her emotional state and take appropriate action. These descriptions demonstrate that agency can be an external or internal capability. Learners may experience external constraints, but the learner's personal agency gave internal alternatives. In addition to the varying levels of learner agency, the potential need for agentic safeguarding exists, as sometimes the environment is not safe enough for the learner to take risks. The learner may decide that the comfort zone is the best place for them for a specific learning situation, if risks involve consequences that may seem too damaging.

A lack of self-efficacy is a characteristic of the initial data, but learners also report developing self-efficacy, for example, by being encouraged by teachers. Bandura (1990b) describes the encouragement of others as one of the four ways to develop self-efficacy. The clinical interviews sought to develop self-efficacy in the learners by giving them the mathematical toolkit. This encouraged them to feel that they had the resources to meet their current needs. These resources were not necessarily mathematical, but rather tools and understanding about the management of their emotions and their options in terms of learning approaches. Thus, I differentiate between the learner's self-efficacy in their mathematical ability, and their self-efficacy in their ability to learn mathematics. This differentiation begs the question of how these aspects relate to each other. One view is that, as they are so closely related, each is a sub-section of the other. Another view is that, whilst a high level of self-efficacy in mathematics would put the learner into the comfort zone, as they would feel comfortable with the subject matter, a high level of self-efficacy in learning mathematics would put them in the growth zone as they have the ability to persevere through any challenges they face. This is an innovative way of understanding the Growth Zone Model (Johnston-Wilder and Lee, 2010) that adds to the current literature.

8.1.2 Self-Determination Theory

As discussed in chapter two, self-determination theory (Ryan & Deci, 2017) concerns the psychological needs of relatedness, competence and autonomy that influence motivation. The need for competence in mathematical learning (Durmaz & Akkus, 2016) was confirmed by the data. The previous chapter highlighted instances where the learners shared experiences of when their mathematical competence and mathematical learning competence were challenged, perhaps typified by Erin bring 'told off for not getting it', and the subsequent anxiety that was caused. The theme I named 'falling behind' detailed an increase in anxiety through a loss of learning competence.

It must be clarified however that I did not explore the motivational state of the learners in the clinical interviews. This means that whilst I can confirm that the mathematical competence of these mathematically anxious learners was challenged, I cannot make any conclusions about their motivation. However, Chris's comment of *'I just didn't want to get told off for not doing enough work because I can't help not doing enough work when I don't understand it'* (Chris, C1, CI1, L66) indicates that she was feeling that her need for (learning) competence was frustrated, and this resulted in anxiety, as predicted by Vansteenkiste and Ryan, (2013). Furthermore, Chris' comment indicates being motivated through external regulation (not wanting 'to get told off') rather than being intrinsically motivated (where she would want to learn because she was interested in the subject). This situation indicates a learning opportunity that is limited due to a lack of opportunities to develop relatedness and autonomy, which increases the risk of anxiety developing.

The strong influence of the need for competence is also confirmed by the data on emotional management. The data reveal that an increase in the competence of the learners in the management of their emotions then increased their motivation for mathematics learning, as in Hayden's and Blake's cases, when they managed to increase their completion rate when tested (data in section 6.4.2 of chapter 6).

The second psychological need that Ryan and Deci (2017) identified as influential for motivation is relatedness. Interestingly, relatedness seemed to be evident when the learners described learning at home but not in the mathematics classroom. The learners describe family members playing key roles in their circles of influence, but not their school peers. The 'falling behind' theme is also relevant here, as the learners describe situations when rather than feeling a sense of relatedness and belonging with their fellow students, they felt 'annoyed cause I couldn't do as well as the other people' (Indigo, Cycle 3, Session 1) and not wanting to ask for help 'because everyone else in the class is like "oh yeah I get it" so I don't really want … to get up and be different from everyone else and ask for help' (Erin, Cycle 1, session 1).

Autonomy is described by Ryan and Deci as 'the need to self-regulate one's experiences and actions' (2017: 10). Increased autonomy can be seen in the actions of Blake and Lynden, who responded to the tools I offered them by taking specific action to include themselves in their mathematics lessons (data in section 6.2.5 of chapter 6) and also by sharing the information I had given them with their teachers, and in the actions of Devon who shared the information form the clinical interviews with her mother (section 6.1.3 of chapter 6). Perhaps the reason why the clinical interviews appeared to have a beneficial impact on their experiences was the autonomy of the learners as evidenced by their actions to develop their competence. The clinical interviews had a beneficial impact on the perseverance and resulting achievement of the learners (section 6.2.5 of chapter 6). The psychological need of relatedness is not evidenced, but this could be because, although I gathered information about the relatedness of the learners, I did not offer any tools to develop relatedness. Future trials of the intervention may benefit from including a tool or strategy which would encourage relatedness in either the clinical interview or the mathematics toolkit, or both. However, the effectiveness of this tool may depend on the learning environment of the institution involved. It does not seem reasonable to expect 11-year-old learners to challenge the ethos of the school if said ethos does not support collaborative learning. To combat this, future trials may wish to deliver the intervention to small groups of learners with similar experiences of mathematics anxiety who could then go on to support each other in their mathematical learning. Although this would not change the ethos in the school, it would provide a safe space for learners to satisfy their need for relatedness.

8.1.3 Well-being

The aspects of learned optimism, confidence and perseverance have been identified as the most relevant parts of mathematical well-being for the purposes of this thesis. Learned optimism was described in chapter two as the individual's responses to either positive or negative experiences, depending on whether they are perceived to be permanent or temporary, influenced by personal or external factors, and caused by general or specific circumstances. With a fixed mindset, as shown by all at the start of the intervention, the learners felt that their difficulties in learning mathematics were permanent, down to personal failings, and caused by mathematics in general. However, the clinical interviews, particularly the elements which involved the Hand Model of the Brain (Siegel, 2010), showed the learners that their difficulties were temporary, as they could then reconnect their thinking brain and re-engage with the learning. Additionally, the input in the clinical interviews on adopting a growth rather than a fixed mindset helped the learners to see that their learning experiences were influenced by external factors rather than any personal inability (section 6.1.3 of chapter 6). Thus, for many of the learners, there was a shift in perceived cause of a lack of progress from personal shortcomings to external factors through the understanding that setbacks and challenges were a necessary part of learning for all learners rather than an indication of personal failing. This shift echoes the findings of Donohoe, Topping and Hannah (2012) who evaluated the impact of an online intervention that was not contextually based in a specific subject and had a slightly larger sample size of 33 pupils and recommended that the effectiveness of interventions in the longer term should be investigated.

The need for the distinction between confidence and self-efficacy can be justified through the comparison of the outward presentation of some learners such as Adam, Erin, Blake and Lynden who appeared very confident in general in the clinical interviews but nevertheless had mathematics anxiety. The identification of confidence as a more global characteristic (Seligman, 1991) and self-efficacy as more localised (Bandura, 1994), even down to a particular task, then enables the learners mentioned above to be characterised as being confident individuals in general but also lacking self-efficacy for mathematical learning. The value of perseverance was demonstrated by Hayden who experienced the benefits of persevering in the growth zone by realising a shift in perspective. Hayden described viewing a task she had initially thought of as difficult as easy once she had accomplished it (section 6.2.3 of chapter 6). Her perseverance resulted in an increase in confidence which in turn increased her mathematical learning capacity (Williams, 2014).

8.1.4 Section Summary

Section 8.1 discussed the findings of this research in terms of the positive psychology areas of growth mindset, agency, self-efficacy, Self-Determination Theory and well-being. The findings support the literature that recognises the importance of building growth mindset beliefs in order to increase agency and self-efficacy. Self-Determination Theory offers an additional layer of understanding to the constructs of agency and self-efficacy in that the human psychological need of autonomy emphasises the importance of internal motivation, an aspect not considered by Bandura who takes a more behaviourist stance. Finally, the section acknowledged the usefulness of the more general terms of optimism and confidence. These more common, but less specific, terms were found to be helpful in describing the more general personality traits of the learners as opposed to their specific level of mathematics anxiety.

8.2 ANXIETY

8.2.0 Introduction

This section considers the findings of the study in the light of the existing literature on general anxiety. In particular, the causes of anxiety and the temperament of those who are prone to anxiety are considered. The understanding that a level of stress need not necessarily be detrimental is shown to be appreciated by the learners. The final part of the section describes how the learners responded to strategies for managing and reducing anxiety.

8.2.1 Why do people get anxious, and who is more prone to anxiety?

This subsection will firstly consider how the literature on why people get anxious is supported or not by the data from this research, and then consider how the literature on who is more prone to anxiety is supported or not from the research data. Recent research has revealed that anxiety is an evolutionary safeguard (Miloyan et al., 2017; Nesse, Bhatnagar & Ellis, 2016). A significant element of the intervention which was developed in this study intended to reassure the learners by helping them understand that anxiety, or the resulting fight, flight or freeze response (Maack, Buchanan & Young, 2014), is not a personal failing but rather a response to an environmental input in the light of previous personal experiences (Siegel, 2010). I shared the information that anxiety could be an understandable response to difficult situations for the learners. The Hand Model of the Brain (Siegel, 2010) supported my explanations, as did further explanation in the first session of each cycle. This approach was productive as, in Hayden's words *'it helps me understand what goes on inside my brain. And … what happens when you get anxious*.' (Hayden, C2, CI 2, L 165). This learner describes the feelings of many others in the sample who had similar experiences. This finding can be explained using various theoretical models. Seligman's theory of Learned Optimism (1991) suggests that this view helps the learner to move to a more optimistic outlook, as they are no longer viewing failings as due to personal causes, but rather as due to environmental factors. Bandura's theory of self-efficacy (1994) suggests that the learner feels a greater sense of self-efficacy through the encouragement of others and is also able to interpret the unpleasant physiological state in a more temporary light. Self-Determination Theory (Ryan and Deci, 2017) suggests that the learner's motivation is increased as their understanding about the nature of anxiety is revised in terms of their perception of their competence: as Devon explains *'it helps you … think that you're not dumb'* (Devon, C1, CI3, L 266). Thus, I would like to claim that the motivation of the learners was increased through the increased satisfaction of their psychological need for competence (Ryan & Deci, 2017) by explaining that they are capable of learning mathematics. They have developed their competence with learning mathematics to enable them to deal with their fight, flight or freeze response.

The second aspect to be considered is how the findings of the research inform the literature on who is more prone to developing anxiety. The distinction of Boyce et al. (2019) of children into dandelions and orchids was supported by the findings of this study that 25 % of the learners experience high levels of anxiety. Boyce's research findings indicated that there will be 15 to 20% of learners who will be more sensitive to their environments. Boyce's research also showed that orchids were more prone to triggering the fight, flight or freeze response. It is not possible to identify the learners who scored the highest levels of mathematics anxiety as orchids in this study as sensitivity was not explicitly measured as part of the research. However, it can be suggested that high levels of mathematics anxiety are correlated to higher levels of sensitivity. This would be an interesting area to pursue in further research, particularly in terms of identifying orchids and their mathematics anxiety scores as compared to other categories of sensitivity.

8.2.3 Is stress always bad?

In chapter two I noted a difference in the terms 'stress' and 'anxiety' and explained that a manageable level of stress can be helpful to focus the attention of the learner and motivate them to learn (Le Fevre, Matheny & Kolt, 2003). The Yerkes Dodson Law (Corbett, 2015) identifies an optimal zone where the stress level is enough to motivate effort but not so much that performance is inhibited. Csikszentmihalyi (1997) describes this optimal zone as being in state of 'flow' and links the fulfilment and satisfaction which result to the perception of the individual of the real or perceived resources available to them. The importance of the perception of the individual rather than the actual facts of the situation is supported by Jamieson et al. (2010), who recommend that teachers support their learners to view stressful events as manageable challenges rather than impossible demands, and to view the resulting physiological effects such as feelings of knots in the stomach as excitement rather than anxiety. I adopted this approach in the clinical interviews by helping the learners to see that being in the growth zone would sometimes feel challenging but ultimately manageable. This was successful, at least for some, as Devon described being in the growth zone as *'it's challenging but I can manage it anyway'* (Devon, C1, CI3, L32).

In addition to the individual's perception of the stressful event being instrumental in their ability to perform in stressful situations, the autonomy of the individual to manage their emotional state is also important. Dhabhar (2018) explains that stressful experiences can improve mental performance, as they increase memory function and increase brain activity, but only if they are time limited. Dhabhar recommends that learners are given the strategies and opportunities to manage the fight, flight or freeze response in order to improve performance. The primary strategy to manage their emotions used in the clinical interviews was the 5/7 breathing, but this did not suit all learners. Blake understood the importance of taking time to calm himself down and decided to do so through drawing. As he describes: *'in my mind, I was saying to myself, draw something, like, thinking of something that I could like, try and make, like, I think I did a reindeer and then I tried to draw a reindeer with all the cracks, and it took my mind of it and then it like… kept me calm. I managed to get onto question… I usually get onto question four or five. I think I got onto question eight or nine.'* (Blake, C1, CI3, L25). In this way, Blake managed his emotional response to this stressful experience and in doing so, improved his performance.

8.2.4 Managing anxiety

There are many ways of managing anxiety. Medication is not the only way to address anxiety, and several alternatives were introduced in chapter two. Dialectical Behaviour Therapy (DBT) was recognised as having a significant influence on the development of the thesis, as this particular therapeutic approach emphasises the importance of the individual recognising their negative thoughts before working to change them (Linehan et al., 1991). This balance of acceptance and change manifested itself in the clinical interviews primarily through the Growth Zone Model (Johnston-Wilder & Lee, 2010) where the first step of emotional management for the learner is to recognise their current emotional state. In order to help the learners recognise, and accept, their current emotional state, I asked them to describe their feelings in each of the zones. An indication of their acceptance of their emotions can be seen by their responses. Some learners were able to describe feelings appropriate to a particular zone and therefore demonstrated radical acceptance (Linehan et al., 1991) of their mathematics anxiety. The app helped by providing a visual portrayal of their emotions. In this example, Blake describes the anxiety which resulted from not understanding the content of the lesson:

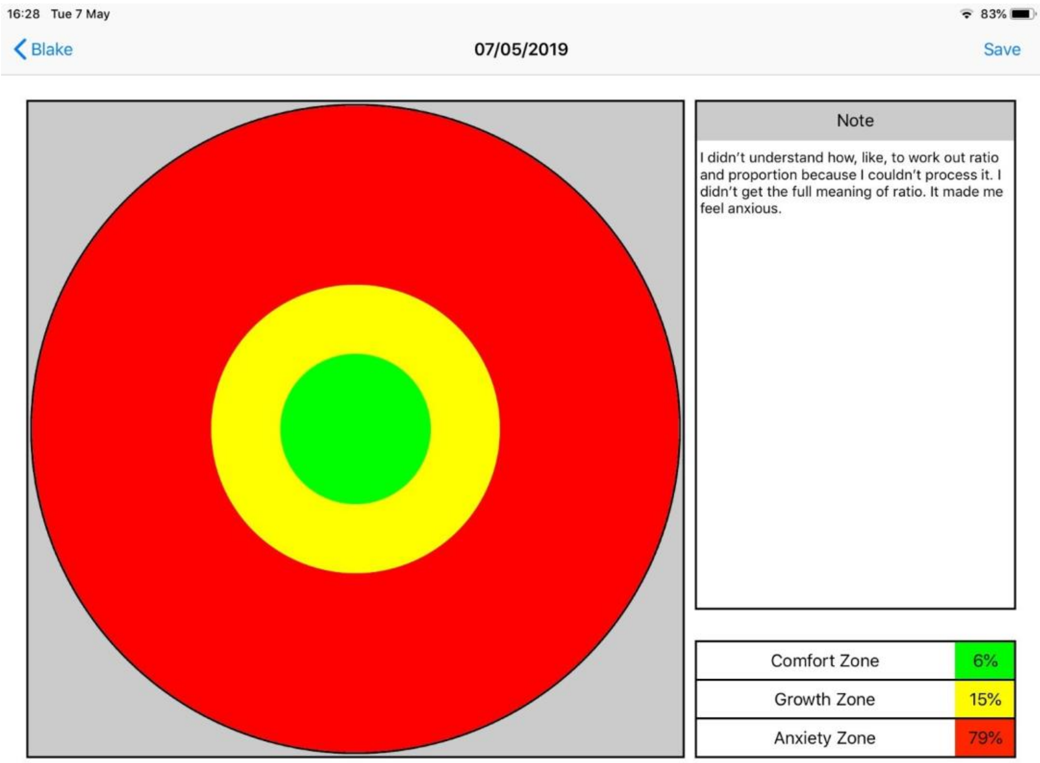


Figure 8. 1 Blake, Cycle 1, Clinical Interview 1

However other learners were seemingly not able to yet accept that they had emotions which could hinder their learning process. Here Adam describes a lesson where he was '*mostly learning*' but then intriguingly finishes the description by saying that he '*didn't suffer any more difficulties*'.

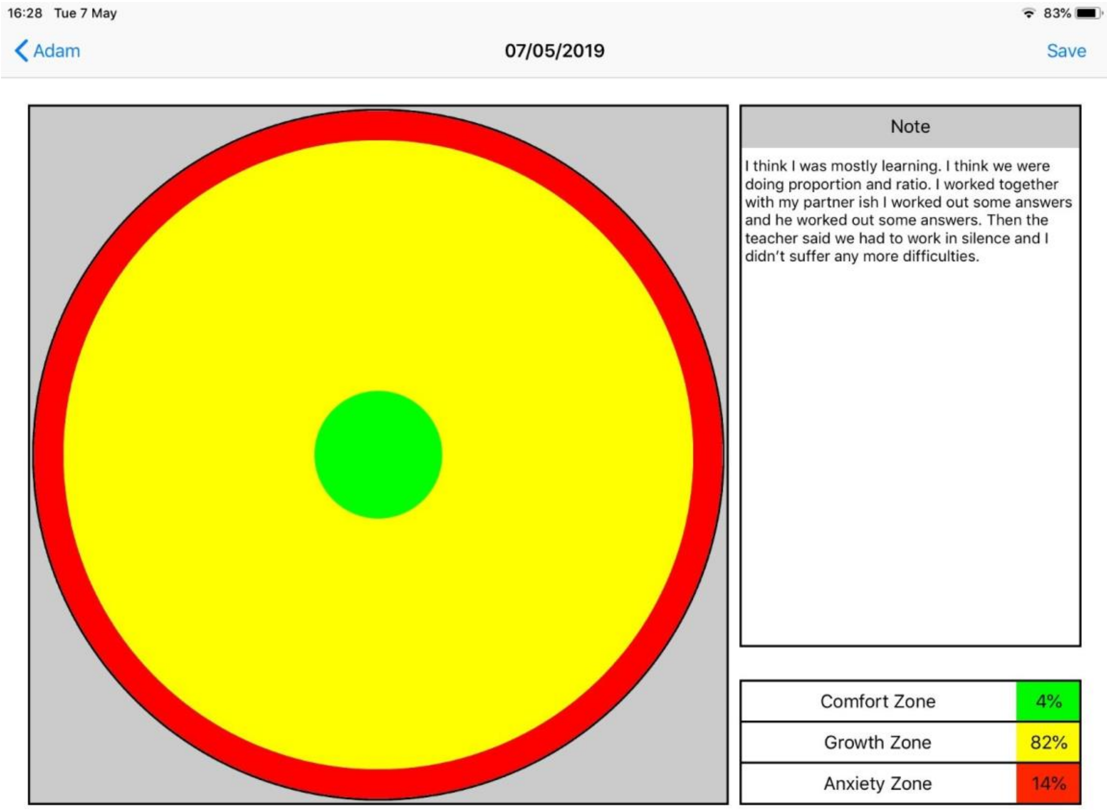


Figure 8. 2 Adam, Cycle 1, Clinical Interview 1

In his next clinical interview, Adam describes his feelings about an upcoming test. It is interesting that instead of saying something along the lines of 'It will be hard, but I will try my best' he says, '*I'm not going to be worrying about it'* (Adam, C1, CI 2, L65*)*. This comment indicates that Adam had not yet accepted that he could sometimes feel anxious. If Adam were able to accept his emotional state and use the GZM as a learning tool, he could be expected to recognise that he would feel anxious about the upcoming test, but that this anxiety would either be manageable in the growth zone or reversible in the anxiety zone.

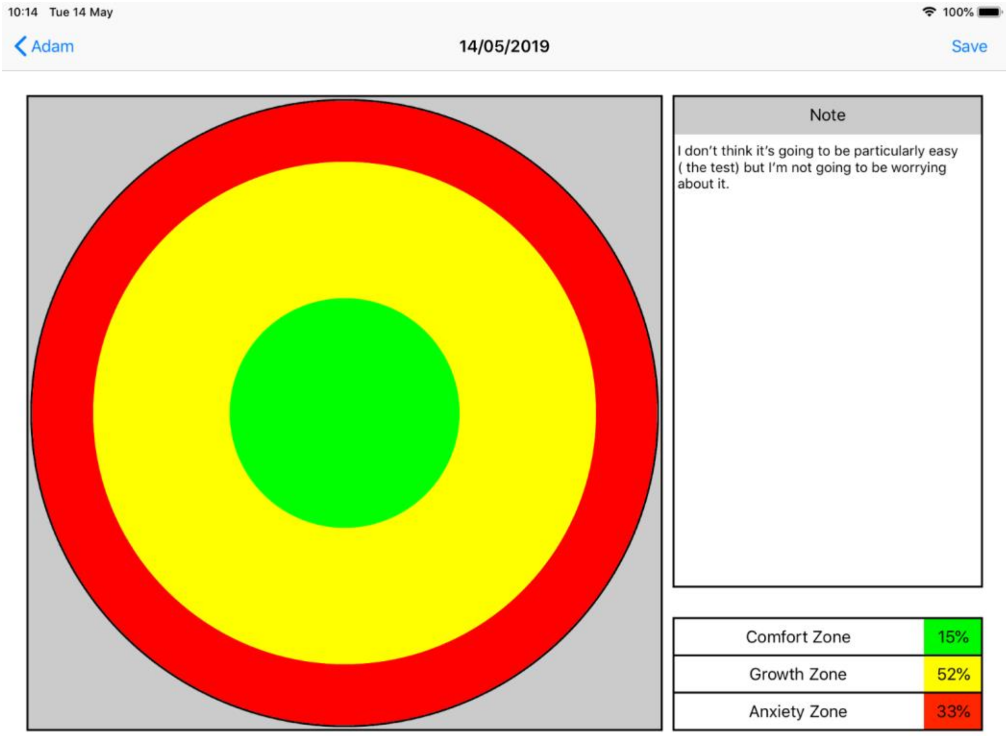


Figure 8. 3 Adam, Cycle 1, Clinical Interview 2

Interpersonal effectiveness is an essential aspect of DBT (Linehan et al., 1991) as the individual is encouraged to identify and address their needs in a proactive manner. Thus, in DBT treatments, the autonomy of the client is valued (Lynch, 2014). Although an inclusion of explicit training for autonomy in the mathematics classroom was outside the scope of this research as it raises many questions around teacher practices and school policies, my questions included an implicit nudge towards increased autonomy which encouraged the learners to consider their possible actions in the classroom. The provision of the maths toolkit further supported this nudge towards increased autonomy, as some learners chose to keep it in their blazer pocket, and others chose to display on their classroom table.

The crisis survival skill of deep breathing, as based on Benson's recovery response (Benson, 1975), was introduced in the clinical interviews and found to be generally helpful. Here Chris explains that *'yesterday I was on the border of anxiety. I did the breathing, and that helped'* (Chris, C1, CI 2, L26). Asking the learners about their experiences with the breathing strategy produced a comment from Devon that typifies the whole essence of this thesis: *'you didn't really know what to do and then you do the breathing and … you think 'oh right that's what I have to do'*, and then '*you see it differently once you calm down'*. (Devon, C1, CI2, L66). However, the breathing strategy did not work for every learner, as Lynden explained that *'the breathing doesn't help that much cause even if I do try and breathe slowly it doesn't wear off the stress that's still on my mind'* (Lynden, C3, CI2, L71).

The crisis skill of distraction (Chapman, 2011) was also employed as an alternative to the deep breathing. I suggested to the learners that they might want to look out of the window in order to gather their composure, which Erin described as *'ignoring the maths'* (Erin, C1, CI1, L100). Several learners came up with an alternative crisis skill that they had arrived at by themselves, through an element of the clinical interviews that had an entirely different objective, the scrumple task (Boaler, 2016). This was the strategy of drawing along the creases in a piece of paper. Blake explained: *'in my mind, I was saying to myself, draw something, and then it took my mind off it and kept me calm'* (Blake, C1, CI3, L15). This outcome, created by several of the learners to meet their individual needs and preferences, may have been encouraged by my approach of recruiting the learners as fellow researchers. In future research, the approach of offering several alternatives to the participants is recommended.

8.2.5 Section summary

This section describes the ways in which the data from this study support the wider literature. The learners were given information about the nature of anxiety and this new (to them) knowledge increased their feelings of competence. The psychological make-up of the learners was not explored in the study, and it was identified as an interesting area for further research. The learners in the study came to appreciate that a mathematical challenge could be a manageable experience rather than a necessarily overwhelming one, and this appreciation depended at least partly on the autonomy of the learner, as did the learner's ability to manage their anxiety.

An interesting yet unexpected outcome of the study is that the ability to manage and overcome feelings of anxiety is useful in all areas of life, as Finley's description of using the strategies to manage anxiety in other situations confirms (section 7.3.2.1 of chapter 7). I suggest therefore that the introduction of these tools should be considered for all learners in all lessons.

8.3 MATHEMATICS ANXIETY

8.3.0 Introduction

This subsection of the thesis considers the findings of the study on the prevalence and causes of mathematics anxiety against that which is reported in the literature. The findings on the prevalence of mathematics anxiety are further broken down into the specific age of the learners, their gender and their previous level of mathematical attainment. The causes of mathematics anxiety are further broken down into personal causes in terms of mindset, agency and self-efficacy, and environmental causes in terms of teacher influence, and to a lesser extent, the influence of parents and peers.

8.3.1 Prevalence of mathematics anxiety

High mathematics anxiety was found in 25% of the 223 learners who were involved in the first stage of the study. To restate from chapter 3, there is a lack of consistency across the scales used to assess levels of mathematics anxiety and the resulting estimates of levels of anxiety, which makes comparison of the findings to the wider literature difficult. However, these learners reported levels of anxiety that are high enough to affect learning and performance (Johnston-Wilder, Brindley & Dent, 2014). A further 20% of the learners reported levels of anxiety which may be invisible but nevertheless still hinder learning (ibid). Combining these groups of high and moderate mathematics anxiety gives a total of 45% of learners which can be compared with the estimate of 59% of the general population, especially when considered in the light of research which indicates that levels of mathematics anxiety increase through secondary school (OECD, 2013; Carey et al., 2019; Maths Anxiety Trust, 2018).

The levels of mathematics anxiety grouped by age as found in this research can be compared to the larger scale Nuffield Report, which identified a high level of mathematics anxiety to be represented by scores over the 90th percentile (Carey et al, 2019) which gives 10%. This normative approach does not reveal the proportion of learners in the study who could be affected by high levels of mathematics anxiety. However, even if just the upper category of high levels of mathematics anxiety is taken to represent the levels of mathematics anxiety in these findings, they are much higher than that of the Nuffield Report. These findings therefore suggest that mathematics anxiety is a worryingly high problem in eleven-year-olds. Further research on a larger scale would illuminate this hypothesis further. As was reported in Chapter 4, this particular age was specifically selected as the learners would have just experienced a large change in their educational provision, namely in the move from primary school where they were mostly taught in the same group, in the same room and by the same teacher, to secondary school, where they are taught in different groups and in different rooms by different teachers. From the findings, mathematics anxiety has a significant effect on learning at this important, post-transition stage of education. It can therefore be concluded that Year 7 is an important point to implement an intervention to address mathematics anxiety, as supported by Walker (2018).

The analysis of the relative mathematics anxiety by gender of the learners proved to be interestingly nuanced. The literature reports that mathematics anxiety is more common in girls, even at the primary school stage (e.g., Griggs et al., 2013; Yüksel-Şahin, 2008; Krinzinger, Wood, & Willmes, 2012; Devine et al., 2012) and the visibility (Ashcraft, Krause & Hopko, 2007; Dowker, Sarkar & Looi, 2016) and impact (Hernandez-Martinez & Pampaka, 2017) of this anxiety increases through secondary school. A comparison of the means of male and female levels of mathematics anxiety in this research supports the literature, in that female learners report significantly higher levels of mathematics anxiety (mean = 27.73) than male learners (mean = 25.59); a difference that was statistically significant ($t(206) = 2.075$, $p = .039$). However, as was explained in chapter 4, personal experience had impressed upon me the importance of recognising that even at the age of eleven, not all individuals will identify as specifically male or female, or may prefer not to give a gender identification, and so the option of ‘prefer not to say’ was given alongside the options of ‘male’ and ‘female’ in the questionnaire. 15 of the 223 learners in the study chose not to identify as a specific gender. When the significance of the means of this small group (mean = 26.47) was calculated alongside that of the larger female and male groups using ANOVA, the findings were not statistically significant (t (2), p = .119). As might be expected, the mean of the group who chose not to disclose their gender fell in between the mean for female learners and the mean for male learners.

These data create a conflict between the usefulness of gender identification working as a proxy for the prevalence of mathematics anxiety in different individuals and the need for research with young learners to recognise the possibility that, for some, asking them to identify as one or the other gender could be distressing or at least problematic. It is therefore suggested that future research categorises participants into alternative categories such as the systemisers and empathisers scale, which includes a neutral category in the middle, developed by Baron-Cohen (2009), for which assessment scales exist. Baron-Cohen recognises that some females can be best categorised as systemisers and equally some males can be categorised as empathisers, and additionally systemising and empathising can be learned across the life span (Baron-Cohen, ibid.). The categories of empathiser and systemiser are therefore neither permanent nor a direct match for gender. The significant difference in gender prevalence of mathematics anxiety can also be explained by stereotype threat (Beilock & Ramirez, 2011) where the majority of female learners conform to the received societal expectations that men are better at mathematics than women.

The frequency of mathematics anxiety grouped by previous mathematical attainment found in this research supported the literature in two ways. The first was that there was a negative correlation between the reported mathematics anxiety of each learner and their reported Key Stage 2 mathematics scores ($r = -.313$, $p < .001$).

Thus, the learners with lower reported Key Stage 2 mathematics scores tended to report higher levels of mathematics anxiety than learners with higher reported levels of Key Stage 2 mathematics scores. This correlation between lower achievement and higher mathematics anxiety is reported in the literature, for example Namkung, Peng and Lin (2019) report a Pearson's Rank coefficient of -.34 from a meta-analysis of 131 studies of school aged students, a level that is only slightly above that found in this research.

The second result of the research that is supported by the literature is that mathematics anxiety affects learners at all levels of achievement (Foley et al., 2017). Despite this negative correlation between achievement and mathematics anxiety, four learners who reported a Key Stage 2 mathematics score of over 110, the highest quartile of this national test, reported moderate levels of mathematics anxiety and a further four learners who scored over 110 in their Key Stage 2 test reported high levels of mathematics anxiety. The impact of these results on learning will be further discussed later in this chapter, but it is suggested that these learners would have achieved higher levels if they were not contending with mathematics anxiety whilst completing their tests.

8.3.2 Personal causes of mathematics anxiety

The personal causes of mathematics anxiety that emerged from the clinical interviews can be characterised as a lack of self-efficacy (Bandura, 1994) although some of the learners reported a developing level of resilient self-efficacy, by being encouraged by teachers for example. Devon reported "*feeling dumb*" (Devon, C1, CI3, L193) in mathematical learning situations, thereby demonstrating her perception that she lacked mathematical ability. However, she also described being encouraged by a teacher "*And then the teacher, was like, no, you're not, you just need to have faith in yourself"* (Devon, C1, CI3, L194). Her teacher was building her self-efficacy through persuasion, one of Bandura's four sources of building self-efficacy, in this description. Adam reported a similar experience "*well I never had, really much confidence in myself even in primary school, but I had a teacher that helped me, um, she believed in me and then, made me a better, made me more confident in maths*" (Adam, C1, CI1, L30).

Adam uses the word 'confidence' in his description, but it has been here interpreted as self-efficacy as the state is improved by persuasion and is particularly focused on mathematics. Confidence is a more global characteristic than self-efficacy (Seligman 1995, Williams 2014) whereas self-efficacy is particular – even down to a particular task. It may be that Adam has issues with both, as 'mathematics' is quite a broad area.

The clinical interviews also revealed the prevalence of fixed rather than growth mindsets in the learners (Dweck, 2017). Erin indicated her expectation that her mother's mathematical ability would be passed down to her through her DNA when she said, '*why didn't I get that gene?'* (Erin, C1, CI3, L181). Other learners indicated their assumption that their lack of understanding was a problem rather than a challenge when they said '*I don't know if I don't understand it or I just don't like it or what'* (Adam, C1, CI1 L36); '*and you don't understand so you're not gonna be good at it.'* (Devon, C1, CI2, L171). Here, Adam and Devon demonstrated a fixed mindset, in that they see mathematics as something to be understood, or not, immediately rather than something that can be understood after engagement and effort. George demonstrated a limitation with mindset teaching, in that he misinterpreted Dweck's conception of the construct. George felt that his lack of achievement was doubly his fault, in that he not only did not achieve enough but also failed to put enough effort into the process of learning. He was therefore putting more pressure on himself as the learner as he had the perception that he just needed to try harder. It was doubly his fault as he felt expected to achieve at mathematics and also expected to have a growth mindset, which he interpreted as trying harder. *'So basically, that proves that if you try, you can actually get good marks. And if you don't try, well that's your fault.'* (George, C2, CI2, L96). This misinterpretation of the growth mindset construct has been latterly recognised by Dweck (2017) who now emphasises the importance of teachers, parents and others having a clear focus on the learning process rather than the amount of effort expended. George may have benefitted from having a range of strategies to use rather than expecting just to try harder.

8.3.3 Environmental causes of mathematics anxiety

The main source of the environmental causes of mathematics anxiety reported in this research came from teachers and their teaching styles. This is not surprising as it is both reported in the literature (Maloney, 2013) and focused on in the clinical interviews, influenced as they were by the age of the learners and the nature of the questions asked. Maloney, Schaeffer & Beilock identify the problem with teaching styles as being a "high demand for correctness with little cognitive or emotional support" (2013:117). This high demand for correctness is typified by Erin's comment that her teachers (in her previous school) *'told me off for not getting it'* (Erin, C1, CI1, L19). George was reprimanded for not listening: *'Because I couldn't listen, I couldn't do anything. It was too frustrating, and I eventually needed help doing it and the teacher told me off for not listening, when I really needed to, I just couldn't pull my brain together'* (George, C2, CI1, L253).

George's teacher seems to misinterpret his non-compliance as wilful disobedience rather than the result of the fight, flight or freeze response. This apparent lack of understanding on the part of the teacher of the impact of emotions in learning, a situation where the handbrake metaphor would be appropriate (Johnston-Wilder et al., 2014), will be discussed further in section 8.4.3 below.

A further aspect of negative teaching styles is the discouragement of collaboration *'we both get into trouble for talking'* (Erin, C1, CI1, L149) and the teacher's explanations '*The teacher explains it to me. But I don't exactly get it cause she's a bit complex the way she explains it.'* (Blake, C1, CI2, L138). It is important to note here that there is no blame intended on individual teachers. As a teacher myself, I understand the pressure that many teachers feel from their Senior Management Team, Ofsted, parents and others. Having acknowledged the difficult situation that many teachers find themselves experiencing, the findings of this research indicate that further research is suggested to improve the consistency of good teaching practice which takes account of the need for psychological safety (Rohnke, 1989).

One learner described the impact of parental actions on his mathematics anxiety. *'When I'm anxious, I think of the consequences of when a letter goes home saying I've done no work because I'm anxious, and how my parents are gonna punish* *me'* (Lynden, C3, CI1, L75). Parental expectations are often reported in the literature as unhelpfully low expectations (Goodall & Johnston-Wilder, 2015) such as 'we are not a mathematics family', or 'girls don't need to be good at mathematics'. However, in this case, Lynden's anxiety is exacerbated by the worry that his parents' unhelpfully high expectations will result in him being punished.

8.3.4 Falling Behind – the vicious cycle of mathematics anxiety

Alongside mathematics anxiety being caused by personal and environmental factors, a third cause unexpectedly emerged through thematic analysis of the qualitative data. I named this cause 'falling behind' to capture the essence of the learners' experiences. The learners describe situations where their lack of understanding results in a failure to meet the expectations of teachers: *'I just didn't want to get told off for not doing enough work because I can't help not doing enough work when I don't understand it.'* (Chris, C1, CI1, L66). The theme seems to involve both environmental and personal causes in that the trigger is the interface between the learner's perceived capability and their perceived expectations. However, this cannot be explained simply through a lack of self-efficacy, as the learners vividly describe situations where their perceived expectations seem to be both accurate perceptions on their part and unreasonable expectations on the part of the teacher, hence the connection with environmental causes. An additional aspect to the situation is that these feelings, although initially caused by personal and environmental factors, are likely to impact on performance, by hindering the capacity of working memory (Foley et al., 2017; Jameson, 2010; Beilock & Ramirez, 2011) and adding an additional cognitive burden (Maloney, Schaeffer & Beilock, 2013). This can then result in a decrease in motivation on the part of the learner to engage with mathematics, further exacerbating the level of mathematics anxiety as they fall behind the other learners in their class.

The anxiety of the learners was seemingly further increased by concerns over appearing to be different. Erin describes feeling the need to conform with her classmates, thereby choosing not to recruit help: *'Well, I still don't, really, ask for help, because everyone else in the class is like 'oh yeah I get it' so I don't really want … to get up and be different from everyone else and ask for help'* (Erin, C1, CI1, L38), while Indigo describes feelings of annoyance as she compared herself negatively to the achievements of her classmates : *'Bit annoyed cause I couldn't do as well as the other people'* (Indigo, C2, CI1, L69). These descriptions indicate that the culture of their classroom learning environments is encouraging an isolated learning experience (Nardi & Steward, 2003) rather than an inclusive and engaging (Johnston-Wilder et al., 2015) learning experience.

The learners described situations where they felt that they were falling behind the progress of their classmates and were struggling to catch up: *'like, even when Miss tries to explain it, in like, stats, I just can't, 'cause it takes me time to process one method and then by the time I've processed that, I've got another two methods to process. And I just, can't really, get it in my mind.*' (Blake, C1, CI1, L29). This lack of appropriate time to consolidate the learning is compounded by the speed of curriculum delivery: '*[the teacher] explains one thing and I just can't… seems like I can't get it the first day, but the second day I just get it all and I can do it really easy. But then my teacher moves on to another subject so it's like I never get the chance to* *improve, and I never get the chance to learn or anything'* (George, C2, CI1, L63). The feeling of falling behind is also exacerbated by an increase in difficulty of the mathematics, as Max and Lynden describe: *'Um, it's got harder, but like some of the stuff I don't really understand that much. It just like makes me a bit sad sometimes'* (Max, C3, CI1, L45); *'I thought that it would only get a little bit get harder. At the start of the year I was ok cause we were doing stuff that I knew and we kept expanding that little bit. But, um, all of a sudden, we're jumping out of nowhere like, y equals something on a grid, or stuff that I never even actually did in primary school and it's just that massive jump that made me feel uncomfortable'* (Lynden, C3, CI1, L68). These learners are in danger of losing motivation (Ryan & Deci, 2017) as their psychological need for competence is threatened by the comparison with their more successful classmates. The problem of learners falling behind their peers despite starting from similar levels of achievement, is supported by the literature on education in general (Crawford, Macmillan & Vignoles, 2017) and for mathematics anxiety in particular (Ashcraft & Moore, 2009).

The other psychological needs of autonomy and relatedness (Ryan & Deci, 2017) are also threatened; if the learners felt an adequate level of autonomy, then they would be able to take appropriate action to address the problem of falling behind their classmates, and if they felt an adequate level of relatedness then they could recruit appropriate support, either from their classmates or from the teacher. An exception to this conclusion can be seen in Hayden's comment: '*well, in primary school I found it, like, hard to catch up, and I did ask for help a bit. Here, I'm asking for help a bit still, and finding it hard to catch up still'* (Hayden, C2, CI1, L34) where even with the evident capacity for autonomy and relatedness to ask for help, she continues to fall behind her classmates. Every learner apart from Finley (whose main concern at the time of the clinical interviews was to do with family issues) described negative feelings surrounding the experience of not understanding the content of the lessons.

To draw an analogy with situations in the outward-bound context of physical education, if a class of pupils was on a mountain hike and a few stragglers were struggling at the tail end of the group, then it is reasonable to expect that no pupil would be left behind, as a principle of good teaching; see, for example, Outward Bound (2021) and to meet Health and Safety Guidelines (Council for Learning Outside the Classroom, 2021). In the mathematics classroom, learners are arguably experiencing harm, through feeling '*sad*' (Max), '*uncomfortable*' (Lynden) and '*annoyed'* (Indigo) and being left behind in the learning process. Suggestions as to strategies which might help these learners and others in similar situations include the use of an element of Dialectic Behaviour Therapy (Linehan, 1991), where the mindfulness approach of 'being' is prioritised over 'doing'. 'Being mathematical' would be having an awareness of the present moment, where learners are given the space and time to think and learn, and thus develop a growth mindset (Dweck, 2017) as opposed to' doing mathematics, where the learners have a focus on achieving. To address the problem with understanding, the teachers could scaffold their teaching more effectively, but also the learners could be given the analogy of scaffolded learning (Bruner, 1967) to help them identify for themselves where they need additional support, and then shown possible strategies to recruit effective support. This approach would help the learners who felt that they were 'falling behind' their peers (section 7.2.3 of chapter 7).

8.3.5 Managing Mathematics Anxiety

The importance of both preventing mathematics anxiety and addressing it once it has occurred is recognised and supported by the findings of this research. To reiterate the findings of Beilock and Ramirez (2011), there is clearly more work to be done in the area of preventing mathematics anxiety, as can be seen by the high (25%) and moderate (20%) levels of mathematics anxiety which were reported in this research by eleven-year-old learners in 2019. It can be concluded that, as these learners have inhibiting levels of mathematics anxiety, they have not been protected from possible mathematics anxiety enough through effective preventative measures.

However, the second stage of this research indicates that mathematics anxiety can be addressed with only two hours of personal intervention. The learners involved developed the ability to *'think about how big the anxiety bit is, how big the growth is, am I learning a lot, or do I need to calm down'* (Erin, C1, CI3, L149). Their personal self-efficacy was developed, through the introduction of neurological information that helped them to *'understand what goes on inside my brain, and what happens when you get anxious'* (Hayden, C2, CI2, L165) which enabled them to re-evaluate their previous assessment of their abilities to help them *'think that you're not dumb'* (Devon, C1, CI3, L260). The learners gained a greater awareness of their emotional state so that they could *'understand more what I'm feeling when I do maths'* (Hayden, C2, CI2, L162) and were given strategies to return to a state of optimal learning by thinking '*about how big the anxiety bit is, how big the growth is, am I learning a lot, or do I need to calm down'* (Erin, C1, CI3, L149). This finding is supported by Jamieson et al., (2018) who had similar results to an intervention which encouraged participants to change the assumptions they made about their current situation and reframe their approach.

The focus of this research was on the learner rather than the practice of teachers (e.g. Mitchell & Carborne, 2011), or the learning environment (e.g. Baker, Cousins & Johnston-Wilder, 2019). The intervention attempted to address the attitude of the learners towards mathematics and to suggest practical tasks to alleviate mathematics anxiety but the main focus on the intervention was on emotional regulation strategies. To address the attitude of the learners towards mathematics, they were encouraged to refocus their mindsets from fixed to growth (Boaler, 2016) by appreciating that making mistakes is a useful part of the learning process '*[when I made a mistake] I thought a couple of times, well, that's a neuron in my brain connected'* (Adam, C1, CI3, L32). Mindful drawing emerged as a helpful strategy alongside a focus on breathing *'after I'd done the breathing and I was fine again'* (Erin, C1, CI3, L61) which has previously been shown to be an effective way of managing mathematics anxiety (Brunye et al., 2013). The findings of the research on the use of emotional control strategies will be considered in more depth later in this chapter.

8.3.6 Section Summary

The findings of this research on the prevalence of mathematics anxiety in eleven-year-olds suggest that this debilitating condition should be more actively addressed in schools. The first step would be to measure the levels of reported mathematics anxiety in each cohort. Although mathematics anxiety negatively correlates with mathematics achievement, the existence of learners with both high levels of mathematics achievement and high levels of mathematics anxiety suggests that mathematics achievement should not be used as an indication of likely mathematics anxiety.

Mathematics anxiety is alleviated by the promotion of growth mindsets (Dweck, 2017) although the introduction of this helpful construct should be carefully and sensitively executed to avoid the learners feeling even more pressure to succeed. Self-efficacy (Bandura, 1994) can be developed through the encouragement of significant others and through the informed management of physiological effects of anxiety. The effect of some teaching styles continues to exacerbate the problem of mathematics anxiety for some learners even at the primary school stage, but the main problem at the secondary school stage, as suggested by the findings of this research, is the issue of learners feeling an increase in mathematics anxiety as they struggle to learn at the same pace as their classmates, and fear being left behind. The identification of a range of causes of mathematics anxiety could suggest that different tools are required to address the impact, but a more holistic approach is indicated by the recognition of the vicious circle (Carey et al., 2019) involved with mathematics anxiety causing a reduction in engagement which in turn causes lower achievement which then increases mathematics anxiety.

8.4 LEARNING MATHEMATICS

8.4.1 Introduction

This section considers the ways in which the findings which emerged from the study were supported or not by the literature on mathematics education. The main finding which related to theories of learning was support for the importance of scaffolding learning, as proposed by Bruner (1967), and explained below in subsection 8.4.2. The evident need for at least some learners to experience a supportive and empathetic learning environment was seen in the research, and this will be explained further below in subsection 8.4.3. The section concludes by considering the construct of mathematical resilience in the light of the data. Support for all aspects of the construct is explained, and the subsection continues by reframing the Growth Zone Model (Johnston-Wilder & Lee, 2010) as a dynamic rather than static model, requiring autonomy of the learner, their awareness of their emotions and then appropriate action to manage those emotions.

8.4.2 Theories of learning

A significant outcome of the research in terms of theories of learning was support of Bruner's scaffolding construct (1967). Having a lack of appropriately structured supports in the form of teaching that explains the concepts at an appropriate level is akin to the learner trying to climb a ladder with spaces that are too big between the rungs. When learning to climb, it is important to have a reach that is challenging yet manageable.

Fig 8.1 is a photograph of my granddaughter Adeline learning to climb. Because the distance between the rungs, or in this case, the hand- and footholds on the slope, were just about achievable for her at this stage in her development, she was able to climb the slope and gained a great deal of satisfaction in the process.

Figure 8. 4 Adeline learns to climb, R. Baker-Frampton

However, had the hand- and footholds been farther apart, she would not have been able to climb. Similarly in the mathematics classroom, if the steps are too challenging for the learner to achieve, then no learning can take place. However, this situation can be addressed by more rungs being inserted, so that the stretch is achievable, as illustrated in Figure 8.5.

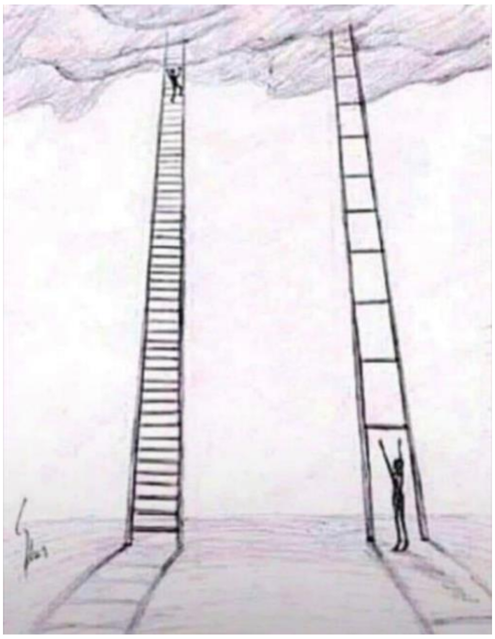


Figure 8. 5 The Ladder Model (Johnson-Wilder, 2020)

Several of the learners described situations that suggest that the teacher did not scaffold the learning appropriately: *'The teacher explains it to me. But I don't exactly get it cause she's a bit complex the way she explains it.'* (Blake, C1, CI2 L138); *'it's been awful. At the start of the year I was ok cause we were doing stuff that I knew and we kept expanding that little bit. But, um, all of a sudden, we're jumping out of nowhere like, y equals something on a grid, or stuff that I never even actually did in primary school and it's just that massive jump that made me feel uncomfortable. And it makes me anxious."* Lynden, C3, CI1, L68). This issue relates back to the autonomy (Ryan & Deci, 2017) of the learner in that it cannot be the sole responsibility of the teacher to decide on the size of the gap. If the learner has the autonomy to do so, they are in the best position to decide on the optimal distance of the next step.

8.4.3 Improving learning

This subsection will consider the findings of the research as they relate to current theories of learning. It must be noted that the focus of this study was not on the learning environment or to improve teaching practices, however some issues emerged which may be suitable for consideration in future interventions. The learners described experiences of learning that were best described by Nardi and Steward (2003) as TIRED – Tedious, Isolated, Rote, Elitist and Depersonalised: *'we both get into trouble for talking'* Erin, C1, CI1, L149). Johnston-Wilder et al. (2016) later revised 'TIRED' to be 'TRIED' to acknowledge that, for some learners, an isolated, rote, depersonalised teaching process is an effective learning environment. However, this approach does not work for all (Nardi & Steward, 2003), and in order to flourish mathematically, those learners who tend towards the empathising end of the systemising / empathising scale may require a teaching approach that is described by Johnston-Wilder et al. (2015) as ALIVE – Accessible, Linked, Inclusive, Valued and Engaging. The ALIVE approach promotes the importance of collaboration and discussion to encourage relational understanding (Skemp, 1986) based on constructivist teaching (Askew et al., 1997) rather than rote learning.

8.4.4 Mathematical resilience

Chapter 3 explained the relationship between mathematics anxiety and mathematical resilience, in particular that, although a higher level of mathematical resilience would help to address mathematics anxiety, the relationship was not directly inverse in that the two constructs could coexist. The resilient learner of mathematics will recognise their mathematics anxiety and actively manage it through the deployment of selected emotional management strategies (Johnston-Wilder & Lee, 2010).

The construct of mathematical resilience initially involved four aspects, which are a growth mindset, valuing mathematical knowledge, perseverance and recruiting support (Johnston-Wilder and Lee, 2010). Johnston-Wider and Lee (2020) now recognise that the learner will also need to know and use coping skills in order to develop as a resilient learner of mathematics. When preparing the plan for the clinical interviews, I identified two of the initial four aspects, namely growth mindset and valuing mathematics, as necessary preconditions which I assumed should be established first before moving on to the other initial aspects of perseverance and recruiting support. This assumption came from my experience as a mathematics teacher but was not based in robust research. The results from the clinical interviews confirmed this assumption, in that the stage of establishing a growth mindset (as part of the wider characteristic of learner agency) worked well in its placement at the start of the first session, as is indicated by Table 6.1 in chapter 6, and Devon's comment that '*it helps you think that you're not dumb, you just need more help to encourage you.'* (Devon, C1, CI3, L260).

The learners reported varying levels of value for mathematics. Adam identified as academic but not mathematical when he said *'I feel I'm more of an English person than a maths person. You know, I prefer writing, I'd like to be an author when I'm older.*' (Adam, C1, CI1, L203). Whereas George expressed more of an appreciation of the value of mathematics when he said *'I know maths is one of the most important subjects. I know I'm gonna need it in my life'* (George, C2, CI1, L244). This comment indicates the motivational stage of integrated regulation (Ryan & Deci, 2017) rather than intrinsic motivation, as George does not inherently enjoy mathematics but appreciated that it will be of value later in his life. The clinical interviews did not take any steps to increase the value of mathematics to the learners, so this aspect was evaluated but not developed. The reasons behind this were that this aspect, although important, fell outside the scope of the research which aimed to support learners in addressing existing mathematics anxiety.

The other two aspects of a resilient learner of mathematics are perseverance and the ability to recruit support (Johnston-Wilder & Lee, 2010). The learners were given tools to manage their emotions which in turn allowed then to persevere with their learning: *'I felt like I got onto a lot more questions, by taking my time and trying not to worry as much'* (Hayden, C2, CI2, L26). *'I managed to get onto question… I usually get onto question four or five. I think I got onto question eight or nine.'* (Blake, C1, CI3, L32). In the last clinical interview, the learner's attention was drawn to the options available to them in terms of recruiting support, and they reported mainly getting this support from their families rather than their fellow learners. Indeed, several learners reported that they were discouraged from communicating with other learners in class situations *'we both get into trouble for talking'* (Erin, C1, CI1, L149).

The view of a resilient mathematical learner that emerges from this research is a little different from that of Johnston-Wilder and Lee (2010), perhaps because it is based on the individual learner rather than the class learning environment. This view takes the form of a series of steps, where the autonomy of the learner is the foundation, with emotional awareness as the next step, and the final step being the need for appropriate action to enable optimal learning. An integral element of this process is the Growth Zone Model (Johnston-Wilder & Lee, 2010) which has proved to be very efficacious in enabling both emotional awareness and emotional management, thus empowering the learner to increase their agency to develop competence and relatedness (Ryan & Deci, 2017). This model has been reframed as a dynamic process which encourages and enables the learner to move towards the growth zone and then learn to safeguard themselves in order to remain in the growth zone, which is the optimal learning situation. This reframed model will be introduced and explained in depth in the next section.

8.4.5 Proposed development of Growth Zone Model and Explanation of the 3As model

8.4.5.0 Introduction

This section describes and explains the '3As' model which was developed as an outcome of this research. The model is a representation of the factors which promote the ability to blossom in the growth zone, or in other words to be a resilient learner of mathematics. The model is depicted, and then each aspect is described. Finally, the manner in which each aspect connects together is explained.

8.4.5.1 Image of model

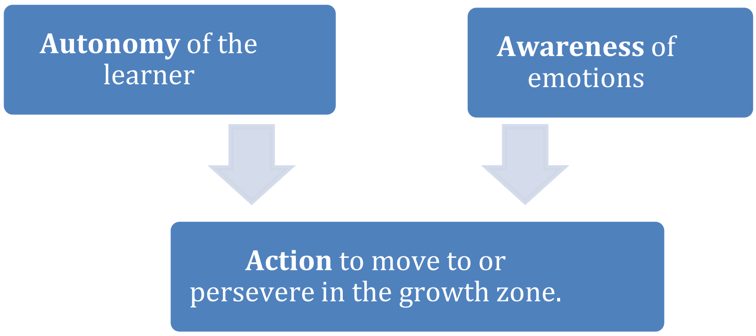


Figure 8. 6 The 3 A's - Flowchart to describe the development of resilience for learning mathematics.

8.4.5.2 Autonomy

The first element of the model to be considered requires the learner to have autonomy in their learning environment. This means that they have both the capacity and the permission to take action when they have identified the need. This step is a prerequisite before the learner is in a position to take action for various reasons. The first reason is that, as explained in section 2.1.2 of chapter 2, the psychological need for autonomy, or control over behaviour, is an integral aspect of motivation and self-determination (Ryan & Deci, 2000), as is the need for psychological safety (Newman et al., 2017). Additionally, although the teacher has an important role to play in motivating the learner and supporting their emotional management, mathematics anxiety can be hidden and triggers can be unexpected, so it is realistic for the learner to notice and act as well as the teacher. This learner involvement has been evidenced in eleven-year-old learners but could also occur with younger learners. Lastly, the learner will experience frustration if they are aware of feeling anxious but are unable to address this feeling (Durmaz & Akkus, 2016). In extreme cases, this frustration can then be seen in behaviours such as throwing chairs (Johnston-Wilder et al., 2015).

Learner autonomy is either strengthened or limited by internal and external factors. Internal factors include the confidence of the learner (Seligman, 1995), their previous experiences (Veresov, 2017) and whether they have a growth or fixed mindset towards learning mathematics (Dweck, 2006). External factors include the environment in which mathematics is being learned, specifically the relationship with the teacher (Dowker, 2016).

8.4.5.3 Awareness

Learners also need to be aware of their emotional state as a lack of awareness of emotions will not enable them to be addressed, and these emotions can limit learning (Findon & Johnston-Wilder, 2018), as has been explained more fully in section 3.1.2. Becoming aware of emotional states that are detrimental to the learning process allows the learner to take the necessary steps to address them, for example through recovery breathing (Benson, 2000).

However, supporting a learner to become aware of their emotional state is not quite as simple as it first appears. Learners may deny that they have maths anxiety because they feel it is not acceptable (Dowker, Sarkar & Looi, 2016), or that the feelings are too distressing (Linehan & Wilks, 2015). Dialectical Behaviour Therapy (Chapman et al., 2011) uses the term ‘radical acceptance’ to mean awareness and acceptance of difficult feelings balanced with a willingness to make realistic improvements (Linehan & Wilks, 2015). The research described in this thesis found that the Hand Model of the Brain (Siegel, 2010) was a useful tool to remind learners that a detrimental emotional state is neither a reflection on their mathematical ability nor a permanent situation, and therefore worth recognising and addressing.

Once the learner is prepared to radically accept their emotional state, the Growth Zone Model (Johnston-Wilder & Lee, 2010) can be used to examine that emotional state. Use of the Growth Zone Model (GZM) can be prompted by the teacher, the learner, supportive adults such as parents or teaching assistants, or by the teaching materials themselves. Depending on which zone the learner identifies as representing their current emotional state, the appropriate action can be taken.

8.4.5.4 Action

The action which would optimally be taken by the learner differs depending on the zone identified as representing their current emotional state. If the learner is in the anxiety zone, then they will need to recover from that state. This is not the time to be engaging with the mathematics, as the fight, flight or freeze response has been activated in the brain and the emotions have taken control. Rather action is needed here to rest and recuperate, perhaps by Benson's recovery breathing, or perhaps by doing some calming drawing. Autonomy again supports this stage as the learner needs to have, and know they have, the freedom to stop focusing on mathematics and proactively address their emotional needs (Johnston-Wilder et al., 2020).

If the learner identifies that they are in the comfort zone, then they will be comfortable but not learning much. An appreciation of the value of mathematics will encourage them to creep out of the comfort zone and into the growth zone, (Johnston-Wilder & Lee, 2017) so that they appreciate that the effort is worth it and therefore develop autonomous motivation (Ryan & Deci, 2000). In addition, in order to creep out of the comfort zone, learners should be ready to struggle and appreciate that this struggle is experienced by many (Johnston-Wilder & Lee, 2017). Learners should also be ready to take risks (Jain & Dowson, 2009).

Even if the learner is already in the growth zone, they will need to take action to blossom in this zone. They will need to know that they can learn from their mistakes (Jain & Dowson, 2009) and so should feel able to take risks, and that learning mathematics often involves struggling to understand concepts but that this is to be expected (Mason et al., 2010). In this zone, the four areas of mathematical resilience come into play, namely valuing the effort of learning mathematics, having a growth mindset, being prepared to struggle and having the autonomy to recruit support, from wherever is most helpful for them (Johnston-Wilder & Lee, 2017).

8.4.5.5 The whole process

The process is hierarchical as autonomy and awareness are the foundations of and prerequisites for action. Autonomy is required for the action step as, no matter which zone the learner identifies as representing their emotional state, a proactive approach is required.

The action stage is in a dynamic and continual loop with the awareness stage, as the learner regularly reviews their emotional state and takes appropriate action. The movement is towards and within the growth zone, towards as learners correct back into the growth zone from the comfort and anxiety zones, and within the growth zone as they seek to widen it in the sense that they can cope with more uncomfortable emotions whilst still learning. Ideally, the teacher or another person acting as a coach should scaffold this process in manageable steps, which can then become internalised, so the learner learns to act for themselves, or request or recruit support from peers or teachers.

The revised Growth Zone Model can be seen in Figure 8.7. Before each section or zone of the model is described in depth, however, a new flow chart which accompanies the model is described and explained.

Effective use of the Growth Zone Model requires that the learner firstly has the autonomy and self-efficacy to proactively manage their emotional state. The autonomy of the learner will depend on the learning environment (for example, whether the learner is permitted to talk to their classmates to recruit support) as well as their personality and general confidence levels. The self-efficacy of the learner for particular tasks will depend on their mindset, as a growth mindset will enable them to understand that even if they cannot understand or answer yet, they will be able to do so with enough time and support, and through the use of this process itself. The Hand Model of the Brain (Siegel, 2010) is an effective tool for educating learners on the neurological process involved in learning.

Secondly, the learner needs to be aware of their current emotional state, and to regularly assess this state. The original version of the Growth Zone Model (Johnston-Wilder and Lee, 2010), either in the form of the app or the Maths Toolkit, is an effective way to enable learners to monitor their emotional state. If the first and second requirements are in place, then the learner can take the third step, which is the action to move into the growth zone from either of the two outer zones, or to self-safeguard and support their continued state in the growth zone. The model shown in Figure 8.7 below describes the requirements for each of these actions.

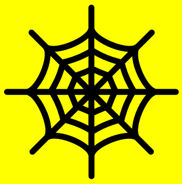
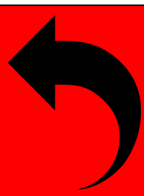
 Creep out of comfort	 Blossom in growth	 Recover from anxiety
Requires: Awareness of lack of challenge Resilient self-efficacy for mathematics and learning mathematics Aware of value of mathematics	*Requires:* Resilient self-efficacy for mathematics and emotional regulation Awareness of value of mathematics Awareness of likelihood of struggle, to seek support and recover from anxiety	*Requires:* Resilient self-efficacy for emotional regulation Emotional regulation strategies Cliff to beach - confidence of recovery

Figure 8. 7 Revised Growth Zone Model (after Johnston-Wilder & Lee, 2010)

Figure 8.7 shows the revised Growth Zone Model, which has been developed from the original Growth Zone Model of Johnston-Wilder and Lee (2010). This model is characterised by an expectation of dynamic movement rather than a static indication of current state. Assuming that the learner has adequate autonomy to carry out the actions in their learning environment, the self-efficacy on both emotional regulation and mathematics, and that they are aware of their current emotional state, then they can move from comfort or anxiety to growth, or proactively maintain their position. Each of the three zones involved in the model will be described in detail and related to existing literature and the supporting data from this study in the next section.

8.4.5.6 Recovering from anxiety

In order to recover from anxiety, the learner firstly needs to be aware of their emotional state. This can be developed by exploring the language to describe feelings with the learners, such as feeling *'anxious'* (Blake, C1, CI1), *'angry'* (Erin,C1, CI3), or *'frustrated'* (George, C2, CI1) as suggested by Lee & Johnston-Wilder, (2017) and Lee et al., (2018). The emotional regulation then requires a form of self-efficacy called resilient self-efficacy (Bandura, 1990a), which involves the degree of self-efficacy being actively developed through training and practice. Learners recovering from anxiety can build resilient self-efficacy by practising their recovery from anxiety and learning that being anxious is not a permanent state but can be reversed (Seligman, 1991). One learner used Siegel's (2010) Hand Model of the Brain effectively and *'knew in my head it was flipping back and forth and I was just reminding myself that it's just the brain'* (Blake, C1, CI2, L63). Another learner demonstrated resilient self-efficacy in her confidence that the tool of Recovery Breathing (Benson, 1975) would be useful: *'I didn't understand this question, I was feeling a bit…' and I was thinking 'ok, so I think the anxiety bit's like massive, so I should start breathing'.* (Erin, C1, CI2, L31).

8.4.5.7 A Personal Insight

My personal use of the Growth Zone Model gave me an additional insight, where I experienced the change in perspective of the boundary between the growth and anxiety zones changing and created the analogy of moving from a cliff to the beach. I volunteered for a university charity called 'Warwick in Africa' and worked in two locations in Tanzania as a mentor for mathematics teachers. As a confident presenter but cautious traveller I knew beforehand that this experience would be challenging in many ways for me, and that I would have to monitor my emotional state and take steps to recover from the anxiety zone on a regular basis. When reflecting on the trip with colleagues upon my return, I came to realise that while I originally viewed the boundary between anxiety and growth as a huge cliff, in that once I had fallen into the anxiety zone it would be very difficult to return to the growth zone, experience of the recovery process reframed my perception of the boundary into a much more manageable transition, like a beach where any wandering into the anxiety zone could be easily rectified by a small change in direction. I therefore was much bolder in taking risks as I was more confident in my ability to recover my equanimity. This change in perspective was evident in some learners in the study, for example: '*Because I did use [the breathing] like, the first week. But I think after I'd used it I sort of thought, I don't need to do it anymore.'* (Devon, C1, CI3, L298). Once this change in perspective from cliff to beach has been achieved, opportunities open up as the learner is similarly less risk averse. This analogy also serves to illustrate the experiences of learners who report that they have not got a growth zone for mathematics at all (Mackrell & Johnston-Wilder, in press). These are the learners who tend to hide in the comfort zone because they perceive the boundary to be easy to cross into anxiety but hard to return to growth, much like a cliff where the edge is dangerous.

8.4.5.8 Blossoming in growth

In order to blossom in the growth zone, the learner requires a different focus for resilient self-efficacy (Bandura, 1990b) from recovering from the anxiety zone, as the focus here is on having both resilient self-efficacy in mathematics itself and resilient self-efficacy in learning mathematics. Resilient self-efficacy in mathematics involves the learner building their perceived ability to engage with and tackle mathematical challenges. Resilient self-efficacy in the learning of mathematics involves the learner actively regulating their emotions, through the growth zone for example, activating coping skills such as chunking tasks into more manageable units and others suggested by Mason, Burton and Stacey (2010) when struggling with a tricky concept, so that they become '*more comfortable with not knowing'* (Erin, C1, CI3, L92). Resilient self-efficacy in learning also involves the learner recruiting the support of more knowledgeable others (Daniels, 2001) such as family members, fellow pupils, teachers and the internet, and the awareness that mistakes are not a setback but rather an opportunity for learning (Boaler, 2016) as Adam explains: '*if I make mistakes it doesn't matter. I need to learn from them' (Adam, C1, CI1, L169*. The motivation to employ these actions to manage struggle and persevere in the growth zone requires an awareness of the value of mathematics (Johnston-Wilder & Lee, 2010) as then the learner can be in a motivational state of integrated regulation if not intrinsically motivated (Ryan & Deci, 2017). Lynden explains his motivation as integrated regulation: *'I didn't really enjoy it as such. I just did it because I kept getting told it's gonna shape my future and I want a good future, so, um, so I clamped down and I actually put my head to it. It's one of those subjects that, you don't have to like it to be good at it'* (Lynden, C3, CI1, L53). Another element to blossoming in growth is that, if learners have experienced the cliff-to-beach realisation that they can recover from the anxiety zone, this reassurance may increase their confidence to take greater risks in their learning, as was discussed in section 8.4.5.1.

8.4.5.9 Creeping out of comfort

The supporting data for this section of the model is minimal, as the learners involved in the research were chosen specifically for high levels of mathematics anxiety, and so showed a greater tendency to have experience of the anxiety rather than the comfort zone. This part of the model is therefore quite tentative. However, it is informed by my previous experience with working with more confident learners who still benefited from the Growth Zone Model to help them creep out of comfort.

The awareness of lack of challenge depends on the learner's understanding of the nature of mathematics learning. If they understand mathematics learning to be characterised by interesting situations involving wrestling with conceptions and struggling to work out efficient and effective procedures rather than getting the answer right most or all of the time, as previously explained in the Blossoming in Growth section above, then they will be dissatisfied with the comfort zone and demand more challenging situations, as Jack describes: '*if it's just easy, it's just writing down the same thing, not actually learning'* (Jack, C2, CI2, L74). Whilst the comfort zone provides a measure of self-efficacy for mathematics, as Adam explains deliberately staying in this zone *'just because I knew I'd do well'* (Adam, C1, CI1, L159), creeping out of comfort requires resilient self-efficacy because the learner needs to know what to do when the level of challenge increases. Awareness of the value of learning mathematics is once again important in the process of creeping out of comfort, otherwise there is no motivation to not stay safe and comfortable (Bandura, 1990b; Rohnke, 1989).

8.4.6 Section summary

This section has considered findings from the present study in the light of the literature on learning mathematics. The key message to emerge from the research is that a significant level of mathematics anxiety exists in the early years of secondary school education, which will have a detrimental impact on learning. To address this mathematics anxiety, the findings strongly suggest that the learner should be encouraged to take personal responsibility for moderating and managing their emotional state. This moderation and management requires the learner to have the prerequisite knowledge, about both the role of emotions in learning and the nature of effective mathematical learning, and to take positive action to maintain or improve their emotional state. The importance of the autonomy of the learner has been highlighted through the section. The analogy of reducing a cliff to the beach was introduced and recognised as an important understanding of reframing throughout the model. The need for resilient self-efficacy was also recognised in every stage of the model.

8.5 CHAPTER SUMMARY

This discussion chapter attempted to draw together the findings presented in chapters 5, 6 and 7 in the light of the two literature review chapters. The first literature review chapter identified the constructs of agency and self-efficacy, which were recognised as integral aspects of emotional management to enhance mathematical learning. Self-efficacy in mathematics was based on a view of the learner being ‘good enough’ rather than performing at an elite level. The additional term of autonomy was included as it contributes the slightly different perspective of motivation.

The findings of the study recognised autonomy as an integral aspect of emotional management to enhance mathematical learning. The first literature review chapter also recognised the need for some level of stress in learning, and this is recognised in the notion of ‘manageable challenge’ existing in the growth zone, as learners come to realise that learning involves challenge. The second literature chapter drew from mathematics education literature on mathematics anxiety and learning mathematics. ‘Falling behind’ was identified as a contributing factor of mathematics anxiety and identified as one which would benefit from greater consideration in the future. Finally, the main theoretical contribution of the thesis is presented in the last section.

CHAPTER 9 CONCLUSION

9.0 INTRODUCTION

This chapter concludes the thesis by summarising the achievements and main findings gained through the research. I demonstrate that I achieved my initial aims by considering each research question in turn, describing the findings, summarising how this compares to existing research and then indicating how the original research described in this thesis adds to the field. The chapter finishes by describing the strengths of the study, the limitations of the study and the ensuing recommendations for learners and practitioners. I mirror chapter 1, the introduction, by describing the significance of the thesis to my personal understanding and development.

9.1 RESEARCH QUESTION 1:

The first research question asked: **'what is the level of mathematics anxiety in the year 7 cohort?'** The learners completed a short questionnaire, and the resulting scores were sorted into three categories, as established by Mahmood & Khatoon (2011). Low levels of mathematics anxiety were reported by 55 % of the cohort, moderate levels of mathematics anxiety were reported by 20% of the cohort and 25% of the cohort reported high levels of mathematics anxiety. Therefore, 25% of the cohort demonstrated visibly high levels of mathematics anxiety, while a further 20% of learners reported mathematics anxiety that was not observable but still having a detrimental effect on their learning. The finding that 45% of this cohort of eleven-year-olds were experiencing enough mathematics anxiety to limit their learning adds detail to the literature, for example the Nuffield report which identified 10% of eight to 13-year-olds as experiencing mathematics anxiety (Carey et al., 2019). Hill et al

(2016) reported that levels of mathematics anxiety were minimal in primary school, but this research concurs with other research (for example, Griggs et al., 2013; Yüksel-Şahin, 2008; Krinzinger, Wood, & Willmes, 2012; Devine et al., 2012) which report significant levels of mathematics anxiety at the primary school (up to 11 years) by finding significant levels in learners who have just moved to secondary school.

A multiple regression analysis found two factors which correlated with mathematics anxiety, namely previous achievement (Marshall et al., 2017; Namkung, Peng & Lin, 2019), and gender (OECD, 2013). These factors have been previously recognised in the research literature, however the relatively small levels of influence, in that only 9.3% of the level of mathematics anxiety can be predicted by the learner's previous achievement in mathematics, and only 1.5% of a learner's mathematics anxiety can be predicted by their gender, indicates that a large proportion of the level of mathematics anxiety is not influenced by either previous attainment or gender. When the factors are combined, they influence 10.9% of a learner's mathematics anxiety. Thus 89.1% of a learner's mathematics anxiety is not influenced by either previous attainment or gender. This finding adds to the literature in that the previously reported influencing factors of gender (OECD, 2013) and mathematical ability (Marshall et al., 2017) (using previous mathematical achievement as a proxy), are recognised but qualified by this research in that the relatively small level of influence is quantified. As previous mathematical achievement has only a small influence on mathematics anxiety, it is important that school staff, parents, policy makers and researchers understand that learners with high levels of previous achievement are also prone. Similarly, as gender has a relatively small influence on mathematics anxiety, it is equally important that school staff, parents, policy makers and researchers are aware that it is quite possible that boys will suffer from mathematics anxiety.

9.2 RESEARCH QUESTION 2:

The second research question asked: '**what is the impact of the intervention on individual learners?'** The 13 learners who opted to participate in the one-to-one sessions initially reported negative emotions associated with maths learning such as nervousness, anxiety, annoyance, confusion and fear. These feelings were justified by the learners with assumptions that they were unable to learn mathematics and descriptions of detrimental actions of teachers and parents. The intervention supported the learners to represent their emotions during learning using the Growth Zone Model (Johnston-Wilder & Lee, 2010 & 2017). Most of the learners (11 out of 13) found the recovery breathing approach (Benson, 1975) to be a calming influence on their emotions. However 2 learners found that a focus on breathing was not an effective strategy, and instead they independently created an approach where they calmed themselves by focusing on drawing activities. This approach allowed them to recover from a state of anxiety.

Confirming the existing research, the learners were able to recognise instances where the emotional part of their brain took over from their logical thinking (Siegel, 2010), and so use the Growth Zone Model to realise when their emotional state needed to be changed in order to learn (Johnston-Wilder & Lee, 2010 & 2017). The research contributed to the existing field of research by further developing the Growth Zone Model (Ibid). Drawing upon the self-determination theory of Ryan and Deci

(2017), the foundational importance of learner autonomy and emotional awareness before any action to address anxiety or challenge complacency in the comfort zone was proposed. Additionally, the dynamic nature of the model, where even if the learner identifies themselves as being in the growth zone, action is required to maintain this optimal state for learning, was proposed.

9.3 RESEARCH QUESTION 3:

The third research question asked: **'How well was this intervention implemented?'** The study found that the intervention was implemented effectively, and indeed could be reduced from 3 to 2 sessions for the learners involved in the study, although this cannot be generalised and there were some indications that, with one learner in particular, the three delivered sessions were all necessary. A significant element of the intervention was the use of an app to track the emotional states of the learners. This app was found to be problematic in a classroom situation for this particular school but did generate some very interesting data from the one-to -one sessions. Further developments of the app are described in the recommendations section, 9.7.

In order to provide an artefact to support the recognition and communication of the emotional states of the learners in the classroom, a toolkit was developed as part of the Design–Based Research approach. This toolkit included a reminder of the Hand Model of the Brain (Siegel, 2010) to encourage autonomy, a representation of the Growth Zone Model (Johnston-Wilder & Lee, 2010 & 2017), (with a small glass stone to act as a pointer) to encourage emotional awareness, a reminder of recovery breathing (Benson, 1975) to aid recovery from anxiety, and further prompts about the value of making mistakes. The co-created toolkit fits in a school blazer pocket to be a constant support, prompt to act, and a tracker for emotions. The learners who co-developed and trialled the toolkit gave very positive indications of impact.

This study added to the field in that it focused on reaching the learner directly rather than the mathematics teacher, as is the case with much research (for example, Beilock & Ramirez, 2011 and Johnston-Wilder & Moreton, 2018). The intention of the study was not to exclude teachers or ignore the value of their involvement. Rather, the study recognised the concerns raised in section 3.2.2, namely that often mathematics teachers are not able to support learners as much as is needed and that this support could be provided by other adults or the learners themselves, once they have been trained. Additionally, the intervention is short and so is economically viable for schools.

9.4 Research Question 4:

The fourth research question asked: **‘How might the intervention be improved?’** Following the research finding that the app was useful for coaching scenarios but could not be trialled in this particular school, it was identified that the app should be developed in another school setting. It was also identified through the research that the long-term effects of the intervention were not measured, in this instance, and therefore wider testing for the intervention, including more robust before and after measures, should be in place in future developments.

9.5 STRENGTHS OF THE STUDY

This study contributes three significant findings to the literature on mathematics anxiety, through the approach of applying research literature on general anxiety causes, prevention and treatments to the context of supporting learners in their management of mathematics anxiety.

The first significant outcome concerns the prevalence of mathematics anxiety in eleven-year-old learners. In addition to the finding that debilitating levels of mathematics anxiety were reported by 25% of the 223 strong cohort, an additional nuance of the prevalence of mathematics anxiety indicated that the current literature on gender and mathematics anxiety should be revised. As gender is increasingly recognised as a spectrum rather than a binary concept, the literature on the prevalence of mathematics anxiety by gender should recognise this development. The findings of this study indicate that the (admittedly small numbers of) participants who preferred not to identify as either male or female reported levels of mathematics anxiety that fell between the lower levels reported by male participants and the higher levels reported by female participants. Larger studies may support this finding and further justify the benefit of updating gender categorization in future studies. This may be achieved by replacing gender categorization with the systemising / empathising spectrum of Baron-Cohen (2009) which recognises five points along the spectrum from extreme systemisers to extreme empathisers, for which assessment scales already exist. This action may result in a more nuanced scale to represent relative prevalence of mathematics anxiety.

The second significant outcome is the early indications of efficacious use of an intervention which directly supports learners in the management of their mathematics anxiety. The use of the GZM in app and artefact format was found to support the intervention. Although the intervention involves a one-to-one interaction between learner and researcher, it only involves a relatively short time span and so promises to be a relatively cost-efficient and elegantly simple method of addressing mathematics anxiety in young learners. The results from this small-scale development of an adapted version of the Growth Zone Model and the evaluation of the accompanying intervention are promising and indicate the value of a wider rollout and more rigorous evaluation with a control group. A wider evaluation would allow further refinement of the methodological approach in terms of pre- and post-evaluation of mathematics anxiety, which was a limitation in the present study. A wider evaluation could also consider the best age and stage of schooling for implementation of the intervention, including primary level and later secondary level.

The third significant outcome of the study is the development of the Growth Zone Model, created by Johnston-Wilder and Lee (2010). This study adds insight into the context of effective use of the GZM, adding the stages of firstly establishing learner **autonomy**, secondly enabling the learners to develop **awareness** of their emotions, and thirdly encouraging learner **action** to move to, or persevere in, the growth zone, the optimal zone for learning, a model which I have named ‘The 3 A’s’. This last stage reinterprets the GZM as a dynamic model, where the learner is continually assessing their emotions and adjusting their actions accordingly.

To summarise, the results of this study have shown that mathematics anxiety can be addressed in an intervention as short as 60 minutes and with a beneficial impact on attainment, although the long-term effects have not yet been explored.

9.6 LIMITATIONS OF THE STUDY

The limitations of this study include a lack of information about the proportion of learners who would benefit from the intervention as indicated by their reported level of mathematics anxiety, a lack of information about the duration of impact of the intervention, and a methodological approach that lacks robustness. These limitations will be examined below.

As the intervention was only targeted at and delivered to learners with the highest reported levels of mathematics anxiety, it is not possible to determine the level of reported mathematics anxiety which would indicate beneficial involvement in the intervention. In order to establish this threshold level of mathematics anxiety, if indeed there is one, a further research study could be designed which would deliver the intervention to varying levels of learners with reported mathematics anxiety. This proposal assumes that the mathematical learning ability of learners with higher levels of reported mathematics anxiety would benefit more from the intervention than the mathematical learning ability of learners with lower levels of reported mathematics anxiety, an assumption which is based on the negative impact of mathematics anxiety on learning. However, it may be that all learners would benefit from an increased sense of autonomy, increased awareness of their emotions and a working knowledge of the strategies that work best for them in terms of managing their emotions. A further research study could answer this question.

As the impact of the intervention was only gathered through the analysis of learner feedback, the next step of a more robust methodological approach is indicated. This wider evaluation could include the assessment of impact of the intervention on the mathematical learning of the learners against that of a control group, both immediately after the intervention and at a later stage to assess the lasting duration of the impact of the intervention.

9.7 FUTURE RESEARCH DIRECTIONS

Future research into the prevalence of mathematics anxiety could consider the possibility of avoiding using gender as a binary construct, in terms of the relative prevalence of mathematics anxiety. Future participants could be offered the opportunity of identifying as other than male or female, or research could adopt the scale created by Baron-Cohen (2009) to measure systemising and empathising as an alternative.

Future research into the specific intervention developed in this study could explore its efficacy for learners with varying levels of reported mathematics anxiety. As discussed above, greater knowledge of the benefits of the intervention in terms of relieving mathematics anxiety and therefore enhancing mathematics learning for different levels of reported mathematics anxiety would inform its use in schools.

An additional variable that could be included in future research into the specific intervention developed in this study concerns the best age or stage of learner.

This research selected learners in their first year of secondary school, but younger learners who have not yet transitioned from primary to secondary school may also benefit from the intervention. Equally, older learners who are continuing with mathematical studies, whether mandatory or not, may also benefit from the intervention.

As previously identified, the long-term effects of the intervention could be evaluated in future research. This would not require a longer intervention but would possibly involve a comparison with a control group of learners, or an additional evaluation of mathematics anxiety using the previously created scale 6 months after the intervention.

Additionally, the efficacy and applicability of the app and toolkit should be further developed, both in and outside classroom settings. These developments could be informed by all key stakeholders, including teachers and learners. Expanding the trials of both artefacts to primary and tertiary education settings would also be a beneficial future direction for research.

9.8 RECOMMENDATIONS

When I presented my study to a group of mathematics teachers, it was clear that, even though some were familiar with emotional regulation practices in schools, they had not thought to apply it to the needs of learners with mathematics anxiety. Additionally, the teachers in the present study were surprised by the levels of mathematics anxiety in their classes, which were higher than they expected. The findings of this study strongly support the recommendation that teachers support learners to develop autonomy in the learning environment, to become more aware of their emotions and how they relate to the learning process, and to take appropriate action to manage those emotions. In this way teachers could support the psychological safety of all of their learners in the context of learning mathematics. Teachers could create a maths toolkit similar to the one developed in this study, and then educate and encourage their learners to use it effectively.

The benefits of autonomy, awareness of emotional and appropriate actions to manage emotions should not solely depend on the actions of teachers to manage the learning environment. Once learners are informed of the principles, they can use them wherever they are learning, be it the mathematics classroom, when completing homework, or real-life situations where mathematics is involved. The findings from this study support the recommendation that learners learn actively to monitor their emotional state, and not only take steps to safeguard their psychological health, and recover from anxiety, but also look for greater challenges when they find themselves in situations that are too comfortable.

9.9 PERSONAL SIGNIFICANCE

The experience of studying at doctoral level has been of great benefit to me personally. The introduction chapter described my experiences prior to beginning a second attempt at doctoral study, and here I follow those research roots by describing a little more of my experiences whilst studying, using the framework of Self-Determination Theory (Ryan and Deci, 2017). The experience of researching and writing this thesis has increased my competence in both the field of academia, through the process of structured support, the challenge of presenting at conferences and the ultimate goal of getting published, and the field of learning at an advanced level, which has been very challenging at times. The ladder image of scaffolded learning (see section 8.4.2 in the discussion chapter) has really helped to increase my autonomy in terms of actively managing my learning. Dunleavy wrote that the process of writing a thesis is like climbing 'a mountain with steps' (2003: 151). The analogy of a ladder is perhaps more effective as there are greater links with scaffolding in that the support can be removed when it is no longer needed. I learnt to add more rungs if the challenge was too great for me to manage, either by asking others or by doing it for myself. I also learnt that I have the right to ask for help, that this is a sign of strength rather than weakness. I now know that it helps me to keep a reflective journal, to draft out my writing, to get feedback from others, and to work in short, regular bursts. Most of all I have learned that, for me, becoming a resilient learner often means just to show up and do something without expecting the results to be of a high standard.

It has been very empowering to be part of a research community. Getting and giving support from fellow students in my cohort on the doctoral programme in the Centre for Education Studies, working with the Warwick Resilience in Education Group to develop ideas and share understanding, and learning about academic writing from more experienced colleagues, has helped me appreciate the psychological need of relatedness from a personal perspective.

Satisfying the psychological needs of competence and relatedness, as I have described in the previous paragraphs, has increased my autonomy, and by doing so has been of significant psychological benefit. I have learnt that I have the ability to succeed if I persevere. I have learned to embrace the opportunity of new experiences, as now I have the skills to self-safeguard and take managed risks. Most of all, this doctorate has helped me to reframe my anxiety from a crippling disability to a manageable side effect of leading an exciting and interesting life.

9.10 KEY CONTRIBUTION AND LESSONS LEARNED

The key contribution of this research is that the theory of developing emotional awareness to address mathematics anxiety has been developed in a new context, that of the use of the Growth Zone Model directly with students outside the classroom. This has been achieved by emphasising the importance of learner autonomy, a viewpoint that combines insights from mathematics education and psychology. Additionally I have contributed practically to the field through the development of an intervention supported by an app and a physical artefact. I have therefore added to theory and produced something useful, which were my joint goals from the outset of the research.

If I were to repeat the study with the benefit of hindsight, I would try to be more confident in my abilities. Much time and effort was spent battling with false notions of personal inadequacy and expert infallibility. I am in the fortunate position of being able to continue researching in education in my current role, and now am able to bring a realistic perspective around my worth and understanding. However, the conundrum is that I have only been able to reach this position though the process of doctoral study, which is why I have named this section ‘Lessons Learned’ rather than ‘Things I would Do Differently’.

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APPENDIX 4.1: MATHS ANXIETY SCALE FOR YEAR 6 & 7 SCHOOL PUPILS

(Adapted from Betz, 1978)

Please fill in the boxes

Gender: (girl/boy/prefer not to say)	Age:
Register Number:	KS2 SATs score:
School Number:	Class number:

Read the sentence and then circle the words that describe how you feel.

Maths makes me feel uncomfortable and nervous.	Always disagree	Sometimes disagree	Uncertain	Sometimes agree	Always agree
I feel calm during maths lessons	Always disagree	Sometimes disagree	Uncertain	Sometimes agree	Always agree
It wouldn't bother me at all to do maths A level	Always disagree	Sometimes disagree	Uncertain	Sometimes agree	Always agree
Maths makes me feel uneasy and confused.	Always disagree	Sometimes disagree	Uncertain	Sometimes agree	Always agree
I almost never get uptight while taking maths tests.	Always disagree	Sometimes disagree	Uncertain	Sometimes agree	Always agree
I feel calm during maths tests	Always disagree	Sometimes disagree	Uncertain	Sometimes agree	Always agree
My mind goes blank and I am unable to think clearly when doing maths.	Always disagree	Sometimes disagree	Uncertain	Sometimes agree	Always agree
I get really uptight during maths tests	Always disagree	Sometimes disagree	Uncertain	Sometimes agree	Always agree
I don't worry about my ability to solve maths problems.	Always disagree	Sometimes disagree	Uncertain	Sometimes agree	Always agree
I get a sinking feeling when I think of trying hard maths problems.	Always disagree	Sometimes disagree	Uncertain	Sometimes agree	Always agree

APPENDIX 4.2: CLINICAL INTERVIEW PLAN

CLINICAL INTERVIEWS SESSION PLAN

VERSION 2

Key

GZM = Growth Zone Model MRG = Mathematical Resilience – having a growth mindset MRV = Mathematical Resilience – valuing mathematics MRS = Mathematical Resilience – optimistic struggle MRR = Mathematical Resilience – recruiting support

Session 1 – Staying in Growth - 45 mins

Timing	Activity	Key Points	Resources	Rationale
5 min	Introductions	A little about me A little about them		Creating a comfortable and safe environment
5 min	Neuroplasticity	New technology - Show MRI scans, describe seeing blood flow, show parts of brain on MRI Explain that knowledge of brain function and growth has changed - ability is not fixed – trying makes a difference	MRI scans Brain sheet	MRG - Growth rather than fixed mindset (Dweck, 2000) Neuroplasticity – learning increases grey matter (Geake, 2009)
5 min	Making mistakes	Discussion about feelings when making a mistake Learning from mistakes - Neuronal growth demo – scrumpled paper	A5 paper	MRG – Stronger neuronal connections after a mistake – doesn't need to be corrected. (Boaler, 2016) (Moser *et al.*, 2011)
5 min	Imagining maths	Draw how you feel about maths, or write some descriptive words	A4 paper folded into 3	MRG -Identifying emotions associated with learning mathematics. (Johnston-Wilder & Lee, 2010)
10 min	Growth Zone Model (GZM)	Sharing the model – explain each part Identifying feelings for each zone	A4 model A5 template	MRG – Learning to recognise emotions -name it to tame it - (Siegel, 2010) to maximise learning potential. GZM - (Johnston-Wilder & Lee, 2010)
10 min	Persevering in growth	Have you ever felt unsure about whether		MRS – Encouraging self-efficacy (Bandura, 1994), perseverance (Williams,

		you could do something but kept trying anyway? What helped?		2014), optimistic struggling (Seligman, 1991)
5 min	Plenary	What will you try before next week?		Reviewing progress and identifying actions for next week

Session 2 – Recovering from Anxiety - 45 mins

Timing	Activity	Key Points	Resources	Rationale
10 min	Review	Recap GZM & descriptive words Review experience since last session & track on GZM	A4 model A5 template	Gather more data about recognition and management of emotions Consolidate MRG learning, address misconceptions, encourage continued use of GZM
10 min	Hand Model of the brain	Parts of brain to parts of hand, emotions taking over – flipping your lid Calming down and taking charge again		MRG – Managing unpleasant emotions and self-safeguarding. (Siegel, 2010)
5 min	Recovering from anxiety	Reflection – what pushes you into the anxiety zone? Have you been there recently? What might you do in the classroom if you realised that you were in the anxiety zone? Create reminder card to prompt appropriate action when in anxiety, as suggested by pupil.	Reminder card with suggestions for classroom appropriate remedial actions	MRG – Managing unpleasant emotions and self-safeguarding. (Siegel, 2010)
5 min	Wading through treacle	What could you do if you got stuck or felt confused about some maths? What helps when you are wading through treacle? Write down strategies on a stuck poster or wading through treacle poster.	A5 paper	MRS & MRR – Strategies for when struggling or stuck. Getting stuck is expected and can be overcome – 'being stuck is an honourable state' (Mason *et al.*, 2010)
10 min	Maths in an ideal world	Draw how you would like to feel about maths or write some descriptive words. Is maths important to you? Why?	A4 paper folded into 3 (from last session)	MRV – demonstration of participant's perception of how valuable maths is to them. Encouragement of appreciation of how useful

				mathematical ability and knowledge is.
5 min	Plenary	What will you try before next week?		Reviewing progress and identifying actions for next week

Session 3 – Creeping out from comfort - 45 min

Timing	Activity	Key Points	Resources	Rationale
5 min	Review	Recap GZM & descriptive words Review experience since last session & track on GZM	A4 model A5 template	Gather more data about recognition and management of emotions Consolidate MRG learning, address misconceptions, encourage continued use of GZM
5 min	Hiding in comfort	Do you hide in the comfort zone? Do you ever take risks in maths lessons, like trying to answer a challenging question?		As emerged from pilot research, possible need to support in process of recovering from learned helplessness (Peterson *et al.*, 1993)
10 min	Creeping out of comfort - worst- and best-case scenario	What would happen if you tried something you have been avoiding, like asking a question in class? What would you do if you ended up in the anxiety zone? Could you recover? How? How might it help to come out of comfort?		Anxiety isn't the end of the world, like falling off a cliff. You can recover from it, so it is more like wading too deep into the sea. MRV – Link to last session – what mathematical learning is desired? MRV - recognising that mathematical learning would be worth a little discomfort
10 min	Circles of support	Who helps you learn maths? Who else might be a help?	Circles of support template	MRR– from Circles of relationship (Walker-Hirsch & Champagne, 1991) to raise awareness of the different kinds of support available.
10min	Review	Look over the last 3 sessions. What has been most helpful? What hasn't been helpful? What else might we have done?		Data gathering for next iteration of action research.
5 min	Looking forward	Next steps and staying in touch.		Ensuring that the participant is ready to finish the sessions.

Appendix 4.3: DBR Cycle Reflection Prompt Sheet

Design-based Research – Cycle review

Date: 29th May 2019

Research title: How can an intervention scaffold year 7 students in learning to manage and overcome their mathematics anxiety?

Cycle number: 1

Collins et al 2004:33
Modifying a design:

- *If elements of a design are not working, modify the design*
- *Each modification starts a new phase (I'm using 'cycle' as 'phase' denotes the stages of my research)*
- *Characterize the critical elements for each phase*
- *Describe the reasons for making the modifications*

From fieldnotes, transcriptions etc:

No	**Successes:** *(elements that are working)*	Evidence reference
1	Timings: I had enough time to talk though all elements of introduction, set the scene, begin to build a relationship in a gentle way and introduce GZM, HMB and RR. I was concerned about this, as sessions that were too short would be a waste of everyone's time, and sessions that were too long would not achieve everything I wanted to achieve. I have worked out that there will be some variability in timings, as learners respond in more or less detail. For next time I will aim for a session lasting between 20 and 30 minutes, and I will be clear about the essential elements of the session, as compared to the interesting extras.	Field notes p36
2	Weekly review of GZM, HMB, RR. I asked how they have used it, and got quite detailed responses (See for example the difference between Adam and Blake on week 2 (14/05/19). A had not recognised the need for any of the strategies, whereas Blake gave a detailed account of their use, and had even informed his maths teacher of his intended used of them (discussion with Blake's teacher). Add this to the script.	Field notes p37 Adam transcription 14May19 Blake transcription 14May19 Field notes p47
3	Asking for their help/involvement in the research – recruiting their support and involvement. Although this wasn't in my script, it felt like a natural approach to take from the start, and they responded well to it. Add this to the script.	Field notes p38 All 7May19 transcriptions

4	Giving them pieces of paper as a reminder. Blake and Erin in particular referred to these in between the sessions and brought them to the sessions. Seeing this made me wonder about a little pack, to include an image of the GZM, a reminder of the HMB and RR, the mistake scrumple task and the getting help task.	Blake 14May19 & 21May19, Erin 14May19 & 21May19
	Failures: *(elements that are not working)*	
	Concerns:	
5	Adam seems to be unimpressed by the strategies. At first, I perceived this as a failure but upon reflection I can see this as a helpful insight to guide my thoughts about further implementation – would it work with all learners, whether they currently experience the need or not? It is true that there is something here for everyone but if Adam doesn't see the need for it now, will he remember it for the future? Or should he be challenged more? What is going on here? Perhaps in future cycles I need to increase the pressure by introducing a challenging year 7 task to those who are successfully avoiding mathematical challenge. The other thing I might check is the learner's responses to the MA questions. Can they talk me through their answers? Again I might only need to do this where I'm not getting a feeling of recognition of anxiety.	Field notes p40
	Surprises:	
6	No problems with learner agency – unlike Annabeth (previous research)'s school, where there was a culture of blind obedience (at least that is how is seemed to Annabeth), none of the learners in SS2 have indicated that they would not be able to stop, think, breathe, etc. This is a good reflection of the learning culture in the school.	Field notes p41
7	As well as demonstrating the growth of new pathways in the brain after making mistakes, the Scrumple task (Boaler, 2016) has proved to be a reassuring and calming task/activity for Blake and Erin, who have used it as an active strategy to calm themselves down.	Field notes p41 21May19Blake. 21May19Erin
8	Rather than talking about 'brain flip' as Siegel does, the learners are describing their minds going 'blank' or 'freezing'. I wonder if these terms mean more to them- they are more descriptive of the feeling. Should I use these in the future?	
9	Chris talked about getting distracted when she got stuck – might this be a common problem? I gave her a few ideas along the lines of a stuck poster. Might this be a problem for more than her?	Field notes p43 14May19Chris
10	Erin seemed to be touching on NLP or CBT when she spoke about her brain 'sabotaging' her learning. Interestingly, she found that doing the breathing helped her to think more rationally – she reconnected thinking and emotions?	Field notes p41 14May19Erin
11	Finley was using the breathing to help her through a challenging and stressful situation at home. She could use the GZM to realise that she was getting nervous and so needed to do something about it. The breathing helped, every time she used it.	Field notes p45
12	It may be worth looking at the circles of support from the school	Field notes p46

	perspective. From what little I've done, I get the sense that the learners do not see their classmates as sources of collaborative support. A few are willing to ask for help but realise that it is not very helpful to be told the answer. Could the school work on collaborative tasks, and teach proper group collaboration skills and strategies?	

Analyzing the design	
Cognitive	5 – who is the target audience? 6- learner agency supported by school culture 7 – recovery response idea achieved through drawing 8 – brain freeze or blank instead of flip 9 – getting stuck increases distraction 10 – learning is sabotaged by MA – reconnecting thinking & feeling enables a more rational response to uncomfortable emotions
Resources	1- timing – 20 – 30 minutes 1 – include a reserve activity 2 – review understanding each week 4 – Maths Toolkit pack
Interpersonal	3 – positioning the learners as fellow researchers rather than sufferers of MA – more positive view
Group or classroom	5 – for the future, should it be classroom dissemination, or small groups, or one to one? Could I use a YouTube video, or series of videos?
School or institution	6 – good indication of school learning ethos from learner agency 12 – school could encourage more collaborative working?
Measuring dependent variables	
Climate variables (e.g., engagement, cooperation, and risk taking)	5 – why is there a difference between Adam and Blake? Why is Blake open to suggestions and Adam not? 6 – good indication of school learning ethos from learner agency 12 – school could encourage more collaborative working?
Learning variables (e.g., dispositions, metacognitive, and learning strategies)	3 – positioning the learners as fellow researchers rather than sufferers of MA – more positive view
System variables (e.g., ease of adoption, sustainability, spread)	
Measuring independent variables	
Setting	
Nature of learners	
Technical support	
Financial support	
Professional development	
Implementation path	

Adapted from Collins et al 2004:33

Design-based Research – Cycle review

Date: 20th June 2019

Research title: How can an intervention scaffold year 7 students in learning to manage and overcome their mathematics anxiety?

Cycle number: 2

(Collins *et al.*, 200433)
Modifying a design:

- *If elements of a design are not working, modify the design*
- *Each modification starts a new phase (I'm using 'cycle' as 'phase' denotes the stages of my research)*
- *Characterize the critical elements for each phase*
- *Describe the reasons for making the modifications*

From fieldnotes, transcriptions etc:

No	**Successes:** *(elements that are working)*	**Evidence reference**
1	*From Cycle 1 review :"For next time I will aim for a session lasting between 20 and 30 minutes, and I will be clear about the essential elements of the session, as compared to the interesting extras*." In session 1 I brought a low challenge/high interest game (Shut the Box) and a high challenge booklet of year 8 maths tasks. These resources were used when examples of situations for comfort and anxiety were needed.	Jack transcription 04Jun19
2	*From Cycle 1 review :"Add weekly review of GZM, HMB and RR to the script.* This is now part and parcel of the session, and is usually revealing interesting insights, although Hayden is very unforthcoming when asked to describe her feelings.	Hayden transcription 18Jun19
3	*From Cycle 1 review :"Add request for help with research to the script.* This is now an integral part of session 1. I explain that, as I am not in year 7, I can't really do the research in their classes, and ask for their help. It has always been well received and their involvement has been enthusiastically given.	All 04Jun19 transcriptions
4		

	Seeing this made me wonder about making a little pack, to include an image of the GZM, a reminder of the HMB and RR, the mistake scrumple task and the getting help task. The packs arrived in time for the second session, and were well received by all except George, who didn't think he would need it. I persuaded him to take it anyway and try it out.	All 18Jun19 transcriptions
5	The learners do seem to appreciate the opportunity to talk freely (given that they are still in a school environment) with me. In fact, for several of them, it has been an experience that feels like the release of pent-up feelings. Some of these children want to be heard, and benefit form the opportunity to share their feelings with the school. My positionality as an outsider who has been allowed access into the school (I wear a green visitor's pass) is interesting here – would they open up in the same way to a member of staff?	Field notes p 49 Field notes p 62
	Failures: *(elements that are not working)*	
6	Compromised confidentiality. This is a circumstance where research confidentiality and ethical practices conflicted with school confidentiality and ethical practices. A member of staff overheard George's rather fraught first session and subsequently looked him up on the school data base, revealing an SEN passport. This is not bad in itself, but it does make me wonder about my ability to preserve the confidentiality and anonymity of the pupils in future publications.	Field notes p 50
7	Hayden and Indigo did not appear to be in touch with their feelings. They both struggled to describe how they felt when doing maths. This made making the GZM meaningful in their experience a difficult task, and I don't think I achieved it.	Field notes p 52 Field notes p 60
8	The app is not working as well for me as I had hoped. The learners would not be able to access it in a lesson situation, as they are not permitted their phones in lessons. The glass pebble and card may be a more practical emotional support tool.	
	Concerns:	
9	Unfortunately, I was unwell for the planned date of the second session and could not deliver it on the date	Field notes p 57

	planned. This resulted in a gap of a fortnight between sessions. This demonstrated to me that a gap of a fortnight between sessions is too long. I felt that the momentum had been lost between sessions, and the learners did not remember the strategies I had taught them as well as the first group did.	
10	The timing of these sessions in terms of the school year is not the best, I think. The learners do not seem to be faced with challenging mathematical learning situations so much – when asked about her last maths lesson, for example, Kelsey said that she didn't actually do any maths in the lesson. Perhaps this is not the best time to be delivering this intervention?	
	Surprises:	
11	Given comment 8 above, the app may not be the best thing for the classroom, but still might have value in a one to one session, where the learner can visually demonstrate their feelings about maths and provide a commentary to explain the circumstances.	App photos & data
12	I seem to be able to condense the intervention into 2 sessions. This is good as I can efficiently deliver the learning. This looks like: Session 1: • Gather previous experiences of learning mathematics • Explain GZM, HMB, RR • Give out Maths Toolkit Session 2: • Gather feedback about use of GZM, HMB, RR • Explain brain scrumple, stuck poster • Review what has been helpful However, this does not give me the opportunity to gather further feedback about the use of the tools, and to emphasise or consolidate their use.	Field notes p 59
13	After discussion with a maths teacher, it may be that a whole class session is beneficial, with further support via	

	support staff for particular pupils. Also, a parent and child pair of sessions might well be of value.	
14	Expectations of teachers – Jack's maths teacher was surprised that he had been selected for involvement as he was top of the class. MT didn't expect any MA in Jack's case. However, Jack described his situation as that of a high achiever who was anxious about maintaining his reputation. In addition, Jack seems to equate learning as remembering, in a very instrumental approach (Skemp xxxx). He described a very systematic approach, where he amasses facts like Lego blocks.	Field notes p 53

Analyzing the design	
Cognitive	14 – Learning = remembering!
Resources	Maths Toolkit
Interpersonal	Design in terms of confidentiality tensions How easy to discuss with supervisor & helpful colleagues
Group or classroom	Who with and for
School or institution	Made welcome Already seeing results Interacting with design What will school get out of this
	Cycles coming together Need for gap between each cycle
Measuring dependent variables	
Climate variables (e.g., engagement, cooperation, and risk taking)	
Learning variables (e.g., dispositions, metacognitive, and learning strategies)	

System variables (e.g., ease of adoption, sustainability, spread)	12 – 2 sessions now
	Things that might change Engagement with number of questions in test Venting – opportunity to talk Teachers more aware of emotions Kids mostly willing to use packs Kids mostly able & willing to share emotions
Measuring independent variables	
Setting	Kids groups, ict
Nature of learners	
Technical support	
Financial support	
Professional development	
Implementation path	13 – discuss implementation with head, head of maths, contact teacher. To include staff training, parent & pupil sessions.
other	Inability to access devices in lessons

Adapted from Collins et al 2004:33

APPENDIX 4.4: DESCRIPTION OF GROWTH APP

THE APPLICATION FOR IPAD REPRESENTING THE GROWTH ZONE MODEL (GROWTH).

Before I began the fieldwork phase of my research, my daughter offered to create a software application (app) for me. This was an assessment included in her robotics and mechatronics degree. I took full advantage of the opportunity by asking her to create an app based on the Growth Zone Model (Johnston-Wilder & Lee, 2010) which would assist and enhance my data collection process. We discussed the scope and parameters of the proposed app, which she then created. In order to publish the app, I had to pay a developer's fee to make it available on the apple site. This financial investment meant that the app was available on iPhone and iPad and I could use it for data collection.

I wanted the app to be based on the Growth Zone Model, but to be dynamic so that learners could share their perception of the relative size of their growth zone. This perception of the model came from conversations about some learners having very small growth zones, and hence moving quickly from the comfort zone to the anxiety zone (personal communication with Dr Johnston-Wilder). I hoped that my interventions would widen the learners' growth zones, thus enabling them to be able to accept a range of emotions and still engage with the mathematics. I also wanted a section of the app to record the verbatim comments of the learners when describing their justification of why they had represented it in that way. Additionally, I wanted the learners to be able to review their progress, so that they could see an increase in relative size of the growth zone. The finished app also included a surface area calculation of the relative percentage of each of the zones. This data was all stored on the app, but I also took screen shots to be able to access the data after the year's subscription to the apple store had ceased.

The app looks like this:

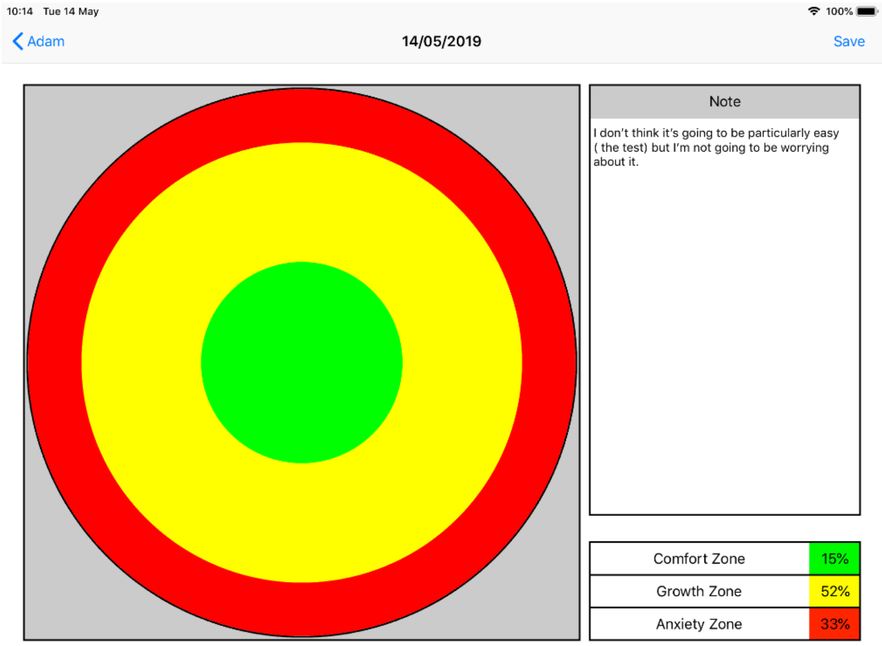


Figure 4.4.1 Screenshot of grOwth, the Growth Zone app.

The key elements of the app can be seen on Figure 4.4.1. These are:

- the main screen on the left, with red, yellow and green zones that are moveable by dragging the boundary of the zone towards the centre to make it smaller or towards the outside to make it bigger.
- the relative percentage area of each zone is reported on the bottom right of the screen.
- on the top left, the pseudonym of the learners is reported, and on the top middle, the date of entry.

- on the top right, the save button can be seen.
- a box to type in the comments of the learner is located to the right of the GZM graphic, which records the learners' explanations of why they arranged the GZM in the way they did.

Once the entry was saved, the app went to the next page, which looked like this:

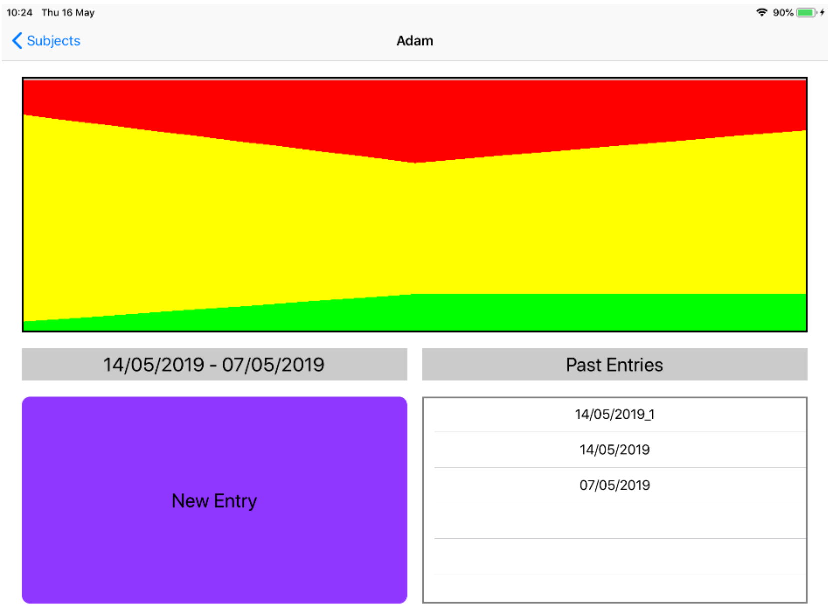
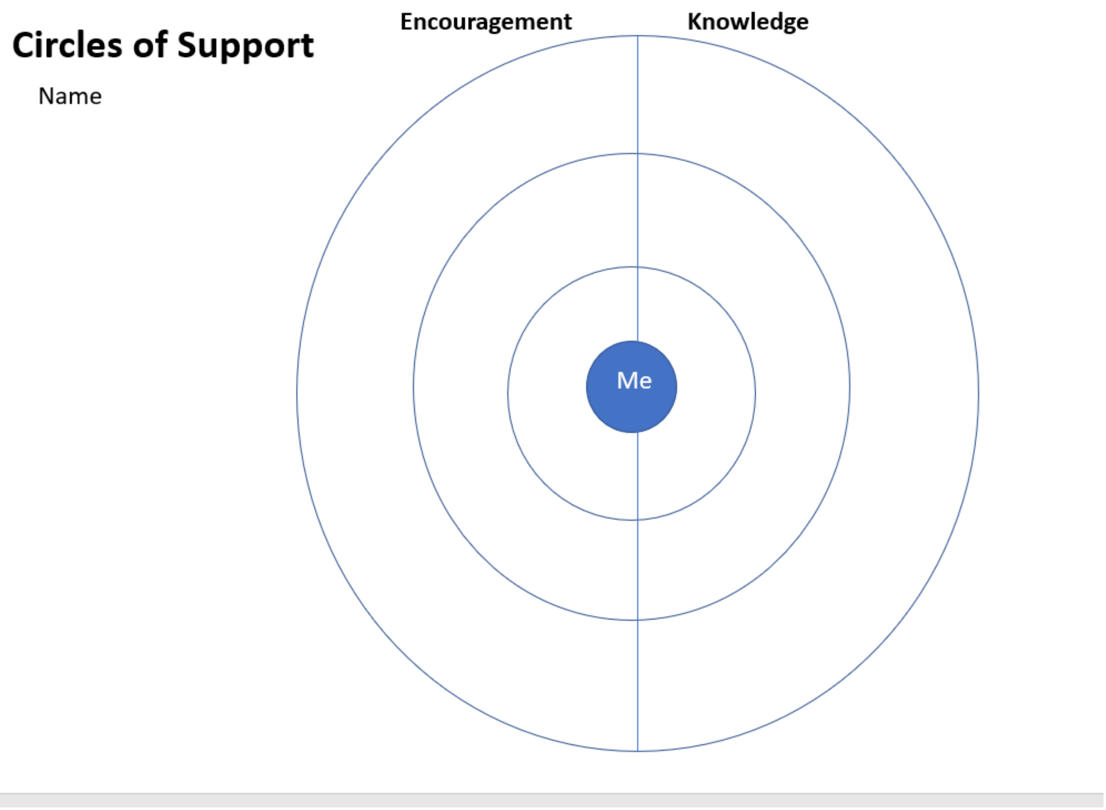


Figure 4.4.2 The second page of the grOwth app.

The top box is a representation of the percentage of surface area for each zone over all the inputted sessions for that particular subject. The bar on the middle left indicates the time range for the entries. The bar on the middle right is a heading for the box below, to where the previous entries can be navigated. The box on the bottom left navigates to a fresh screen for a new entry.

APPENDIX 4.5: CIRCLES OF RELATIONSHIP



APPENDIX 4.6: ETHICAL APPROVAL

WARWICK

Application for Ethical Approval for Research Degrees
(PhD, EdD, MA by research)

Student number: 1796347

Student name: JANET BAKER

PHD ~~MA by research~~ ☐

Project title: Developing the self-management of mathematics anxiety

Supervisor: Sue Johnston-Wilder

Funding body (if relevant):

I have read the Guidance for the Ethical Conduct of Research available in the handbook.

METHODOLOGY

This study involves:

- The administration of maths anxiety and resilience scales by mathematics teachers to their year 6 and year 7 classes, before and after an intervention.
- Whole class teaching sessions to introduce strategies to manage emotions during mathematical learning.
- One to one sessions for maths anxious pupils to develop strategies to manage emotions during mathematical learning. These sessions will be audio recorded to provide information on the application and effectiveness of the strategies.

PARTICIPANTS

The possible participants include year 6 (10 to 1 1 year olds) and year 7 (1 1 to 12 year olds) from two secondary schools and their feeder primary schools.

RESPECT FOR PARTICIPANTS' RIGHTS AND DIGNITY

Each participant's right to stop their involvement with the research will be explained to them at the start of each session and respected throughout. All participants will be treated with respect and consideration at all times. Their dignity will be valued and protected.

PRIVACY AND CONFIDENTIALITY

Confidentiality will be assured through the use of a coding structure that identifies the school, class and register point of the pupil. Students in the one to one sessions will select pseudonyms for themselves. In this way, the data will be anonymised so that each participant will not be identifiable by anyone other than me. The confidentiality of the sessions will be preserved at all times, except in the case of any arising safeguarding issues (see below). Research data will be stored securely. Hard copy data will be stored in a locked filing cabinet. Electronic data will be stored on an external hard drive, which will be stored in a locked filing cabinet. Confidential data will be deleted or shredded as soon as it is no longer required.

[redacted]

CONSENT

Each step of the research has been thoroughly planned and submitted to my supervisor for checking. I will adhere to the session plan at all times possible and discuss necessary alterations with my supervisor.

PROTECTION OF PARTICIPANTS

I hold an enhanced DBS form.

In the whole class session, I will begin by teaching the hand signal to indicate anxiety, and encourage the pupils to use it if they are feeling uncomfortable. I will ensure that the teacher or a teaching assistant is on hand to support any such pupils away from the classroom.

I will reassure participants in the one to one sessions that they can withdraw at any time. I will give them a card to both remind them of this option and help them indicate that they wish to withdraw.

CHILD PROTECTION

Will a CRB check be needed? ~~Yes~~ No (If yes, please attach a copy.)

I hold an enhanced DBS form.

ADDRESSING DILEMMAS

The most likely ethical dilemma I can foresee is that, in the one to one sessions, issues could arise that the participant would wish to keep private but I feel that their parents and/ or the school need to know about. I cannot promise confidentiality to the participant if their safeguarding is at stake. I therefore need to make it clear to the participants that major issues will be shared with their parents and/ or the school.

From participants:

As the participants are underage, written consent will be sought from the learners and their parents. In the case of the anxiety and resilience scales, an explanatory letter for the administering teacher will outline the process of securing informal consent. For the whole class session and the one to one sessions, I will also secure informal consent at the start of each session.

From others:

Consent will initially be secured from the headteachers of the participating schools. An introductory email will be sent to inform the headteacher of the purposes and procedures of my research. In addition, I will offer the headteachers the opportunity to meet with me face to face to discuss any concerns they may have. Consent will be indicated by their written reply to my email.

Consent will be secured from the parents of likely participants. A letter will be sent, with the permission of the school, to inform parents of the purposes and procedures of my research. A form will be attached to the letter, and the parents will indicate their consent by returning the letters.

Participants will be explicitly informed of my status as a doctoral student at Warwick University.

COMPETENCE

concerned that the negative feelings or experiences that they may share with me would get reported back to the school, or to particular teachers. I will reassure them that, as long as these are not safeguarding issues, I will maintain their confidentiality and discuss any disclosures with them in advance.

The completion of the anxiety and resilience scales may cause some participants to feel upset or uncomfortable. I will ensure that the administering teachers are prepared for such an eventuality and have additional staff on hand to comfort participants away from the main class.

Another concern I have is that I may inadvertently give a message about mathematics that conflicts with that of the teacher. To avoid this, I will take every opportunity to share my message with the teaching staff so that I can become aware of any conflicts and avoid them.

MISUSE OF RESEARCH

I am working under supervision. I will follow the ethical guidelines set out by BERA 201 1 , and will ensure that any publication of this research takes place in only reputable conference settings and reputable journals.

SUPPORT FOR RESEARCH PARTICIPANTS

In the whole class and one to one sessions, I will be alert for any signs that participants are becoming upset and support them to recover. In addition, in the whole class session I will have taught the hand signal to indicate anxiety and will take appropriate action if it is used. In the one to one sessions, I will again be alert for any discomfort and take appropriate action. If sensitive issues are raised, I will address them if I can, or make use of alternative means of support such as is school policy. The message that the session can be stopped at any time by the participants will be reinforced. To help the participants to do this at a time when they may be feeling high levels of emotion, a visual sign on a card will be at hand for them to touch to indicate their needs.

INTEGRITY

I will consistently endeavour to ensure that my research and subsequent reporting is honest, fair and respectful to others. I will offer the participating school teaching staff the opportunity to verify all relevant Written records, to confirm that they are honest, fair and respectful. My supervisor will also ensure that my research and reporting is honest, fair and respectful.

WHAT AGREEMENT HAS BEEN MADE FOR THE ATTRIBUTION OF AUTHORSHIP BY YOURSELF AND YOUR SUPERVISOR(S) OF ANY REPORTS OR PUBLICATIONS?

Sue Johnston-Wilder and I have agreed that there will be instances of joint authorship and other instances when I will be the sole author. The decision on whether the authorship is joint or sole will be based on the level of contribution from each of us.

OTHER ISSUES

Please specify other issues not discussed above, if any, and how you will address them.

Signed:
Student: [redacted]
Supervisor: [redacted] Date: 03/10/2018
Date: 0/(6

Please submit this form to the Research Office (Donna Jay, Room Bl .43)

Office use only

Action taken:

- [x] Approved
- [ ] Approved with modification or conditions – see below
- [ ] Action deferred. Please supply additional information or clarification – see below

Name: Michael Wyness

Signature: [redacted]

Date: 17/10/18

Stamped: Centre for Education Studies
University of Warwick
Coventry CV4 7AL

Notes of Action:

Appendix 4.7: Information Sheet for Participating School

Study title: What happens to mathematical resilience in year 7 when I help pupils to manage their mathematics anxiety in year 6?

Information sheet for participating secondary schools.

Many thanks for showing interest in this research study. The purpose of this document is to provide additional information to enable you to make an informed decision for your school and your pupils about taking part.

The purpose of the study

As a maths teacher, I come across many learners who get very anxious about learning mathematics, and this anxiety often prevents them from reaching their potential. This study looks at ways to help year 6s and year 7s overcome that anxiety and make more progress with their mathematical understanding.

This study involves the measurement of mathematics anxiety and mathematical resilience in your year 7 mathematics classes with two short questionnaires. They should take no more than ten minutes each. I then offer those pupils who identify as likely to benefit three-to-five face to face sessions with me, lasting between half an hour and an hour. I will explore their past and present experiences with learning mathematics and try out ways to improve their learning experience. I will then offer up to four of your feeder primary schools the opportunity for the same intervention with their year 6 pupils.

Why have I been invited to participate?
You have been invited to take part either as you have already shown interest and involvement in mathematics anxiety and mathematical resilience through the NCETM Central Maths Hub (https://www.centralmathshub.com/resilience.html), or because one of your feeder primary schools has shown an interest in being involved.

If I give permission for the school to participate, do my pupils have to take part?
It is up to your pupils and their parents to decide whether or not to take part. If they do decide to take part they will be given another information sheet, similar to this, to keep. They will also be asked to sign a consent form. They are still free to withdraw at any time and without giving a reason.

What are the possible benefits of taking part?
Your involvement will further understanding of self-management of mathematics anxiety and the development of mathematical resilience, and improve the support and guidance offered to students. It may result in significant improvement in mathematics progress in affected students.

Confidentiality and data protection
All information collected about your pupils will be kept strictly confidential (subject to legal limitations). Confidentiality, privacy and anonymity will be ensured in the collection, storage and publication of research material through the use of password protected files and cloud storage. All data will be anonymised. Data generated by the study will be retained in accordance with the University's policy on Academic Integrity. The data generated in the

course of the research will be kept securely in electronic form for a period of ten years after the completion of a research project.

What will happen to the results of the research study?
The results of this research will inform my doctoral studies.

Who is organising and funding the research?
I am conducting the research as a doctoral student at the University of Warwick, within the Centre for Education Studies, under the supervision of Sue Johnston-Wilder who can be contacted by email if desired on [redacted] .

Contact for Further Information
For further information, contact Janet Kilpatrick Baker
[redacted]
https://warwick.ac.uk/fac/soc/ces/postgrads/pgr/eportfolios/u1796347/

Thank you
Many thanks for taking time to read the information sheet.

Janet Kilpatrick Baker

Date: October 2018.

APPENDIX 4.8: LETTER TO TEACHERS ON ADMINISTERING THE SCALE

Study title: What happens to mathematical resilience in year 7 when I help pupils to manage their mathematics anxiety in year 6?

Instruction Sheet for administering the mathematics anxiety scale and the mathematical resilience scale

Many thanks for agreeing to take part in this study.

This sheet explains the procedure for administering the mathematics anxiety scale (MAS) and the mathematical resilience scale (MRS).

You should have a brown envelope for each teaching group, with enough copies for each pupil. They can be completed in pen or pencil. Please ask your pupils to complete the following:

Gender: (girl/boy/prefer not to say)	Age:

Please give each pupil the sheets which correspond to their register number. Explain to the pupils that the scales are thus anonymous but the number enables me to pair the two scales; it is the class profile that is being studied. If any pupil is absent, please do not use their register number for another pupil.

Register Number:	KS2 SATs score:

These cells should be already completed, so please tell your pupils to ignore them.

School Number:	Class number:

The pupils should now complete the scales independently and in silence by reading each sentence carefully and then circling the words that best describe how they feel. The anxiety scale should take 5 to 10 minutes to complete, and the resilience scale should take 10 to 15 minutes to complete. Please read the questions aloud if you feel that is appropriate for the needs of the class.

Once the scales have been completed, please collect them and put them into the relevant brown envelope. Thank you very much for your help.

Contact for Further Information

For further information, contact Janet Kilpatrick Baker
[redacted]
https://warwick.ac.uk/fac/soc/ces/postgrads/pgr/eportfolios/u1796347/

Janet Kilpatrick Baker
Date: October 2018.

APPENDIX 4.9: INFORMATION FOR PARTICIPANTS

Parent/Guardian and Participant Information Sheet

<u>Study title:</u> **Managing maths anxiety and developing maths resilience**

Your child has been invited to take part in a research study. Before you decide whether or not to allow them to take part, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully.

The purpose of the study

As a maths teacher, I come across many people who get very anxious about learning mathematics, and this anxiety often prevents them from reaching their potential. My study looks at ways to help people overcome that anxiety and make more progress with their mathematical understanding.

This pilot study involves three to five face to face sessions with me, lasting around half an hour. We will explore past and present experiences with learning mathematics and try out ways to improve the learning experience.

Why has my child been invited to participate?
Your child has been invited to take part as their secondary school has agreed to be involved in the research. The headteacher and mathematics department are fully informed and involved in the study.

Does my child have to take part?
It is up to you to decide whether or not to allow your child to take part. If you do decide to allow them to take part, you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part, you are still free to withdraw your child at any time without giving a reason.

What will happen if my child takes part?
We will arrange a mutually convenient time with your school for the sessions. This will take around half an hour at some stage in the school day.

What are the possible benefits of taking part?
Your child's involvement will further understanding of the self-management of mathematical anxiety, and improve the support and guidance offered to students.

Will what my child says in this study be kept confidential?
All information collected will be kept strictly confidential (subject to legal limitations). Confidentiality, privacy and anonymity will be ensured in the collection, storage and publication of research material through the use of password protected files and cloud storage. All data will be anonymised. Data generated by the study will be retained in accordance with the University's policy on Academic Integrity. The data generated in the course of the research will be kept securely in electronic form for a period of ten years after the completion of a research project.

What will happen to the results of the research study?
The results of this research will inform my doctoral studies and will be used for my thesis.

Who is organising and funding the research?
I am conducting the research as a doctoral student at the University of Warwick, within the Centre for Education Studies. I am supervised by Sue Johnston-Wilder who can be contacted by email ([redacted]) if you require confirmation or have any concerns.

Contact for Further Information
For further information, contact Janet Baker
[redacted]

[redacted]

Thank you
Many thanks for taking time to read the information sheet.

Janet Kilpatrick Baker
[redacted]

07875 153250

https://warwick.ac.uk/fac/soc/ces/postgrads/pgr/eportfolios/u1796347/

Date: April 2019.

Appendix 4.10: Consent Form for Stage 2

Consent Form for Parents/Guardians

Managing maths anxiety and developing maths resilience

Researcher:
Janet W K Baker
PhD Candidate
University of Warwick

[redacted]

	Please tick box	
	YES	NO
I confirm that I have read and understand the information sheet for the above study and have had the opportunity to ask questions.		
I understand that my child's participation is voluntary and that I am free to withdraw them at any time, without giving reason.		
I permit my child to take part in the above study.		
I agree that my child's data gathered in this study may be stored (after it has bee anonymised) and may be used for future research, anonymised.		
I agree to the interview being audio recorded.		
I agree to the use of anonymised quotes in publications.		

Name of pupil:

Name of parent/guardian:

Date:

Signature:

Name of Researcher:

Date:

Signature:

APPENDIX 7.1: EXAMPLE CODING – HAND MODEL OF THE BRAIN

Date	**14th November 2019**
Phase	**3 and 4**
Umbrella Theme	**Hand Model of the brain**
Code:	Brain flip / freeze
Quote identifier : E7	
Janet: Do you think the hand model of the brain will help as well? Erin: yeah, because my hand's right in front of me Janet: you've got it with you all the time, haven't you! Do you remember how to do it? Can you show me how to do it? [Erin demonstrates hand model of brain] that's it, that's it Erin: and then I want to go like that [flipping hand]	
Quote identifier : E9	
Janet: I haven't really got a picture of the hand model of the brain, but I could put one together. Or do you think, is there another way of doing that, I wonder? Erin: I don't know. Janet: You've shown me your hand doing this, so it's obviously something that you remember by moving your hand. Erin: Yeah	
JKB thoughts – so here we have confirmation that a learner can understand the HMB, and remember it, and use it. Erin appreciates the link to her hand, which is always immediately available. Erin also seems to appreciate the importance of the hand flipping to represent brain freeze.	
SJW thoughts –	
Quote identifier – D5	
Janet: so what happens is, your mind goes blank, and it freezes, it's flipped, so the thinking part of your brain isn't engaged. Is that something that you've ever felt when you've been doing maths? When you think 'why can't I get this, this isn't making any sense' Devon: yeah like sometimes, you get it like, what's this, and then you ask the teacher and you can do all of it. I think it's just that you look at it and you think you can't do it. Janet: yeah Devon: but then like, when someone explains it, in a way that you understand, and like do it, then I understand it, they've explained it in a way that I understand, yeah, if that makes sense.	
JKB thoughts – after explaining the HMB to Devon, she can relate to the experience of brain flip. I like her explanation 'you look at it and think you can't do it'. I wonder how helpful this realisation is that first impressions may not be reliable?	
SJW thoughts –	
Quote identifier – D6	

Janet: good, and then when we meet next week, you can tell me how you've got on with the recovery breathing, and if you've thought about the hand model of the brain in your maths lessons, and also with the growth zone model. (x) [showing on paper] so this is the comfort zone, and this is the growth zone, and this is the anxiety zone. That's where you might want to think about the hand model of the brain and the 5/7 breathing. You can take this piece of paper away with you. What would be best to write down on here to remind you? Devon: um, I don't know, like, think about how the brain flips.
JKB thoughts – this quote indicates that Devon finds the HMB an accessible, and appealing tool.
SJW thoughts –
Quote identifier – C10
Janet: The first thing I want to tell you about is this brain flipping, when you feel that you just can't think. Is that something that you've ever felt? Chris: yeah Janet: can you think about when you last felt like that? Chris: um, (x), um, it was, well, we're doing ratio right now in maths and I'm not that sure about it, and I'm pretty sure that [brain flip] happened last week. Janet: mm hmm, that your brain flipped? Chris: yeah
JKB thoughts – I wish I could have drawn out more here – however, Chris can identify a brain flip situation when she was learning ratio.
SJW thoughts –
Quote identifier : C11
Janet: So I want you to think about your last lesson on ratio and proportion. And with your finger, move the circles to show how much time you spent in comfort, how much time you felt in growth, and how much time you felt anxious. [Chris adjusts GZM]. Yes? Good. And the other thing we can do is to make a note of why you felt that way. So can you tell me why… Chris: um, because there were some parts of it I knew, (x), but then, quite a bit of it, I didn't know. But, and then sometimes, my brain was, just, just froze. I just couldn't think. Janet: [Janet is typing] what did you say after 'there were times when my brain froze' ? Chris: and, I wasn't sure how to deal with it, then it was frozen, but … Janet: [Janet is typing] so it was frozen for a bit? And not in good way? [Janet is typing] okay. Do you want to read that, and check that I've written what you wanted to say? Chris: [reading] yeah
JKB thoughts – Aha – I did draw out a little more slightly later in the interview. What a lovely quote – my brain was, just, just froze. I just couldn't think" I could use this in future when describing brain flip.
SJW thoughts –
Quote identifier –F3
Janet: So the other thing I talked to you about last week was the hand model of the brain and thinking about your emotions and your thinking sometimes becoming a bit disconnected. Is that something that you thought about last week? Finley: Yeah Janet: Can you tell me a bit more about that? When you thought about it, or what difference it made? Finley: Um, I can't remember when, but it's just… I was just thinking about what you said with the… I think it was in a maths lesson or something.

Janet: So you were doing it with your hand there. Is that something that helps you think about it, actually disconnecting your… Finley: Yeah Janet: …fingers and your thumb with your hand? And when you were in the maths lesson, did that help you think, it's not me not being able to do it, it's just my brain disconnecting. Finley: Yeah. Janet: Yeah? And then what did you do after that? Did you do the breathing? Finley: Yeah. Janet: And that helped? Good. Well I'm glad that's starting to be useful.
JKB thoughts – Finley was not very talkative in the sessions but did show me the HMB with her hand. She couldn't express it in words, but seems to have found the model useful, as demonstrated by her hand movements.
SJW thoughts –
Quote identifier – E8
Erin: Yeah. Well I was doing my homework like, I don't know, a couple of days ago and I got really confused. I had like a little panic attack. I was like, I can't do it. And then I did like the breathing thing and, like, cause normally it's just a little bit I don't understand and it helps, but I was like, wow, it really really works. Cause I was like so confused I was like crying and I was having a fit and I was throwing things and I was like, oh, I could do the breathing thing. And then it worked and I was like, ok. Janet: So before the breathing you were… Erin: I was really angry. I was like, I can't do it. Janet: You were angry, you were upset. You were crying. And then you did the breathing how many ins and outs did you have to do? Erin: I think it was about fifteen? Twenty? I don't know. Janet: So quite a lot. Erin: Yeah. Janet: And then how did you feel afterwards? Erin: I felt really, like, calm. And I just felt really, like, more comfortable doing the homework. Janet: And the homework that previously you'd been really confused about. Erin: And then it kind of like, cause I felt like my brain, you know that thing, it was already a bit, like, up, emotion thing. And then it went. Janet: So you're taking your fingers away from your thumb. Saying that the thinking brain had come away from your emotional brain. Erin: Yeah. It was already a bit up, and then it was like, it was really far. It was folding backwards. And then when I did the breathing thing it was, like, securely on. Janet: It came back on again. Erin: Yeah. Janet: And then when you looked back at your homework, what were you able to do? What was that like, being able to do your homework again? Erin: Well, my mum heard me, like, because I was upstairs in my room, my mum was like, are you ok? And I was like yeah, it's just homework. So I was like, more ok with it, and I was… yeah.
JKB thoughts – here Erin reflects on her experience on recovering from anxiety by using RR and is then able to link that to the HMB to demonstrate the way the RR helped her to reconnect her thinking brain to her emotional brain. This is a great (powerful) example of the tools in action. Reading this quote has prompted me to move the breathing node to a higher level, as one of the three tools.
SJW thoughts –

Quote identifier – I7
Janet: So sometimes those emotions take over, and the thinking is disconnected because there's no time to think. You've just got to act. And those emotions get you ready to either fight, or flight, which means run away, or to freeze. And that's the three ways that it can use to keep you safe. It gets you all ready for those. The problem is, if you start to feel you're in danger in a maths classroom, in a classroom, here, hopefully you won't fight anybody. And hopefully you won't run away. So what happens is your brain freezes. Stops thinking. It says, ok, if I stand very still the danger will go away. Which stops you learning. Do you think that ever happens to you? Do you ever think, I just can't think straight, I don't know why I can't understand this. Indigo: Yeah. Especially like in tests. Like, usually, like, in class, it's like you're normal. When you're just doing a normal lesson it's quite easy, but then… Janet: Yeah Indigo: When you do a test you kind of just worry, and then forget everything you've learnt. Janet: Yeah. Which is annoying, isn't it? Indigo: Yes. Janet: And that's because your brain thinks, oh, we've got a test, we've got a dangerous situation, so I've got to be ready to fight or run away or freeze.
JKB thoughts – I isn't relating her experience to the HMB yet, but can identify a situation where her worry has the result of forgetting previously learned knowledge.
SJW thoughts –
Quote identifier – J5
Janet: And then, the other thing we talked about last time was when your mind goes blank or your brain gets frozen. So maybe that was how you felt yesterday in your test, when you thought, I'm not sure how to do this. Jack: Yeah, that's how I felt.
JKB thoughts – so I seem to be building up a fair amount of evidence that learners are relating to the HMB
SJW thoughts –
Quote identifier –
Janet: The other thing we talked about was your brain flipping, the hand model of the brain. Did you think about that at all last week, or notice it happening? Blake: I kind of like, I didn't do the actions but I knew in my head it was flipping back and forth. Janet: Right, can you remember a time it was flipping? Can you tell me about a time when it was flipping? Blake: Well, a minute ago, I'm just in maths now, I got sent from maths. And we're doing angles and I was doing geometric problems. I got stuck on a question and I was like, under the table I was doing the actions under the table. Janet: What do you mean, you were flipping your hand? Blake: Brain flipping. Janet: Oh so under the table you were making your brain. Ah. Blake: I was just like reminding myself it's just the brain. And I asked the teacher for help. Janet: Ah, so do you think you would have done that before? No? So thinking, it's just my brain flipping, helped you get the confidence or the nerve to ask the teacher for help? Blake: Yeah

Janet: And was the teacher able to help you? Was it a good thing to do to… Blake: Uh huh (affirmative) Janet: Ah, that's really interesting. Thank you.
JKB thoughts – this is a great example of the HMB actively helping a learner to recover from being stuck and get assistance. Here B both visualises the HMB and physically acts it out , but under the table.
SJW thoughts –
Quote identifier – C12
Janet: Alright… Can you tell me a little bit more about that? You were in your maths lesson, and what made you notice that it might be a good idea to start doing the breathing? Chris: Because I was really stuck on what to do, and I just… I just had no idea and I was really confused, and so then I realised that I felt like I was about to go into brain freeze, and then I did the breathing.
JKB thoughts – this is in the wrong place – I have moved it to the RR node.
SJW thoughts –
Quote identifier – D7
Devon: I did it a bit in the test yesterday, cause we had a test yesterday, but that was near the end because I understood the first part. Janet: Right, but coming to the end of the test, you felt that you needed it, and… Devon: Yeah, cause, like the time was up on the board and we only had, like, three minutes left. Janet: Oh right. So you did some breathing. Devon: Yeah. Janet: How many times did you breathe? Devon: Like three. Janet: Yeah, and what… Devon: I think. I can't really… Janet: But not ten. Not ten or twenty. Devon: No, not ten. Janet: So you did the breathing about three times and then how did that feel differently? Devon: I don't know just sort of able to concentrate on the question and then sort of try and work it out better. Janet: Right. Devon: It's like blank, like you said. Janet: It was a blank. So remember when I showed you the brain flipping? Devon: Yeah. Janet: So is that really when you felt that your brain had flipped and you'd gone blank? Devon: Yeah sort of like you didn't really know what to do and then you do the breathing and it's like… you sort of think 'oh right that's what I have to do', and then you sort of see it differently once you calm down. Janet: That's really interesting. You see it differently once you've calmed down.
JKB thoughts – this is mainly about breathing but I have added it here as D recognised that her mind has gone blank. Also her insight that ' you see it differently once you've calmed down' is very revealing – another useful quote here.
SJW thoughts –
Quote identifier – D8

Devon: I explained to my mum, cause I said I'd had the lesson and stuff… Janet: Yeah. Devon: And I said about that you said that the brain flips and about the emotions and stuff. I think it sort of made more sense why I do blank and freak out a bit. Janet: Yeah. Devon: And everything. Maybe that's what's happening inside the brain that makes it blank and freak out a bit. Janet: Yeah. And did that help, explaining it to your mum? Devon Yeah. Cause then my mum was like, 'oh, right, is that ___ like about, like, I understand now', so me and her understand more. Janet: Right. Right. And so it made sense, and you think 'yes, that's what happens to me sometimes'. Devon: You think that's why you blank sometimes and you get scared, when you see, like, the big number.
JKB thoughts – here D feels that the HMB makes sense and explains her experience enough to explain it to her mum, who encourages her in return. Understanding the neurological processes is important for learners and their parents.
SJW thoughts –
Quote identifier – D9
Devon: It's not my strongest subject, angles, I didn't do that well, but… Janet: You don't have to do it… you don't have to get them all right. Devon: Yeah. Janet: But the important thing is trying, isn't it? That's where you learn. So… you've… I feel like I can do the breathing now to calm down. So have you been practising a lot, then, to… Devon: no, like just, like, in the test, when I did the test and stuff, like I felt like that was a way, so like… un-blank your brain and carry on doing it, like understand that it's not that hard. Janet: I like that, un-blank your brain. I'll use that. Un-blank your brain. Mm. That's good. And you've written here that you feel more confident in maths now.
JKB thoughts – D is recovering from anxiety by , in her words, 'unblanking' her brain
SJW thoughts –
Quote identifier – B7
Blake: It was kind of like, in my mind, I was saying to myself, draw something, like, thinking of something that I could like, try and make, like, I think I did a reindeer and then I tried to draw a reindeer with all the cracks, and it took my mind of it and then it like… kept me calm. Janet: So that helped? Blake: Yeah. Janet: And, because you were calmer, did that help with learning the maths? Blake: Yeah, it did. I managed to get onto question… I usually get onto question four or five. I think I got onto question eight or nine. Janet: Oh, my goodness. So normally you get onto question four or five, and now you're getting double the amount. Blake: Yeah. Janet: And what was happening in the past, then, did you get to question four or five and then stop, or did it take you ages to get to question… Blake: I like got to question five, and then I'd, like, stop, cause I'd be like, nervous to do any more because I couldn't think of it. Janet: Right, so you'd get to question four or five and then feel that your brain had… Blake: Flipped

Janet: Yeah, and then you couldn't do any more. So remembering that you could just fill in the creases and that would calm down your brain.
JKB thoughts – B is able to relate his experience to the HMB, specifically a brain flip.
SJW thoughts –
Quote identifier – C13
Janet: Did your brain freeze at all? Chris: I don't think so. Janet: Ah. Chris: Because we've been on this topic for a while. We're on the end of it. I know it more, I understand it more, so then I… cause when I don't understand it that's when my brain freezes.
JKB thoughts – C relates the experience of brain freeze to when she doesn't understand the mathematics
SJW thoughts –
Quote identifier – C14
Janet: Maybe that will be something that helps. And the five seven breathing, is that something that you've thought about at all? Chris: Yeah, like, it does help cause like, a few weeks ago now, I had it, I did, my brain froze and I did do the breathing and it really helped. Janet: So again, knowing that just helps you… the next time, you don't worry quite so much. Chris: Yeah.
JKB thoughts – and here C is able to recognise that her brain has frozen or flipped and take action to recover through breathing.
SJW thoughts –
Quote identifier – C15
Janet: I wonder if you could just look back and think about what we've done the first session and the second session and this session, and think about what's been most helpful, or most useful, and if there's anything that really hasn't been hugely helpful at all. Just because I'm thinking about what I'm gonna do next time with the next year sevens. Chris: I think the scrunching of the paper and the breathing were the most helpful to me, because when my brain freezes, I now know how to get it back, and be able to carry on with my work. Janet: Right. Chris: And then with the paper, it just helps me really like, relieve, like the annoyance of it, so then I'm not all grumpy and cross. Janet: So you said that actually crunching up the paper again helped you feel a little bit better. Chris: Yeah.
JKB thoughts – again C is able to recognise that her brain has frozen or flipped and take action to recover through breathing. Evidence of increased agency here through the use of the tools.
SJW thoughts –
Quote identifier – D10
Janet: What you thought was the most helpful thing we'd done, and if I'm going to think about doing this with other year sevens, what would be most helpful to do again. What do you think? Devon: I don't know, there's like a couple of things. Like the explaining like the hand model of the brain, cause then it sort of made more sense and you could like, understand why you get

anxious, so then you could think about it and think, oh no, it's not because I'm dumb, and like everyone is like it sometimes, but it's just that, like some people would be like it in English, but I'm not like it in English. Some people won't be like it in maths but I'm like it in maths. So like everyone has it in some subject or something. So like it helps you, like think that you're not dumb, you just need like, more help to like, encourage you and, like, get you like going and like on maths… if that makes sense. Janet: So that's something I should share with other year sevens? Devon: Yeah.
JKB thoughts – there's a lot to unpick here. 1. understanding the neurological processes is very helpful to explain why the anxiety occurs 2. It helps this learner to move away from a fixed mindset - she realises that she isn't dumb 3. She realises that she is not the only one – everyone is like it sometimes. 4. She realises that she gets this from mathematics, but others might be affected in other subjects or situations 5. She moves away from learned helplessness to realise that she needs (and presumably can benefit from) more help.
SJW thoughts –
Quote identifier – G16
George: I've got all the things in my brain that can help me. The one thing that just doesn't seem to come to me is my thinking brain. Sometimes, because, you see, I know it's not like you're gonna be really bad one day and you're gonna come back and get like an A plus in your GCSEs. That's not gonna happen, I know. You have to learn. But for me, I'm just trying to find a way what I can understand, not have to… I can understand, I can listen really well and I can, just, go on to get a good life. I don't wanna be that guy that has a terrible job or lives homeless on the street. I don't want to be that guy. I want to be… I want to be a guy who has a good life, makes lots of money, and can actually do something rather than just work at McDonald's or something. I really just want to have a good life. Like, but my… my brain just thinks that it's the right way for me… my brain is, doesn't have all the energy provided in my brain to understand. See, if I…
JKB thoughts – I don't think this is in the right place – this is more about understanding than HMB.
SJW thoughts –
Quote identifier – G17
Janet: Do you want a tissue, sweetheart? George: I'm fine. I just… just got some sand in my eye. Janet: Ok, there's a tissue and there's some water and there's some chocolate, and you can stop any time. So, if you're feeling that, oh dear, I need to reengage my thinking brain again, people have found one way to do it which is by breathing in for a count of five… George: Is there any way, shape or form, where I can get my brain to just concentrate and not have me going off into my own little world, and just actually let me concentrate? Is there any way shape or form where that can happen? Because I really, you see, the teacher's talking really gets boring for me, and that's where I go off in my own little world. And you see, I don't wanna do that. I really want to listen to the teachers. I just don't want… if I get a good life with a nice house, a lot of money, and a nice family and like, whatever, and a nice job, then I can start to enjoy my life. And then I can start to…
JKB thoughts – I am really struggling here to get G to understand the HMB, and I don't think I have managed it. He is more concerned about maintaining focus in the classroom when it gets boring for him, rather than when he gets anxious. This seems to be more about getting out of comfort rather than recovering from anxiety. Perhaps there is something here about meeting the needs of the learner, where G has different needs to those that the HMB can assist with?

However, using this as a description of something that can happen whilst in the comfort zone might be useful.

SJW thoughts –

Code	HMB awareness

Quote identifier – K6

Janet: So whenever you next feel, I'm not getting this, I don't understand it, and start to panic, then think, it's ok, I just need to reconnect my thinking brain. Does that make sense?
Kelsey: Yeah
Janet: Is that something that you feel from time to time?
Kelsey: Yeah. A lot.

JKB thoughts – K relates strongly to the description of the HMB

SJW thoughts –

Quote identifier – H9

Janet: So what do you think has been most useful?
Hayden: The comfort growth and anxiety.
Janet: Ok, and why is that? How has that been useful?
Hayden: Well, it like, makes me understand more what I'm feeling when I do maths. Um, and probably the hand.
Janet: The hand model of the brain.
Hayden: Yeah. It, like, also helps me understand what goes on inside my brain. And like, um, like what happens when you get, like, anxious. And yeah.
Janet: And that's been useful?
Hayden: Uhuh.

JKB thoughts – another example here of the HMB being appreciated to help understand brain processes and the impact of emotions. I think the sub groups here are a bit blurred – I should reorganise this umbrella code.

SJW thoughts –

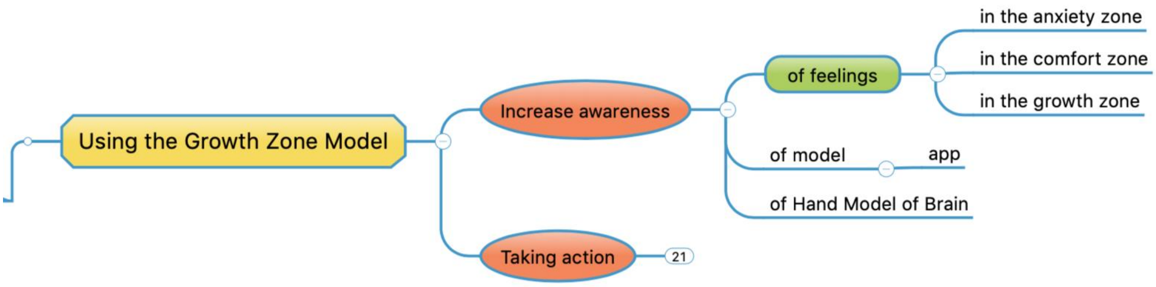
Quote identifier – I8

Janet: And what did you do when you felt panicky?
Indigo: I did the five seven.
Janet: Right, and the five seven breathing helped you?
Indigo: Yes.
Janet: Can you tell me a little bit more about that? I'm thinking about how I might help people recognise that they're feeling panicky.
Indigo: Um, well, I kind of just went quite blank. Like I didn't know what was… just forgot stuff. And I just thought I couldn't really answer the questions well.
Janet: Yeah. So did you remember that when your mind went blank, that it was just that your thinking brain had disconnected with your emotional brain.
Indigo: Yeah.
Janet: And did that help?
Indigo: Um, well, yeah.
Janet: Yeah. So that helped and you thought, that's alright I just need to get back from panicking to the growth zone.
Indigo: To the growth zone, yes.

JKB thoughts – Indigo demonstrates the realisation that feeling panicky and going blank are reversible with breathing. Another good example of brain flip.
SJW thoughts –
Quote identifier – K7
Janet: Has that happened at all in the last couple of weeks? When you felt, I just can't think straight. Yeah? Kelsey: Yeah. Sometimes my maths teacher gives me a lot of hard work. And I kind of like get confused. And then I think again, like, oh yeah, I know that. And then like all of a sudden, like five minutes later my head goes blank again. So it's like confusion on what to do. Janet: Yeah.
JKB thoughts – Here K identifies the experience of brain flip with being confused .
SJW thoughts –
Quote identifier – L12
Janet: Ok. So tell me how you feel when you feel anxious. Lynden: How I feel. Well, um, many things happen. Uh, when I'm anxious, I think of the consequences of when a letter goes home saying I've done no work because I'm anxious, and how my parents are gonna punish me. I also, uh, the way I respond to when I get anxious is, um, I tend to just shake and just lose my mind. Like my mind is just blank. Cause it's too much work piling on. And it's also really stressful. And sometimes it can even get depressing, having that much stress on you, in maths as well.
JKB thoughts – this is a vivid description of the brain flipping.
SJW thoughts –
Quote identifier – L13
Janet: Does that make sense, that your brain goes blank? So it's not that you can't do it. And it's not that you're not able to think about it. It's just that your brain's working very hard to keep you safe. Is that something that happens to you often? Or sometimes? Lynden: It's actually pretty rare, to be fair, because it's just when I get too much hard work and it's not up to my level and there are other students in my class who would say, like, ooh that's easy. But as I know everyone's not to the same ability and I sometimes downgrade myself. Because I'm thinking I'm not as good as them as such. So that's when it starts to happen, when they're all acting like it's easy and I'm feeling really stupid about myself cause apparently I'm supposed to, uh, think it's easy too.
JKB thoughts – hmm. Here Lynden recognises that this vivid experience is infrequent – but still unpleasant for him to experience. He describes the feeling of falling behind here.
SJW thoughts –

APPENDIX 7.2: EXAMPLE CODING - INCREASED AWARENESS OF GROWTH

Phase 5 of data analysis



Theme name *(is it punchy? Can the words of the learners be used?)*

Using the GZM to increase awareness of feelings in the growth zone

Theme description *(what aspect of the data does it describe?)*

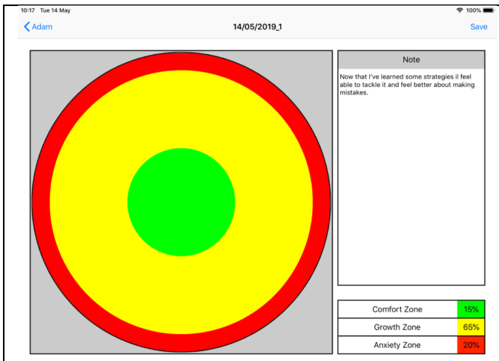
In this section I am focusing on instances where the learners describe their feelings in the growth zone.

Theme rationale *(why is this of interest?)*

Having already looked at learner descriptions of feelings in the anxiety zone and the comfort zone, it will be very interesting to see if I have anything of value for the growth zone. I suspect that I had a preconception that this would be the hardest one (I say to one learner that we will leave the growth zone until last, as it is the hardest). This preconception may well have affected the data, both in nature and in quantity.

Describing feelings when in the growth zone.

Adam CI 2 DBR 1
Janet: So, I was thinking of asking you to do another growth zone model plot at the end. Do you feel… once we've talked? It doesn't matter if it's the same or different, but think about what you're feeling now about maths and whether there's any change. (pause) Ok, and any particular reason for that? Adam: Well now that I've learnt some strategies I feel like I'll be able to tackle it easier and feel better about making mistakes.



Adam seems to be approaching mathematics struggle in a more positive way here.

Adam CI 3 DBR 1

Janet: Have you been thinking about the growth zone model?
Adam: Yes. Yeah.
Janet: Any thoughts about that?
Adam: Just thought to myself about what zone I'm in a couple of times.
Janet: Right, so when's that been, in lessons? Or at home? Or…
Adam: Yeah, in maths lessons.
Janet: In maths lessons. And which zones have you been in?
Adam: Usually growth, I think.
Janet: Yeah? And how did you know you were in the growth zone?
Adam: Because I was… the questions were challenging but I did get most of them correct.
Janet: Right, so you felt challenged.
Adam: Yeah.
Janet: And what did that feel like to feel challenged? To have a challenging question?
Adam: It felt ok. Yeah. I just felt like I was learning, and with the neurons thing.

Would Adam have recognised that he was in the growth zone if he didn't get most of the questions correct? He recognises that he was challenged, but success does still seem to be an important factor to him. He does however recognise that he was learning.

Blake CI 1 DBR 1

Janet: Okay. Are there any times when you're in the growth zone, when you feel like you're getting it?
Blake: [shakes head]
Janet: no? No times at all? [Blake appears to be getting upset] That's alright love, don't worry about it. Hopefully we can show you some ways, so that in the next few weeks, you can feel a bit happier about it.

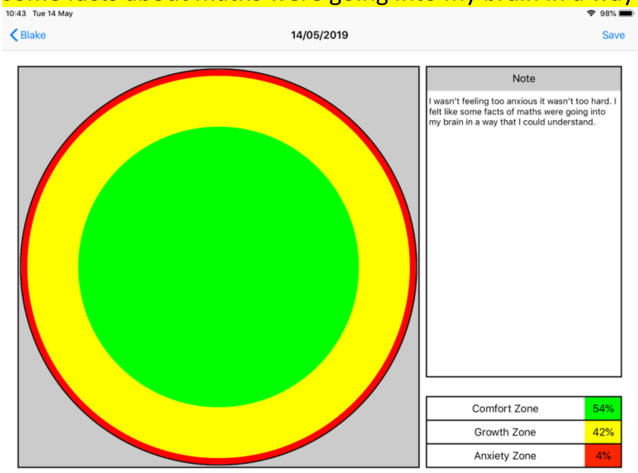
Blake does not appear to be able to relate to the growth zone at all.

Blake CI 2 DBR 1

Janet: [Shows Blake the GZM] Do you remember looking at this picture in the last session?
Blake: Yeah
Janet: Yeah? Do you remember what each of the bits, each of the areas, stand for?
Blake: Yeah. So, boring [comfort zone], challenging [growth zone], you don't really know what it means [anxiety zone] .
Janet: So the anxiety is where you don't know what it means. So might you not know what it means when you're in growth as well?
Blake: You don't… it depends, because you kind of know what it means. You have an understanding but you don't know fully.

For Blake, being in the growth zone requires some level of understanding of the concepts. He cannot envisage being in the growth zone without having a degree of understanding.

Janet: [Asking Blake to record his feelings on the GZM app] Can you think about the maths lesson you've just come out of, and just use one finger.
Blake: What, with the techniques you taught me?
Janet: Yeah. If you were going to pull it out to use the whole circle, yeah, that's it. It'll work like that. Yep. So tell me why you've put it like that.
Blake: Oh I didn't mean it like that. Can you go back?
Janet: Ok.
Blake: So more growth.
Janet: More growth. So can you tell me why you've put it like that?
Blake: Because I wasn't feeling too anxious, and… but it wasn't too hard. Uh, and I felt like… some facts about maths were going into my brain in a way that I could understand.



Here Blake refers to an awareness that he is learning in the growth zone.

Chris CI 3 DBR 1

Janet: Ok, so tell me about how you got on this last week.
Chris: Well this last week I've been understanding what we're doing in maths a lot more, so I've not been able… not been having to do the breathing as much.
Janet: Ok.
Chris: But I'm still in the growth zone.

Reading this back, I am fascinated by the word 'but'. What does Chris mean by this word? I wish I had followed this up more – does she mean that even when she doesn't understand, she is still in the growth zone?

Devon CI 3 DBR 1

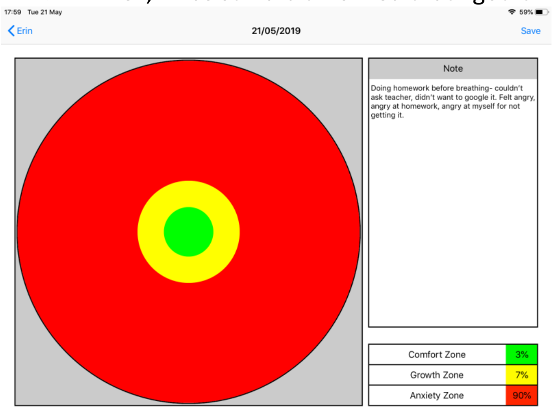
Devon: I think it's sort of better actually, cause we've moved on to a new topic, because I said we did the test thing.
Janet: Yeah.
Devon: And every time we do the test we move on to a new topic. Like a different… a different topic. After we've took the test on the other topic. And the new topic's, like, I'm finding it really easy.
Janet: Quite straightforward
Devon: Like, not really easy but, like, probably in like the growth zone. Like, it's challenging but I can manage it anyway.

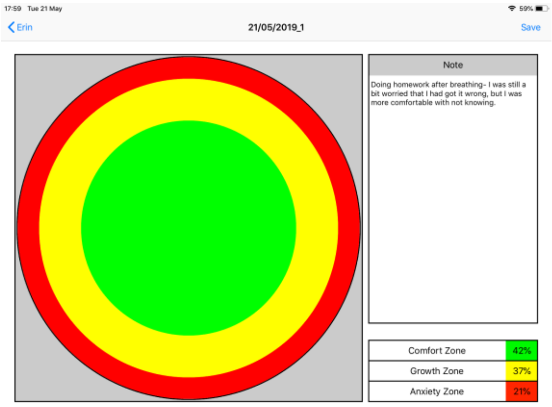
This is an excellent description of the growth zone – manageable challenge.

Erin CI 3 DBR 1

Janet: What difference did the breathing make? Yep? So this is after breathing. Doing homework after breathing. Tell me how you felt here?

Erin: Well, I was still a bit worried that I got it wrong, but I was more ok with getting it wrong.



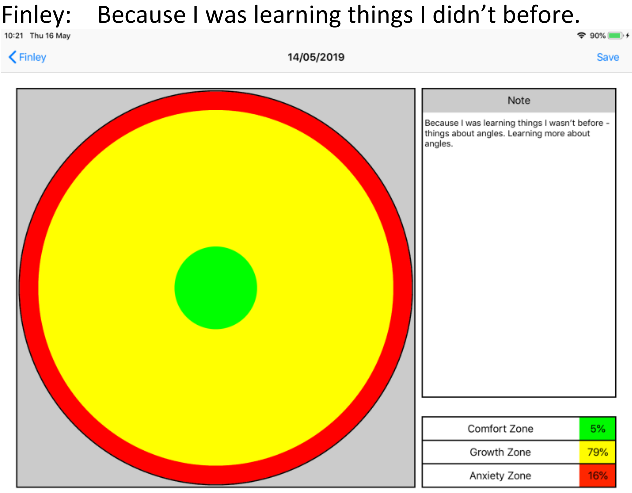


This looks very much like the growth zone to me – Erin is still a bit worried but managing to cope with these uncomfortable emotions.

Finley CI 2 DBR 1

Janet: Do you remember last week you did this with your finger? So if we just stick to thinking about maths lessons, think about your maths lesson and where you were with the growth zone model in your last maths lesson. Ok. Tell me why you've put it to there.

Finley: Because I was learning things I didn't before.



Finley doesn't describe her feelings but does focus on the learning.

Indigo CI 1 DBR 2
Janet: can you remember how you were feeling in your maths lesson? Indigo: Yeah. Janet: Can you show me on the app how you were feeling? Indigo: Mostly like this. Janet: Right. So mostly growth. So tell my why you were feeling like that. Indigo: Um, because, uh, it was like, quite hard but then it was quite easy because I was learning it. And I sort of understood it but I kind of like… *[I seem to have failed to record this data on the app]*
Indigo seems to relate learning with an easy experience – getting to flow state perhaps? She does not yet see a hard experience as a learning opportunity.

Kelsey CI 2 DBR 3
Janet: How have things been going? Kelsey: Um, they've been alright. I guess I've been a little concentrated. You know what I mean. And, um, it's been alright, to be honest. I kept my head down. And I was doing a lot of work, cause I did a test once. And I got like… cause I had like a whole sheet but I don't know how much I've got. So I got like twenty, but I don't know what out of. But yeah. Janet: Tell me how you felt while you were doing the test. Kelsey: I felt positive about myself cause I was in here when I did it. Janet: Oh right. So it was nice to be in here. Kelsey: Yeah. Gives me strength. And it, like, I guess it makes me like a little bit concentrate… makes me concentrate a little bit more. Cause there's like, no shouting. It's not like a whole classroom where people shout. So yeah. Janet: So would you say that you were feeling… do you remember when we looked at this last time, the growth zone model, do you remember that? Kelsey: Yeah. Janet: And the different areas. Where you'd feel comfortable, but it's not hugely interesting, a little bit safe. Kelsey: Yeah Janet: And then the growth zone where it gets a little bit more interesting, a little bit more challenging, but might start to get a little bit uncomfortable. And then anxiety is when you start to feel panicky. Kelsey: Yeah. I guess I was like a bit in the growth zone. Janet: Do you want to put the pebble where you think. Ok, so you're in the growth zone when you did the test. Kelsey: Cause there was still a little bit, like, it was still challenging. But I still got round to do it.
Kelsey recognises the balance of challenge and success in growth. How is this different to Adam? I'm not sure - I think I might be viewing the situation in an overly subjective way.