Implementing mastery approaches for the reduction of mathematics anxiety in primary school pre-service teachers

This thesis is submitted in accordance with the requirements of Liverpool Hope University for the degree of Professional Doctorate in Education

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Declaration

Implementing mastery approaches for the reduction of mathematics anxiety in Pre-service teachers.

This thesis is an original work composed by the undersigned candidate in fulfilment of the requirements for the degree of Professional Doctorate at Liverpool Hope University and has not been submitted previously in support of any degree qualification or course. All sources of information therein have been specifically acknowledged, and the content of the thesis is legally allowable under copyright legislation.

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Abstract

Geraldine Parks Implementing mastery approaches for the reduction of mathematics anxiety in primary school pre-service teachers.

Research indicates that mathematics anxiety is a significant issue that negatively affects teachers' ability to teach, and pupils' acquisition of numeracy. Mastery approaches to mathematics pedagogy have been proposed as one potential solution to reduce mathematics anxiety in teachers and learners. This study tested the hypothesis that using a mathematics mastery approach across a ten-week mathematics teaching module with primary school trainee teachers would reduce anxiety and anxious thoughts and feelings associated with teaching mathematics, as well as lead to increased confidence, motivation and attentional control, and less anxiety through training. The methodology of pedagogical action research (PedAR) was adopted, with the study taking place at one teacher-training college in Northern Ireland.

A quasi-experimental sequential mixed-methods design drawing on quantitative and qualitative approaches was used, with two five-week cycles of quantitative data collection separated by a period of qualitative methods to inform preliminary analysis and reflection. The study included primary school trainee teachers in the second year of a Bachelor of Education degree. The cohort was split in two, with one group receiving a mathematics mastery intervention over ten weeks, whilst the other experienced teaching as usual. The mixed-methods approach enabled insights from the first cycle of data collection to inform the second cycle, as is typical for PedAR.

Teacher mathematics anxiety and anxiety in teaching mathematics was measured before and after the intervention. In addition, a visual analogue scale was used to measure students' weekly feelings of self-efficacy, motivation, anxiety, and attention following each mathematics class. The qualitative data comprised semi-structured interviews, undertaken between the two five-week cycles. Quantitative data indicated no significant change in mathematics anxiety before and after teaching. Comparing weekly measures indicated some advantages of the mastery approach compared with teaching as usual, with the mastery group reporting increased mastery (reflecting increased student self-reported self-efficacy) in the mathematics material in the last five weeks compared with the first five weeks of teaching. In addition, qualitative data suggested that students responded favourably to the mathematics mastery approach. The results have important implications for the development of pedagogical approaches for the delivery of teaching and learning in teacher training mathematics provision.

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1. Introduction

This thesis explored mathematics anxiety in student teachers and investigated whether it can be overcome or mitigated by using a mathematics mastery pedagogy. This is a critical issue as research demonstrates that mathematics anxiety can be transmitted from significant adults to children and the cycle of anxiety needs to be broken so future generations of children will develop a stronger confidence and gain enjoyment from mathematics.

With increased global testing by the Organisation for Economic Cooperation and Development (OECD), there has been growing attention in the wide variations in performance in mathematics and a desire to understand variation between individual learners, diverse geographical areas and across different countries (Foley, Herts, Borgonovi, Guerriero, Levine & Beilock, 2017). This focus sits alongside a worldwide increased emphasis on Science, Technology, Engineering, and Mathematics (STEM) subjects in education as governments across the world seek to produce and develop a skilled workforce to meet growing demands (Gough, 2015). Countries with resilient and vibrant economies are often those who promote STEM subjects (Marginson et al., 2013). Governments, companies, and industries in the private and public sectors are focusing on encouraging education and training in these areas, often measuring the performance against those on a global level (Cambridge, 2017). The trends in International Mathematics and Science Study (TIMSS), for example, has monitored trends in mathematics and science achievement every four years since 1995 in learners aged 10 and 14 years, providing nearly three decades of data. Similarly, the Programme for International Student Assessment (PISA) represents an assessment that measures 15-year-old students' reading, mathematics, science, and literacy is in its 8th cycle since its inception in 2000.

1.1 Current international standards

In the most recent available report (TIMSS 2019 in Mullis, Martin, Foy, Kelly and Fishbein, 2020), East Asian countries such as Singapore, Chinese Taipei, Korea, Japan, and Hong Kong outperformed the other TIMSS countries in mathematics by substantial margins at both 10 and 14 years of age (TIMSS

2019 in Mullis et al.,2020). In the PISA (2022 in OECD 2023), Singapore scored significantly higher than all other countries in mathematics, reading and science, and along with Hong Kong (China), Japan, Korea, Macao (China) and Chinese Taipei, it outperformed all the other OECD countries in mathematics. PISA (2022) further noted that an average of 69% of students are at least basically proficient in mathematics in the OECD countries and in 16/81 countries more than 10% of students were high performing (this included the UK). It should be noted that in PISA (2022) assessments, the OECD average dropped by almost 15 points in mathematics compared to PISA (2018) because of the 'shock effect' of COVID-19 on most countries.

1.2 National standards

The OECD (2016) reported that the UK faces a shrinking pool of skills and there are too many adults in the UK who lack basic numeracy skills for everyday life (OECD, 2016). The number of adults with basic skills has continued to decrease since the Covid-19 pandemic with 57% of respondents saying they did not want to improve mathematics and numeracy; the chief reason is because they think they are already good at it (National Numeracy, 2022). Data indicate, however, that people may be overestimating their skills, with over half the working population having the numeracy levels expected of a primary school child (National Numeracy, 2022). In the decade after 2009, the UK rose from 27th to 18th (out of 81 countries) in the international league tables but remains one of the least numerate countries in the OECD. More than 8 million adults have numeracy skills below those expected of a 9-year-old and around a third of young people fail to pass GCSE mathematics (National Numeracy, 2022).

Northern Ireland (NI) levels of attainment have also been a cause for concern. NI took part in TIMSS for the third time in the 2019 cycle although only at the younger age range. In terms of performance, mathematics attainment for 9–10-year-olds in NI remained high compared to other countries on the international tables considered by OECD, and the scores were not significantly different from the scores in 2015 and 2011. Whilst overall performance was high, the main concern was the attainment variability between learners. Just over a quarter of pupils reached the advanced international benchmark (the sixth highest percentage internationally) and the gap between the highest and lowest achieving children was wide. The National Foundation for Educational Research (NFER, 2020) analysed the responses to understand the implications for teaching and found that whilst the overall international position appeared good, in terms of the lower performing pupils, four percent did not reach the low international benchmarks compared to zero percent in the better performing countries (NFER, 2020). In other words, whilst good mathematical achieving students were doing well compared to the OECD average, weaker achieving students were performing poorly, with scores lower than both England and the Republic of Ireland. PISA (2022) also illustrated NI underperformance compared to England, and this was more evident in the post-primary sector, highlighting a need to reverse the trend.

The current PISA tests in NI were administered against a backdrop of political and social instability, coinciding with a time post-covid and of no devolved government, declining education budgets and industrial action by teaching unions. This context impacted negatively on participation with the final weighted response from schools being 61%, which is below the PISA technical standard of 85% (NI statistics and research agency, 2023). The PISA (2022) data for Northern Ireland was based on a random sample of pupils who participated voluntarily, rather than a census of all pupils. This means that there is a degree of uncertainty in the findings because there is always at least some chance that it does not fully represent the overall population of pupils. A key objective of international large-scale assessments, such as PISA and TIMSS, is to learn from high performing countries (NI statistics and research agency, 2023). In addition to looking at high performing countries, it is also important to look at countries which are geographically close and culturally similar, to see if strategies can be shared for improvement. Educators have indicated that it can be problematic to borrow pedagogy from culturally diverse countries (Jerrim & Vignoles, 2016) and it is for these reasons that results from a range of countries were considered in this study and particular attention has been paid to England and the strategies used in recent years which resulted in improvement in the league tables.

In response to the PISA 2012 rankings, the department for education (DfE) initiated the Teacher exchange programme in 2014 with the focus of incorporating the strengths of Shanghai mathematics teaching into English schools with an emphasis on the use of the pedagogical tools employed by Shanghai schools in an English context. The format involved a visit first by English teachers to Shanghai for 2 weeks to observe Chinese teachers in context, and then a return visit to England. During this time, the visiting Chinese teachers were observed teaching mathematics by teachers from neighbouring schools, and a discussion around teaching methods used was held, with an explicit focus on 'mastery' (National Centre for Excellence in the Teaching of Mathematics (NCETM, 2014b). Following from the teacher exchange programme, mathematics hubs were established in England to support the various strands of the updated mathematics national curriculum and to promote the teaching of mathematics mastery. These hubs, which are coordinated by the NCETM, provided teachers with a means to share expertise, obtain professional development and develop mastery teaching skills with a core purpose to support schools and colleges by ensuring professional development support and spreading examples of best practice for the benefit of students and teachers.

At this time, the Republic of Ireland also launched its new primary curriculum framework which was based on creativity, risk-taking, collaboration and opportunities for reasoning and solving real-life problems (NCCA, 2014). Government interventions and investment ensured professional development and resourcing for education to ensure teachers were trained and equipped to deliver the framework and increase opportunities for the children.

NI however was facing a political void resulting in no growth, a lack of guidance, professional development, and investment, which widened the practice in the jurisdictions. Despite being in a very favourable position previously (DENI, 2011), education in NI was being left behind and there were no government structures to support, guide or invest for several years. Although the aim of the NI curriculum (CCEA, 2006) is to be a skills-based curriculum, the chief inspector of education recommended that mathematics classes needed a makeover with collaborative problem solving the focus for the future (ETI, 2016) and this recommendation remains current for the recent new government.

1.3 Contributions to under-performance

Several factors have been considered to help understand the differences in performance between and within countries. Some studies have considered that mathematics learning is connected to teaching time and quality (Foley et al., 2017). Considering time, teaching time for mathematics in NI was considerably higher than the international average (203 hours and 154 hours per year respectively), yet the evidence from TIMSS (Mullis et al., 2020) suggested there is no clear pattern between the amount of time spent on mathematics teaching per year and achievement in mathematics. As time does not appear to be an influencing factor at least in this data, the quality or approach to instruction may be a contributing factor to under-performance, and this is one of the factors considered in this study.

The discussion of further factors that may be linked to mathematics' performance have included ethnicity (Riegle-Crumb & Humphries, 2012; Cheryan & Bodenhausen, 2000), as research has considered why students in Asian countries perform better. This performance however is not confined to Asian countries, as ethnic minority students express more positive attitudes towards mathematics than white students in both the USA and the UK (McGraw et al., 2006; Nguyen et al., 2020). Another consideration is gender as there is a skills gap between males and females across all age groups (Baird & Keene, 2019). This difference has also been linked to attitude and gender stereotyping (Walton & Cohen, 2003; Spencer et al., 1999), which includes the role of parenting, the value parents place on the subject and how this value is communicated differently to sons and daughters (Berkowitz, et al., 2015; Eason et al., 2017). It is not just parents who communicate differently between gender, as teachers and role models have also been found to be different in their treatment and expectations in the classroom with boys and girls (Beilock et al., 2010; Boaler 2009).

The TIMSS (2019) data also signposted the learning environment and suggested that pupils experiencing positive school learning environment factors achieved more than pupils who do not. Consistently pupils in safe and orderly classrooms showed higher levels of achievement than pupils who were not and teacher expectation also influenced outcomes.

The complex profile of factors linked to achievement are highlighted in the OECD (2009) study which illustrated that some individuals with high cognitive ability perform below their expected outcomes in mathematics, despite having the same instruction time and quality as their peers with a similar cognitive profile. Whilst learning mathematics can be difficult for some, there is increasing interest in understanding individual differences in achievement beyond cognitive ability (Dettmers et al., 2010). Functional numeracy includes the application and confidence in using mathematical skills in the context of everyday life and work, and it is this application of skills and subject knowledge which requires development by current and future primary school teachers. Evidence highlights that with effective teaching methods there are limited barriers to mathematical success in schools (Boaler, 2016). Whilst there are a few children with special educational needs who will find mathematics learning more difficult, Boaler (2016) estimates that 95% of children have the potential to improve, however it is imperative they have skilled teachers who have the confidence and competence to develop their potential.

Other factors linked with achievement include working memory and links to mathematics anxiety (which will be abbreviated to MA). Ashcraft and Kirk (2001), for example, found that adults with higher working memory were able to manage both mathematics tasks and anxiety-driven thoughts more successfully. Similarly, Miller and Bichsel (2004) found that adults with high working memory performed better in calculations and problem solving. A negative impact of test anxiety was further found to have an influence on achievement (Zeidner, 1998) and students who reported the lowest levels of anxiety attained the highest achievement levels (Putwain, 2008). Ramirez & Beilock (2011) found student attitude also affected outcome and the TIMSS (2019) data also found that pupils who had the most positive attitudes towards mathematics had higher average achievement scores, and clarity of instruction was also associated with higher student achievement.

Mathematics anxiety (MA) can explain underperformance, influencing the achievement and consequently the future educational and career paths of individuals (Mammarella et al., 2019). The literature consistently demonstrates a negative relationship between anxiety and academic outcome and MA and mathematics outcomes (Szczygiel, 2021; Zhang et al., 2019; Ma, 1999). These findings apply across a range of different individuals in mathematics, impacting learners with mathematics learning challenges (Prevatt et al., 2010), typically developing learners (e.g. Wu et al., 2012), and high achievers (Tsui & Mazzocco, 2007).

1.4 Mathematics Anxiety

Mathematics Anxiety (MA) is a debilitating emotional reaction to mathematics that is increasingly recognised in psychology and education (Carey et al., 2019). It has been defined as "a feeling of tension and anxiety that interferes with the manipulation of numbers and the solving of mathematical problems in ordinary life and academic situations" (Ashcraft, 2002). How students think and feel about themselves is argued to shape their behaviour, especially when facing challenging circumstances (Bandura, 1977). MA varies in individuals from feelings of mild discomfort to a strong fear and avoidance of mathematics that can negatively affect performance (Hembree, 1988; Keogh et al., 2004), self-esteem (Peleg, 2009; Thomas & Gadbois, 2007), and cognitive skills linked to learning (Zhang et al., 2019). MA is not confined to test or classroom settings but can emerge in any situation where mathematical thinking is required, resulting in those who experience it avoiding any kinds of mathematics situations and career activities involving mathematics (Carey et al., 2019).

1.5 Understanding pathways to mathematics anxiety

Many adults do not move on from negative mathematical experiences in school, and an early negative experience can be carried with them across development (Boaler, 2016). Research has focused on the development of frameworks and a research evidence base to understand the origin of MA. The available body of knowledge and research findings relating to evidence of the effect of MA on teachers and students are causes for concern (Koch, 2018). According to Ramirez et al., (2018), the development of MA in students is governed by their perceptions, interpretation and appraisal of previous mathematical experiences and outcomes. Whilst MA may be linked to previous mathematical experiences and outcomes, this process can also reflect a negative experience of mathematics through poor teacher instruction (Devine et al., 2012; Gresham, 2018), the communication of negative verbal information about the subject, or a 'contagion' where the teacher, or trusted adult, vicariously passes on their own dislike or anxiety of mathematics to learners. Research in anxiety recognises these diverse pathways to fear and anxiety (King et al., 1998).

1.6 The impact of the teacher

Research has demonstrated that teachers are one of the most influential factors impacting children's achievements (Smith, 2010), and the link between teacher MA and the achievements of pupils has been well-documented (Beilock et al., 2010; Ramirez et al., 2018). MA can have a significant effect on a teacher's confidence and their ability to teach Mathematics, as Beilock et al., (2010) concluded that "highly math-anxious teachers are the worst math teachers" (p.1862). The findings on teachers' impact on pupil achievement were illustrated in the NI chief inspector of education's report from the Education and Training Authority Inspectorate (ETI, 2018) which was followed by recommendations from the Council for Curriculum Examinations and Assessment (CCEA see Owens, 2019) with resources to help teachers develop an understanding of MA and strategies to moderate it. Their findings aligned with the Mathematics Anxiety Trust survey (IPOSO, 2019) which suggested at least one in five people experience MA, and therefore there is an urgent need for action by teacher educators and governments to provide pre-service teachers with knowledge, good practice and an understanding of key factors that influence children's learning (Koch, 2018).

Current and future teachers need training in methods to understand and reduce their own and their pupils' MA and to increase teacher and student self-efficacy in the classroom. It is important therefore that the education and training of pre-service teachers follows a methodology that enables them to develop a positive attitude and develop problem solving skills in their teaching. In addition to the need to demonstrate a positive attitude, inspection evidence from the ETI (2018) pointed to a lack of understanding of the difference between problem solving and investigative work, and strongly suggested that the teaching of problem solving was not good enough. The report further outlined the need to enhance the quality in the provision provided for children to enable positive outcomes.

1.7 The focus on pre-service teachers

Although pre-service teachers are required to pass GCSE mathematics as an entry requirement, the OCED (2022) has repeatedly noted that the education and skills system in the UK can generate qualifications without developing improvement in underlying functional skills. In England, the Office for Standards in Education, Children's Services and Skills (Ofsted) inspect services providing education and skills for learners of all ages. Ofsted (2008, p.4) has consistently reported "a heavy emphasis on teaching to the test preparing pupils to gain a qualification but not equipping them well enough mathematically for their futures". Ofsted (2008) further stated in the summary for improvement in *understanding the score,* that primary and non-specialist teachers need to be supported in subject knowledge and post-primary, or specialist teachers need support in pedagogical skills. This report further noted that "initial teacher education should include relevant enhancement of subject knowledge and key mathematical skills" (Ofsted, 2008 p.7). This is important because despite the rapid expansion of educational opportunities, initiatives such as the National Numeracy Strategy, the promotion of the subjects through National Mathematics Week and a well-qualified cohort of young people, basic skills have remained weak (Kuczera et al., 2016).

Many students entering primary teacher education programs have been found to have negative feelings about mathematics (Cohen & Green, 2002; Levine, 1996). These feelings are typically characterised as MA (Ingleton & O'Regan, 1998; Martinez & Martinez, 1996; Tobias, 1993). Koch (2018) suggested that some pre-service teachers may have latent MA, which may affect their acquisition of the required teaching skills needed in this subject. Pre-service teachers with MA in a primary education degree typically avoid mathematics courses unless they are compulsory (Boaler, 2016), however once they become qualified teachers and are in the classroom, they are required to teach mathematics to young children. Avoidance of the subject can affect the development of subject knowledge, confidence in subject delivery, and negative feelings towards the subject (e.g., Gresham, 2018). The combination of MA and limited knowledge (due to class avoidance, and lack of appropriate pedagogy) can result in this group being ill-prepared for teaching when they graduate. Consistently, Geist (2015) further outlined that the greater the confidence and knowledge of the teacher combined with their level of enjoyment of mathematics and the level of confidence in their mathematical ability, the higher teachers rate the importance of teaching mathematics particularly in pre-school (<4 years) and primary school (4-11 years).

1.8 Prevention and intervention for Mathematics anxiety

MA can be reduced through mathematics education to increase skills and training, and thus develop positive attitudes (Beilock et al., 2010). Mathematics is often taught as rule-based, and some teachers point to a level of security in the belief that it is right or wrong. Teaching mathematics in a 'rule-based' way may relate to poor teaching practices, reflect a lack of mathematical knowledge, inadequate preparation, or a fixed mindset approach believing that this is the way things are and cannot change (Koch, 2018). A less formal and less rule focused approach does not imply decreased rigour, but simply another way of looking at mathematical problems, of focusing on finding patterns, creativity and seeing connections and similarities. Devine et al. (2012) stated that presenting mathematical problems in a less formal and a less 'rule-bound' framework may help overcome the fear associated with MA, thus helping pre-service teachers and their pupils to perform better.

Building on the proposition of a less formal approach and a 'failure-as-enhancing', the growth mindset approach of Boaler (2016) and Dweck (2006) outlines that making mistakes and learning from them is an intrinsic part of mathematics, with successful teaching emphasising engagement and enjoyment versus achievement and performance. These researchers argue that by including this growth mindset in teaching, students can acquire the confidence to face challenges, to make mistakes and enjoy mathematics. The aim is to reduce the anxiety which may be created through a 'right or wrong' belief. This approach links to the pedagogical underpinning in using a mathematics mastery approach which is used in the high performing East Asian countries (Boyd & Ash, 2018).

1.9 Mastery pedagogy

The mastery principles used in East Asian pedagogies encourage the development of a conceptual understanding of mathematics, with a focus on whole class teaching where most learners progress at the same pace (Jain & Hyde, 2020). In addition, it suggests that all learners can be successful if they are given time to develop their understanding (Bloom, 1968). Boylan et al. (2019) developed these ideas by describing pedagogy as whole class, interactive teaching that develops conceptual understanding and procedural fluency. Vignoles and Jerrim (2015) further emphasised the importance of language, mathematical representations and having high expectations of learners so they become fluent in their use of mathematical concepts while developing a deeper understanding of them. Further definitions have also focused on the need to understand mathematical structures (Haylock & Cockburn, 2017), whilst others have highlighted that students should be able to develop skills to effectively solve problems in learning (Drury, 2018).

1.10 Orientation to the current project

This project compared two groups of pre-service (undergraduate student) teachers in their second year of studying for a Bachelor of Education degree. One group was taught using a traditional pedagogy, while a second group followed the same curriculum content but were taught through a mastery pedagogy approach. The research measured student mathematics anxiety before and after teaching, and explored self-reported efficacy, motivation, anxiety, and attention as they moved through the mathematics education programme. Using mixed methods, it further adopted a pedagogical action research approach to measure the thoughts and feelings of students in the mastery pedagogy group via semi-structured interviews halfway through the teaching module. The interview data was originally used to inform the second block of teaching but was also considered to complement and extend the quantitative weekly data.

The research questions were:

- Does mathematics anxiety affect a student teacher's confidence and competence in teaching in a primary school?
- Do mathematics mastery principles improve levels of mathematics anxiety?

The primary research aims utilised quantitative data to consider whether mastery teaching pedagogy compared with teaching as usual would:

- Significantly decrease students' mathematics anxiety and anxiety about teaching mathematics before and after the teaching module
- Significantly decrease students' mathematics anxiety and increase their attention and motivation through teaching
- Significantly increase students' perception of subject knowledge and feelings of competence / self-efficacy

In order to meet these aims, this study included two objectives:

- To use the Maths Anxiety Scale for Teachers (Gangley et al. 2019) to measure pre-service teachers' general mathematics anxiety and anxiety about teaching mathematics before and after intervention to see if there has been any change in either the teaching as usual pedagogy group or the maths mastery pedagogy group over a ten-week teaching period.
- To construct a Visual Analogue Scale (VAS) to measure the feelings of all students from both groups each week after a teaching session. This scale would measure the self-reported feelings of the students using four constructs: their perceived mastery of the subject, their concentration in class, their self-reported feelings of anxiety and their motivation.

In addition, the aim of the qualitative data was:

- To explore student thoughts and experiences in the mastery pedagogy group narratives to:

i. Establish convergence with quantitative data in student narratives associated with this teaching approach
ii. Inform the second block of teaching and revisit it during analysis to gain further insight into the quantitative data

Secondary exploration aims considered whether:

- Feelings of anxiety and anxiety about teaching would be associated with each other and linked to reports of anxiety, attention, motivation as well as student perceptions of subject knowledge and feelings of competence / self-efficacy as teaching progressed

In order to meet these aims, the objectives were:

- To construct semi-structured interviews within a mixed methods paradigm to uncover the opinions of pre-service teachers regarding a mastery pedagogy
- To produce recommendations to inform the second block of teaching
- To use a sequential comparison model to compare the information from the qualitative and quantitative data.

Primary hypotheses:

- There would be a significant decrease in reports of mathematics anxiety and anxiety about teaching mathematics after the teaching module in students who experience mastery teaching (compared with the teaching as usual group)
- As teaching progresses, students who experience mastery teaching (compared with the teaching as usual group) would report increasingly lower feelings of anxiety, increased attention, and more motivation
- As teaching progresses, the mastery group (compared to the teaching as usual group) would report increased subject knowledge and feelings of competence / self-efficacy.

1.11 Summary of the thesis

The literature review presented in Chapter 2 sets the context for mathematics teaching with international, national, and local standards being analysed. In addition to exploring the current relevant literature, this review explored the gaps in the current research. The methodology in Chapter 3 outlines the positionality, epistemology and paradigm used in the thesis and examines the action research model and the contribution this research makes to the body of knowledge. In addition, Chapter 3 includes a summary of the research design including the sampling, justification and the instruments used in data collection. Ethical considerations and the analytical strategy are also included. Chapter 4 presents the results and data analysis and considers the focus and design of the analysis and the implications of the findings in relation to the research question. The discussion presented in Chapter 5 considers the interpretation of the results and the potential implications of the findings for changes to mathematics pedagogy in the classroom. It further looks at how the findings from the thesis fit with and extend existing research. Chapter 5 additionally considers the limitations of the study and the future direction of research on this topic. The conclusion in Chapter 6 summarises the key findings the contribution of this work to the field of knowledge and highlights the practical recommendations for addressing mathematics anxiety in pre-service teachers.

2. Literature review

2.1. Context and background

The UK could have as many as 24 million working age adults with low numeracy skills, (Jonas, 2018). PISA (2022 in OECD 2023) defined being proficient in mathematics as being able to reason through complex real-life problems and find solutions by formulating, employing, and interpreting mathematics.

The National Numeracy charity reported that inadequate numeracy skills cost the UK economy approximately £25 billion per annum. The level of numeracy in the UK needs to be addressed urgently to make the economy internationally competitive, as economies with higher-skilled workforces tend to have higher rates of economic growth (Vignoles, 2016). Over the past ten years, there has been a growing interest in what has been described as a "mathematics crisis" in the UK (Carey et al., 2019). Evidence suggests that while functional literacy skills amongst working-age adults are increasing, the proportion of adults with functional mathematics' skills had dropped from 26% in 2003 to only 22% in 2011 (National Numeracy, 2014), and the new research from National Numeracy (2022) indicates that it has not improved over the past decade.

This chapter explores the literature relating to the history and context of mathematics education and how the curriculum influences MA, with a particular focus on NI. It analyses important international, national, and regional data to evaluate the need for pedagogical intervention and to justify the need for changes to pedagogy for pre-service teachers. The philosophical and empirical literature surrounding attitudes and beliefs is discussed and a critical analysis of the literature which considers the manifestations of MA and how it relates to general (trait) anxiety and test anxiety is presented. The chapter provides a summary of pathways to risks, before considering interventions and methods to overcome MA. The context and definitions of mathematics mastery and a justification for this pedagogy is presented prior to considering the value of the research and the current gaps in knowledge on this topic.

2.2 Defining mathematics anxiety

Historically mathematics anxiety has been given a variety of labels including numeraphobia, arithmaphobia, mathemaphobia and mathematics anxiety. These terms are often used interchangeably and have developed over time (Singh, 2019). Mathemaphobia was a term used by a teacher describing her students' emotional reactions in the face of mathematical tasks and challenges (Gough, 1954). Tillfors (2003) defined mathematics phobia as a learned emotional response that can be classified into two types as *general* or s*pecific* (arithmophobia or numerophobia). Whilst numerophobia relates to a fear of numbers and arithmophobia relates to doing things with numbers, over time these two terms have become synonymous, and it is the difference in *genera*l fear or the *specific* fear which has been considered. General arithmophobia or general numerophobia is the fear of all numbers. It has been linked with frequent, severe, and intense anxiety that can seriously affect the ability of the students to do mathematics (Olaniyan & Salman, 2015). Specific arithmophobia is the fear of some specific numbers and this type of phobia is often rooted by superstition or religious phobias (Kunwar, 2020). Specific arithmophobia is considered less serious than general arithmophobia as it relates to limited numbers.

Dreger and Aiken (1957) coined the term 'mathematics' anxiety' (cited in Dowker et al., 2016). Ashcraft (2016) defined mathematics anxiety as a condition in which negative emotions and even feelings of pain and suffering predominate responses when an individual must solve a mathematical problem. MA is proposed to be a negative emotional reaction to mathematics that can interfere with the ability to perform mathematical tasks (Carey et al., 2019). Ashcraft (2002) stated that it often results in the avoidance of situations required to perform mathematical calculations, where students experience less practice and exposure to mathematics and reduced competency. This in turn leads to underperformance, underachievement, and a cycle of increased anxiety.

2.3 Presentation of MA

Numerous studies have shown that emotional factors play a significant role in mathematics performance with MA playing a particularly key role (Ashcraft, 2016; Vargas, 2021). A common emotion vital for survival and experienced by everyone is fear. Fear is a primitive, emotional response that alarms us of danger and thus protects us, and when experiencing anxiety, a person will experience some fear. Anxious feelings are more likely to be long lasting and are often associated with possible or anticipatory (not actual) worries and concerns. If a fearful situation is accompanied by emotions that are difficult to deal with it may turn to a phobia or anxiety (Singh, 2021). MA can have varying degrees of severity ranging from simple anxiety to states of phobia (Vargas, 2021).

MA is not merely a psychological phenomenon that limits the ability to solve mathematical problems; people who experience MA may feel a physical reaction that can be likened to pain (Lyons & Beilock, 2012). Maloney et al. (2013) outlined that tension, dislike, worry and frustration can be experienced during an activity or anticipation of the activity. This can cause shortness of breath, nausea, dizziness, or panic attacks (Singh, 2021).

To explain the different elements of anxiety more fully, a tripartite model was developed which proposed that phobias or anxieties can be conceptualised in terms of three responses: cognitive, physiological, and behavioural (Lang 1968,1977). King et al. (1991) documented the variety of responses which can be aligned to these responses. Cognitive responses include fearful and self-deprecatory thoughts such as about one's understanding and performance in mathematics (e.g., the fear of not being successful, or an inability to process information). Physiological responses include increased heart rate, butterflies, and changes in respiration. Behavioural responses include avoidance, lack of engagement or anger and avoidance of anxiety-inducing prospects or activities (Koch, 2018). Individuals who experience MA, generally present with avoidance including boycotting mathematics activities, courses and career paths that require the mastery of some mathematical skills (Hembree, 1990; Ashcraft & Ridley, 2005).

2.4. General anxiety, test anxiety and mathematics anxiety

Students with MA are not homogenous, and it is important to identify whether students are mathematics anxious in the context of having a variety of anxieties or whether their anxiety focuses specifically on mathematics (Carey et al., 2016). Although MA is related to other forms of anxiety, it can be distinct in terms of the effects on performance (Hill et al., 2016). Some students reported feeling anxious about mathematics, rather than general anxiety (Ashcraft & Ridley, 2005; Hembree, 1990; Wigfield & Meece, 1988), but it is important to consider the potential relationship between mathematics-specific anxiety (MA) and internal problems such as test anxiety and general (trait) anxiety. Kazelskis et al. (2000) demonstrated that although test anxiety and MA have common elements, they can be thought of as separable constructs. Further evidence also indicated that MA was separable from trait anxiety (Betz, 1978). Whilst research showed that pupils with MA also showed higher levels of test anxiety and trait anxiety (Punaro & Reeve, 2012; Wang et al., 2014), Hembree (1990) revealed that there was a moderate relationship between MA and test anxiety and only a small relationship between MA and trait anxiety.

Although measures of MA are multidimensional, data have suggested that MA is a better predictor of performance in mathematics than test anxiety or trait anxiety (Lukowski et al., 2019). In addition, anxiety about taking mathematics tests was a factor that was separable from anxiety about performing mathematics calculations, which was specific to MA and goes beyond trait anxiety and test anxiety. Gierl and Bisanz (1995) also demonstrated that while both MA and test anxiety predicted general achievement in young children, there is evidence that MA and performance can show specific correlations regarding aspects of mathematics, and when considered simultaneously MA was the strongest predictor of mathematics achievement.

2.4.1 Age and gender differences in mathematics anxiety

Negative attitudes towards mathematics have shown to increase when children reach secondary education (from approximately age 12) and persist throughout adulthood (Dowker et al., 2016). Consistent with the core elements of MA, one report found that a considerable proportion of 15-year-olds globally reported feelings of helplessness and emotional stress when dealing with mathematics (OECD, 2014), with 61% worrying they will get poor grades, 59%

reporting that they worry it will be difficult for them, 33% reporting that they get very tense doing mathematics homework, and 31% reporting getting nervous doing mathematics problems (OECD, 2014).

MA however has also been identified in younger children. Krinzinger et al. (2009), for example, undertook a longitudinal study of children at the beginning of formal schooling (aged 6-8 years) and administered timed calculation tasks and the mathematics anxiety questionnaire (MAQ: Thomas & Dowker, 2000) four times at 6-month intervals. The study revealed a close relationship between MA and mathematics ability on evaluation of mathematics in young children. The results stressed the need to assess MA during early primary school years as the time when it most probably first emerges. At school, many people develop a perception that they are unable to work with numbers and this perception can be hard to overcome (Onoshakpokaiye, 2022). Having a negative experience with numbers works against people's desire and capacity to engage not just with numbers, but with numeracy-related learning more broadly (Marr et al., 2003). There is also a link with mathematics and intelligence which is a damaging misconception, as students internalise this as if I fail at mathematics, I am unintelligent (Boaler, 2016). The myth that mathematics is for brilliant people acts as a barrier to mathematics success in school and is pervasive (Chestnut et al,. 2018). Although it is unclear where this myth originated, Chestnut et al. (2018) suggested that it may come from common misconceptions regarding what doing mathematics entails, as some individuals believe it involves complex mental operations which only some can accomplish.

This finding has implications for initial teacher education, as future teachers need to be aware of this phenomenon from children's earliest days in school. Building on this research, findings suggest that MA may detrimentally affect not only how young children perform mathematically, but also *how much* mathematics some children learn (Vukovic et al., 2013) and thus expectations for young children should be considered.

Further studies have additionally shown differences between gender in mathematics achievement and confidence about the subject. Research from the National Numeracy (2022), for example, found that women were twice as anxious as men about using mathematics and numbers. Almost a fifth of the UK population (18%) said mathematics and numbers made them nervous, but when split by gender a polarised story appeared: 24% of women agreed, compared to 12% of men. Gender differences in MA studies consistently show that females have higher levels of anxiety compared with males (Devine et al., 2012), regardless of performance in mathematics (Breda et al., 2023; Bian et al., 2017) and females rated themselves as having lower mathematics ability compared with males (Callan, 2015; Devine et al., 2012; Hembree, 1990; Wigfield & Meece, 1988).

Moreover, male students report increased confidence about their STEM abilities compared with female students, but this confidence did not translate into results in national exams, as females outperform males in mathematics and science subjects at GCSE (Nicole et al., 2010). However, 63% of working aged women in the UK were found to have the numeracy level expected of a primary school child, compared to 45% of men. This was not the case in the international tests as the average mathematics score for boys was significantly higher than that for girls, and these gender differences were consistent across the UK (OECD, 2023). This anomaly can be considered in the context of learner self-efficacy. Whilst there may not be any more girls than boys with cognitive mathematics difficulties (Devine et al., 2013; Lewis, et al., 1994), they may be more susceptible to negative emotions in mathematics learning (Devine et al., 2018).

Several hypotheses have been proposed to explain the higher levels of MA in girls despite performance. Greater MA in girls may relate to their lower self-perception and confidence (Cvencek et al., 2014; Pajares, 2005) or perhaps boys are less likely to openly state their negative feelings (Ashcraft & Ridley, 2005). Boys' answers to questions about worries and anxiety, for example, are more affected by a recall bias as well as social desirability biases (Dowker et al., 2016), and gender stereotyping about mathematics (Appel et al., 2011). Bian et al. (2017) found that gender stereotyping can begin as young as six years old. It was also noted that girls who received unrequested help in mathematics from parents or teachers were more likely to believe that they did not have what it takes to succeed (Bhanot & Jovanovic, 2005).

In terms of social influences, teachers who are anxious about their own mathematics abilities can impart these negative attitudes to some of their students. Interestingly, this transmission of negative math attitudes may contribute to gender differences in attitudes to mathematics. Beilock et al. (2010), for example, found that girls are more socially sensitive than boys in early educational settings, i.e., being more likely to be influenced by their teachers' anxieties than boys. Given that most early years teachers are female, and females have shown to be more mathematics anxious than males, (Hembree 1990), female teachers MA negatively relates to girls' mathematics achievement.

In understanding gender differences in mathematics anxiety, Callan (2015) further points to historical patriarchy and the idea of legacy and culture as an explanation for increased mathematics anxiety in females. As institutions of power were historically overwhelmingly dominated by men with "the theological underpinning to the social norm that men 'did' mathematics and women 'did not' … making the concept of the mathematical woman seem unnatural and even taboo" (Callan, 2015, p.6). Callan (2015) points to the early writing of Myrdal and Klein (1956; reprinted 2001) that outlined social ideals and the 'Cinderella Complex' (Dowling, 1990) that caused women to feel they did not need to focus on mathematics. The increased fear that females have towards mathematics may have origin in patriarchy's deliberate naturalisation of women as non-mathematical (Callan, 2015). In support, Fershtman et al. (2011) assert that human behaviour is governed by the shared values and standards of society, with its expectations and rules. Further studies have shown that the relative lack of number confidence and higher levels of mathematics anxiety in women is likely to be transferred onto future generations (Beilock et al., 2010), and this must be investigated to break the cycle for future generations.

2.5 Theoretical framing of pathways to MA

As the causes of MA are thought to be highly varied and complex (National Numeracy 2022), the theoretical framing of pathways were not a simple process but required considering a variety of pathways which connected and fluctuated depending on individuals and situations. Various theoretical models have aimed to develop frameworks to understand risk factors for MA more clearly including the deficit theory which suggests that people who start out with poorer mathematics performance are more likely to develop anxiety about mathematics (Tobias, 1986), the reciprocal theory which offers a bidirectional relationship between MA and mathematics (Carey et al., 2016; Ma & Xu, 2004), and the social-cognitive theory which posits that perceived support from others influences an individual's self-efficacy (Bandura, 1977). Other considerations are the cognitive challenges of the individual and their self-efficacy including the presence of a fixed or growth mindset. Although all these models help to explain MA, fundamentally it is a fear response, and the acquisition of fear formed the theoretical framing of this discussion. The analysis of MA for this study therefore was considered within Rachman's (1977) three-pathway theory of fear acquisition; direct conditioning, modelling, and transmission (Rachman, 1977; 1991).

2.5.1 Direct conditioning

Direct conditioning is often described as the dominant pathway to fear (Reynolds et al., 2015). Rossnan (2006) suggested that fear is often linked to a child's first experiences of mathematics. Early experiences of mathematics activities are described as a ladder with each encounter adding to a negative or positive experience and a high frequency of negative experiences can lead to an acceptance of failure and increased anxiety (Petronzi et al., 2019). Although the level of negative encounters which lead to MA will be different for everyone depending on resilience levels, failure is argued to be a key factor leading to MA (Ashcraft, 2002). For example, research suggests that individuals who experience MA can trace it back to numeracy apprehension, a fear of failure, avoidance or disengagement and an insecurity of mathematics procedures in the home or early education (Ashcraft, 2002).

Some individuals experience cognitive challenges with the acquisition of mathematics skills or other mathematics or learning difficulties (Passolunghi, 2011; Rubinsten & Tannock, 2010). A range of terms are typically used to refer to problems in learning mathematical concepts and skills, including math difficulties, math disability, mathematical learning disability, mathematical disorder, specific disorder of arithmetic skills, math anxiety, and developmental dyscalculia (DD). These terms all implicate low numeracy skills; however, they are not synonymous (Rubinsten & Henik, 2009).

Devine et al. (2018) carried out a large-scale study of school pupils and found that MA was twice as common in learners who experience dyscalculia which is a specific and severe difficulty in an individual's ability to process numerical information that results in a failure to develop fluent numerical computation skills, and that cannot be ascribed to sensory difficulties, low IQ, or inadequate education (Rubinsten & Henik, 2009). DD typically persists beyond the school-age years into late adolescence and adulthood (Wilson & Dehaene, 2010) and is further associated with experiences of anxiety and panic when facing tasks that exceed cognitive thresholds. When the mental load is exceeded, the student finds it difficult to consider, process, or retrieve information, yet is aware of expectations. Unable to reconcile the disparity between demand and ability, learners who experience DD can experience a frustration with mathematics work and to conserve energy, are unable to use cognitive functions to perform tasks. This anxiety or panic response is a result of the brain's inability to perform as expected. It is a stress response, not the cause of an inability to process quantitative information (Chinn, 2020).

Negative experiences of learning mathematics whilst at school have been linked to lower mathematics attainment, low self-esteem, and to being out of work later in life (Mehta, 2022). In addition, personal characteristics associated with negative experiences of mathematics can impact the learner's self-esteem (Abbasi et al., 2013), learning style (Sloan et al., 2002), attitude (Hembree, 1990) and self-efficacy. Self-efficacy has been linked to number-confidence (Tyres & Aston, 2023) and represents a large part of how individuals view their mathematics ability. Low number confident students have reported that these feelings can stem from their prior experiences of mathematics (O'Leary et al., 2017).

In addition to highlighting direct conditioning. Additional researchers have shown that vicarious conditioning has a role and have looked to experiences in the classroom (Beilock et al., 2010) and at home (Luttenberger, Wimmer and Paechter, 2018) to understand the emergence of MA.

2.5.2 Vicarious conditioning (modelling)

Fears can be acquired by observing another individual's fear objects or situations, and this process of vicarious learning has become established as an indirect pathway to fear acquisition (Askew et al., 2008; 2013). The role of fear and influential adults is very important, and the role of parents' behaviour is the most frequently explored factor in the development of children's specific fears. Mathematics experts have identified that many parents have faced difficulty in their own numeracy experiences which could result in their negative attitudes being transferred to children (Gunderson et al., 2012). In considering this idea of transference, mathematics experts noted that due to their own difficulties, parental expectation was that the child would also experience similar challenges. In support, Gerull and Rapee (2002) showed that children expressed greater fear and avoidance of stimuli (in this case a rubber snake and spider), following their mothers' adverse reaction. The findings suggest that if children witness the mother having an adverse reaction to mathematics activities this can indirectly transmit MA to the child.

In the early years, the teacher can be seen by the child as being in the role of parent during the school day, thus their influence is great. If a teacher demonstrates dislike of the subject or exhibits a lack of confidence, this response may also trigger fear and anxiety responses in children (Muris & Field, 2010; Percy et al., 2016). It is important that influential adults are aware of the behaviours modelled around young children and present positive responses to mathematical activities. Negative evaluation from peers and teachers can also act as a contagion and reflects a combination of direct experience and negative information (Ashcraft & Krause, 2007).   It is therefore particularly important that children have teachers who ensure their mathematics learning experiences are positive and that mistakes are viewed as a typical pathway to learning (Boaler, 2009).

2.5.3 Transmission of information and instructions

In addition to modelling negative responses, experiencing negative information about mathematics from parents, teachers, and peers, can increase a child's level of MA. For example, positive information and modelling had a notable effect as positive information was more effective than modelling in reducing fear beliefs and significantly reduced behavioural avoidance (Brewester & Miller, 2020). Similarly, Soni & Kumari (2015), considering 600 students in India, found that parents with elevated levels of MA conveyed the idea that mathematics was difficult, and this had a strong positive relation to their children's MA which was in turn negatively related to the children's mathematics performance. Pressure by parents or teachers for the child to perform may lead to self-consciousness about not meeting expectations (Yuksel-Sahin, 2008) and MA could be caused by the information given to the child including the test and examination (due to the pressure to perform well) (Ramirez & Beilock, 2011). To prevent the development of fear, it is important that influential adults ensure that children experience success and support in their early experiences and encounters and their mathematics-related activities are positive and enjoyable (Clark et al., 2021). In the United States, Beilock et al. (2010) found that children with high-mathematics-anxious teachers learned less over the school year than those with less mathematics-anxious teachers. In the transmission of information, it is important that influential adults give appropriate responses and model excitement and curiosity in mathematics, transmit messages which are accepting of mistakes and ensure the children's experiences are positive. In addition to Rachman's framework, further researchers have looked at mindset in the classroom. Giving positive feedback to children encourages a growth mindset with a message that failures are pathways to learning rather than pathways to fear, with effort leading to success. The growth mind framework therefore links to Rachman's (1977) three-pathway theory of fear acquisition and provides an alternative outcome.

2.5.4. Growth and fixed mindset

Researchers suggest that everyone has a mindset, a core belief about how they learn (Dweck, 2006). Growth mindset has been defined as a belief that improvement in learning and achievement increases with challenging work and individual effort, and a growth mindset can motivate students to take on a more rigorous learning experience and to persist when encountering difficulties (Dweck & Yeager, 2019). A fixed mindset reflects a belief that individuals can learn things, but they cannot change their basic level of intelligence (Dweck & Yeager, 2019). Cote (2022) outlined that someone with a growth mindset views intelligence, abilities, and talents as learnable and capable of improvement through work. Individuals with a growth mindset have a greater awareness of errors and are more likely to correct the error showing enhanced reactivity and attention to learning from mistakes (Mangels et al., 2006).

In contrast, individuals with a fixed mindset believe that you can either achieve highly in mathematics or you cannot and often combined with other negative beliefs about mathematics it hinders success. Boaler (2019) argued that practice in school can lead to the assumption of a fixed mindset that can continue through development and into adulthood. Further studies have found that feelings of anxiety are associated with a fixed mindset (Gonzalez, 2023), and research has found that difficulty understanding mathematics materials and poor subject knowledge can impact confidence, perception, and self-efficacy (Dowker, 2019).

Self-efficacy has been defined as having positive beliefs in "capabilities to organise and execute the courses of action required to produce given attainments" (Bandura, 1997, p.477). Most studies have found a positive relationship between self-efficacy in mathematics and performance (Klassen, 2002; Passolunghi, 2011; Tariq & Durrani, 2012). Siegel et al. (1985), for example, showed that self-efficacy accounted for a considerable proportion of variance in mathematics performance, beyond that of MA and similarly revealed strong direct relationships between self-efficacy and both MA and choice of math-related careers (Lee, 2009). One important contributor to self-efficacy is experience of mastery, alongside seeing others succeed (Bandura, 1982).

Students' self-efficacy can be developed by supporting them to achieve genuine academic improvement and then help them recognise and reflect on their growth (Coe et al., 2014). Relatedly, academic self-efficacy is important when we try to persuade students they can do better, as they persist, bounce back, and use feedback, to help see the value of their efforts (Fletcher-Wood, 2022).

Motivation has been highlighted as a factor in achievement in mathematics as poor motivation is often a response to repeated failure (Coe et al., 2014) which leads to low self-belief, a lack of enjoyment, and a fixed mindset. People with low intrinsic motivation for mathematics showed a negative association between MA and mathematics performance (Coe et al., 2014). It is thus argued that both intrinsic motivation and levels of anxiety are important when considering mathematics achievement and both variables are important and considered in this study. A growth mindset can improve motivation, and along with encouragement, it is important when helping students to try harder.

While having a growth mindset may represent an advantage to improving understanding and performance in mathematics, subject knowledge is also needed as subject knowledge influences self-efficacy and confidence. Sherman & Fenema (1998) indicated that the lack of sufficient background or knowledge in mathematics to do mathematical activities and low self-esteem reinforces MA. Even good mathematics students can experience fear, anxiety and lack confidence in the absence of adequate subject knowledge. This subject knowledge is easier to develop with a growth mindset and the student is open to new learning and believes in their ability to grow. With a fixed mindset, it is harder to persuade the student that it is possible to develop and increase their subject knowledge.

Some researchers dispute the idea of fixed and growth mindset stating that mindset theory was not proven, and that mindset theory was overstated (Burgoyne et al., 2020), and Li and Bates (2020) found no link between growth mindset and achievement. Other researchers signpost reflection on practice and motivational factors (Yeager et al., 2019) and point to research which indicate the effects of a short, online growth intervention which was "most beneficial for students confronting challenges" (Yeager et al., 2019, p. 364).

Expecting children to work at speed may also contribute to MA as Ashcraft and Faust (1994) found that people with high MA solved problems more quickly but less accurately than those who were less anxious. MA seemed to result in students rushing to finish the task as quickly as possible to get away from an unpleasant experience, and some studies found that MA is stronger for timed than untimed mathematics activities (Dowker, 2019). This study therefore considers pedagogy and way of working with the implications for MA.

2.6 Application to the classroom

The complexity of teacher's beliefs and anxieties interactively contribute alongside subject knowledge, to the attitudes, subjective experiences, and expectations they hold (Holm & Kajander, 2012). Teacher characteristics can be diverse and may lack aspects related to teaching and learning; good teacher-student relationship, use of students-centred/innovative approach of teaching, counselling, critical, positive attitude towards mathematics, improved mathematics curriculum, breaking down topics into units and the application of ICT in teaching mathematics (Ihechukwu, & Ugwuegbulam, 2016). Individuals who reported higher MA were more likely to report that their teachers behaved in a manner that was hostile, insensitive, impatient, and critical.

Zhang and Wong (2015) further suggested that many teachers already possess a set of beliefs and myths about mathematics before entering the classroom, and many "do not consistently possess sufficient subject knowledge for effective mathematics teaching" (Zhang and Wong 2015, p.466). Boylan et al. (2017) also identified both teacher beliefs and poor subject knowledge as barriers to good teaching. Teacher subject knowledge played a significant role in MA consistent with the abstract nature of delivery when it did not relate to the lived experiences of the pupil (Kunwar, 2020). Expertise depends on the depth and structure of the individual's knowledge, and the key to creativity and critical thinking was to teach the subject well so that students develop deep, structured knowledge (Fletcher-Wood, 2017). Beswick (2012) advocated that attention needs to be paid to the knowledge and beliefs student teachers have on entering the courses, and in shaping classroom practice (Beswick et al., 2012).

Currently mathematics is often taught and learnt as a set of techniques where there may be little development of any real understanding of what is going on or why. Campton and Stephenson (2014) argued there is a gap between teacher's knowledge and enabling students to learn, thus both teacher-knowledge and teaching strategies should be combined in numeracy teaching for pre-service teachers. Kolb (1984) claimed that if pre-service teachers are to be effective, they need ability in four different areas: concrete experience, reflective observation, abstract conceptualisation, and active experimentation. They must be able to reflect on and view their learning from several perspectives and use decisions to problem solve and be able to move from the concrete to the abstract (Peker, 2009).

Many teachers are not aware that a proportion of the students in front of them are experiencing MA or that they themselves as teachers can unwittingly transmit their anxiety to their students (Liu, 2016). Carey et al. (2019) stressed that teacher training should highlight the role of both cognitive and affective factors in schools and look at the role of MA both in the teacher and the effect it has on the child. It is important that this issue is tackled at source, with the teacher and at the earliest point in their career. Highly anxious teachers are poorer teachers (Beilock & Mahoney, 2015) and there needs to be methods to overcome this contagion. Understanding MA and identifying the characteristics are built into this study to heighten awareness and help student teachers appreciate the importance of overcoming MA

2.6.1 Intervention and prevention in the classroom

There have been many studies on how to overcome MA (Furner & Berman,2003; Whyte & Anthony, 2012; Hlalele, 2012), with Boaler (2016) arguing that MA is underpinned by incorrect beliefs about mathematics and intelligence. These studies recommended that a first step to helping children or students with MA is for parents and teachers to tackle their own anxieties and belief systems in mathematics, and to believe that everyone has the capacity to improve (Dweck and Master, 2009).

One key intervention is to develop the power of 'YET' when a student believes they cannot do something a teacher can introduce the idea of 'yet' to convey that learning is a continuous process (Dweck, 2016). It is important that pre-service teachers develop this belief and have an awareness of their own potential MA before they can impart interventions to their students, thus awareness and understanding are key to this study.

Alongside interventions that can increase mathematics achievement in the classroom, it is important that all learners have a strategy to identify and explain how they are feeling. Introducing learners to ways in which they can identify their emotions and feel they have some control may be useful in understanding and overcoming MA and building resilience. Agency for the learner and those who support them has been presented as an approach to building mathematics resilience and prevent young learners being exposed to risk (Johnston-Wilder et al., 2020).

The Growth Zone Model (GZM; Figure 1) is a tool for enabling awareness of emotions to develop in the mathematics classroom with a shared language, thus enabling learners to develop mathematical resilience (Johnston-Wilder et al., 2020). The GZM gives a framework for learners to name and communicate their feelings. It is important for students to understand the value of the mathematics they are studying, why they are learning this topic and the need for persistence and perseverance when meeting challenges especially if they feel anxious. The aim of the Growth Zone Model (GZM) is to help learners to distinguish responses from "productive nervousness to panic" (p.1427) and to try to prevent students getting to the stage of anxiety where they are no longer productive.

Introducing this model to teachers in training may give them a mechanism to position their feelings but also a model which they can develop for use in the classroom when they begin to teach. The Johnston-Wilder et al. (2020) research reports that the model helped learners to understand and communicate their growth zone; in the current study its use in a mastery pedagogy helped students to understand how they could move through to their growth zones. By using a pedagogy that provided the security of collaborative work and gradually moved to independent work they could build resilience and understand their responses as they moved through the zones. The model suggests that having the environment and knowledge to move from the anxiety zone (which is often in solitary working) back to the comfort zone (which may be found in the security of group work) could be a move from something fearful to it becoming challenging and enjoyable (Liu, 2016). By using this model, and developing understanding through a mastery pedagogy, pre-service teachers can support children to understand that everyone will make mistakes, and it helps learners feel safer getting into and staying in their growth zone but also to move into a comfort zone when they have identified feelings of MA (Lee & Johnston-Wilder, 2018).

Evidence suggests that some student teachers lack competence and confidence in mathematics both in terms of how they learn and how they teach (Bolden et al., 2013). Teachers' subject knowledge in mathematics as well as their mindsets can have a considerable impact on their ability to teach effectively (Boaler, 2016) and for pre-service teachers 'curriculum coverage' would not be enough (Murray & Passy, 2014). Freeman et al. (2014) advocate inquiry-based learning in mathematics courses for pre-service primary school teachers including instructional strategies, problem solving and subject knowledge. Boaler (2009) promotes encouraging teachers to understand mathematics anxiety as this may be beneficial and when it could negatively affect learning.

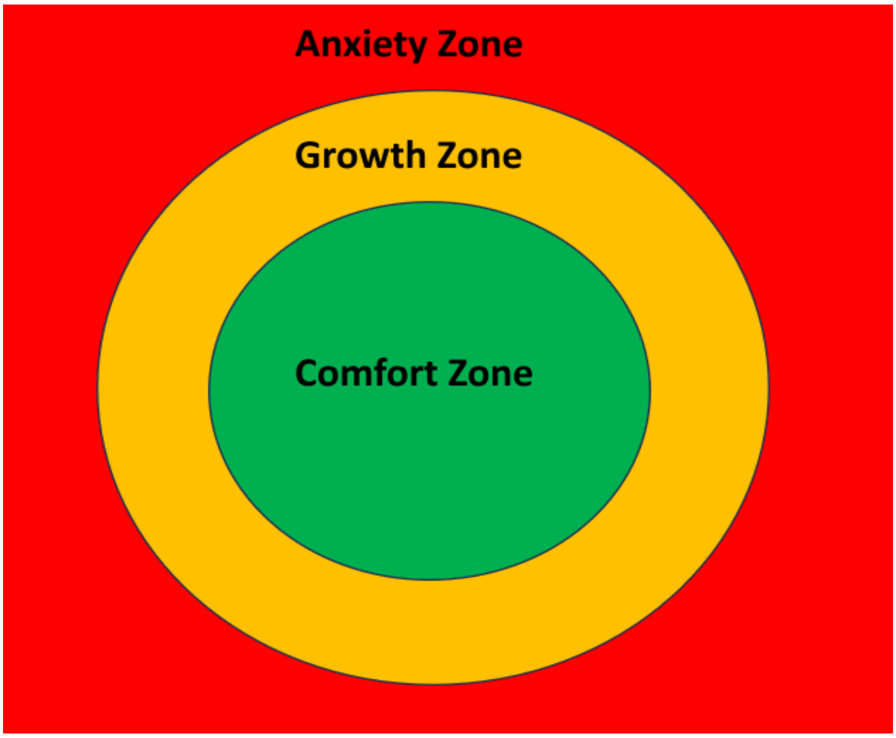

Figure 1 Growth Zone model (GZM) (Lugalia et al., 2013)

2.7 Mathematics teaching anxiety in pre-service teachers

Bolden et al.(2013) highlighted that pre-service teachers lack confidence and competence in their ability to teach mathematics, yet research on MA in pre-service teachers is limited particularly in the UK (Hunt and Sari, 2019). Mathematics teaching anxiety is different from anxiety when executing mathematics but it is a relatively new construct measured in pre-service primary school teachers who are under increasing pressure to deliver high quality instruction to their pupils (Bosica, 2022). Research findings have indicated that anxiety towards teaching mathematics predicts the adoption of a more traditional teaching style (Hadley & Dorward, 2011) with teacher-centred practice being most common when mathematics teaching anxiety increased. Hunt and Sari (2019) state that more needs to be done to ensure teachers/trainees are supported and not placed under undue stress with regard to teaching maths, and therefore the need for a pedagogy which reduces mathematics teaching anxiety and is more child-centred is necessary. Maths mastery is a pedagogy which is considered to be less teacher-centred and focused on problem solving, embedded in communication and focusing on everyday mathematical encounters.

2.8 Orientation to the current project: Mathematics Mastery as an intervention for MA in pre-service teachers

Evidence in favour of pre-service teachers having a knowledge of mastery pedagogy to enhance their teaching came from a variety of sources. For example, the Education Endowment Foundation (EEF, 2015) found that on average, mathematics mastery pupils in England made more progress than non-mathematics-mastery pupils. Whilst this study included children, teachers must be skilled in the pedagogy to teach it. Teacher-knowledge is a factor in mathematical high achieving countries such as China, Singapore, Japan, and South Korea (Barber & Mourshed, 2007) as primary mathematics is taught by specialist teachers who only teach mathematics. In contrast, across the UK and Ireland teachers teach across subjects therefore support for subject knowledge is an issue and additional training is important for mastery teaching. Moreover, evidence suggests that a significant impact can be made on student teachers' attitudes, both their own learning as well as teaching mathematics, and this can be achieved using representational approaches, coupled with discussions about connections between them (Bolden et al., 2013).

Mathematics mastery provides sets of lesson activities, teacher support materials, and a professional development programme that is collaborative, embedded in practice and mathematically focused (Boylan et al., 2018). One of the aims of this study was to improve teacher self-efficacy through pedagogical subject knowledge. While previous studies undertaken by EEF (2015 & 2021) have shown a positive impact on subject knowledge, pedagogical approaches, and beliefs (Boyd & Ash, 2018), throughout the cohort of participants in the English teacher exchange programme, the main effect was an increased confidence in teaching mathematics based on the mastery approach (Blausten et al., 2020). This research was inspired by these outcomes as an incentive for introducing mastery to the student teachers.

2.8.1 A definition of mastery

Mastery has been described as comprehensive knowledge or having learnt something to the extent that it can be used without difficulty (Drury, 2014). Nunes & Bryant (1998) used the term to imply when a child has mastered a concept, they have a good understanding of it, make connections between it and other concepts and can reason and apply it in different contexts. Drury (2014) gives a detailed definition of mastery in mathematics as:

"A mathematical concept or skill has been mastered when, through exploration, clarification, practice and application over time, a person can represent it in multiple ways, has mathematical language to be able to communicate related ideas, and can think mathematically with the concept so that they can independently apply it to a totally new problem in an unfamiliar situation." (Drury 2014, p.9)

According to Askew et al. (2015), the term mastery has been used in four separate ways: a mastery approach, a mastery curriculum, teaching for mastery, and achieving mastery of topics and areas of mathematics. A mastery approach is described as a set of principles and beliefs including having high expectations for a child and promoting a growth mindset. A mastery curriculum builds on the idea that all children can do mathematics, provided that the curriculum content addresses teaching concepts securely and makes connections between different mathematical ideas (Askew et al., 1997). Whilst there are a variety of definitions on what mastery means, the teaching approaches used with mastery principles focus on the guidance set out in the Cockcroft report (1982: para 243) which outlined best practice:

'*Exposition by the teacher; discussion between teacher and pupils and between pupils themselves; appropriate practical work; consolidation and practice of fundamental skills and routines; problem solving, including the application of mathematics to everyday situations and investigational work*.'

Boylan et al., (2019) developed these ideas by describing these pedagogies as a whole class, interactive teaching that develops conceptual understanding and procedural fluency. Vignoles & Jerrim (2015) further emphasised the importance of language, mathematical representations and having high expectations of learners so that learners become fluent in their use of mathematical concepts while developing a deeper understanding of them. Further definitions have also focused on the need to understand mathematical structures (Haylock & Cockburn, 2017). While others have highlighted that students should be able to develop skills to effectively solve problems in learning (Drury, 2018).

2.8.2 Singapore versus Shanghai Mastery

In the pursuit of developing a mastery curriculum, the teacher exchange programme in England involved collaboration with teachers in Shanghai. The educational culture of Shanghai has been described as 'knowledge transmission' (Tan, 2012, p.156) with the focus on instruction through a centralised system which is carefully considered, systematic and well-funded. The emphasis on knowledge transmission and practice seems to produce a procedural and teacher-led style with lots of drill and practice, but there is more emphasis on a concrete-pictorial-abstract (CPA) approach and teacher talk. A review of the teacher exchange programme found evidence that "Shanghai whole-class interactive teaching aims to develop conceptual understanding and procedural fluency. This was achieved through lessons designed to be accessible to all, through skilful use of teacher questioning and incremental progression" (Boylan et al., 2019, p.26). Whilst it was noted that there are subtle differences between the English system and the Shanghai system, the overall structure of schooling and curriculum was seen to be similar Boylan et al., 2019).

Influenced by the Cockcroft report (1982), the Ministry of Education in Singapore developed an approach which saw sequencing material as CPA –a version of Bruner's (1966) ideas about learning mirroring the *enactive, iconic, symbolic* modes of representation. The broad aims of the mathematics education in Singapore are to enable students to:

- Acquire and apply mathematical concepts and skills.
- Develop cognitive and metacognitive skills through a mathematical approach to problem solving.
- Develop positive attitudes towards mathematics (Ministry of Education, 2012, p.7)

In Singapore mastery, the content is focused on the building of foundational skills and exploratory learning: "we've got to teach less to our students so that they will learn more" (Loong, 2004, p.24).

Just as Shanghai was chosen as a similar curriculum to the English system, my focus was on teacher training in NI, and I was searching for similarities and a 'best fit.' In Singapore, there is one route into teaching: all teachers are trained by the National Institute of Education (NIE). The NIE partners with the government to oversee this teacher preparation and assists with the placement of teachers in government schools to complete their professional training. To develop suitable candidates, "prospective teachers are carefully selected from the top one-third of the secondary school graduating class, by panels that include current principals" (OECD, 2010, p. 169). This is aligned to the teacher training format in Northern Ireland, where there is only the university route to teaching, student teachers are placed in schools to complete their professional training and the entry requirements are high, requiring top achieving students (Hagan and Eaton, 2020).

Central to the mastery approach is the belief that with the appropriate resources, support, teaching and time, all children can succeed mathematically (Boylan et al., 2019, p. 34). It aims to develop a uniform expectation of high standards of achievement in mathematics for all students (NCETM, 2014a; 2014b). Thus, the aim is that "most of the pupils progress through the curriculum at the same pace." In mastery, all students in the class are introduced to mathematical concepts at the same time, with time given for all learners to master these concepts before moving on. During practice and implementation time, additional support is given to those who need it ensuring that all learners can be successful if they are given time to develop their understanding (Bloom, 1968). For the faster learners or those achieving at a different pace, differentiation is achieved by emphasising deep knowledge and through individual support and intervention (NCETM, 2014a; 2014b). An important feature of the teaching for mastery approach is the focus on methodical, careful, curriculum design and lesson planning to "foster deep conceptual and procedural knowledge" (NCETM, 2014a; 2014b). Whilst mostly students have been exposed to a traditional two-part lesson, the mastery approach introduces the three-part lesson which originated in Japan and was adopted by Singapore (Tozzo, 2017).

2.8.3 The structure of a Singapore – style Mastery lesson

Tozzo (2017) outlined that all mathematics teachers should have a foundational structure to their lessons. In the West, the most common and traditional is a two-part lesson structure commencing with the teacher using multiple examples or an explanation, and the second part is independent practice with a question and answer or review session at the beginning of the class. This structure is different to the 'Singapore mastery structures' where class time is mostly spent on discovering procedures, developing algorithms, and exploring ways to solve problems before the teacher demonstrates a solution.

Figure 2 outlines the 3-part lesson structure most common in a Mastery lesson utilised in the current stud

Lesson phase		Outline
Anchor Task	**Exploring**	One problem or stimulus is presented to students, and they are encouraged to explore it. The lecturer uses this time to observe their responses and prompt further exploration with questioning to ensure that all students are challenged.
	Structuring	The lecturer gathers students' ideas for solutions and the class discusses them as a whole group, often re-exploring new suggestions.
	Journaling	Students record what they have been doing in their mathematics journals the way children will in school – there is an emphasis on showing things in diverse ways and effective communication of thinking.
Reflect and refine		The on-line textbook is used, and the lecturer guides the class through the textbook solutions to the problems they have been discussing. There is a greater emphasis on explanation during this phase.
Practice		The lecturer starts by guiding the class through examples of similar problems to the one they have just done. Then, students work through more examples independently with the lecturer supporting them if necessary. All questions are typified by their mathematical variation – they are designed to extend student's thinking rather than just be lots of examples presented in the same kind of way.

Figure 2 (Adapted from Boyd & Ash 2017)

2.9 Gaps in current research

Robinson (2022) highlighted that there is limited research into the needs of students in initial teacher training (ITT) in the UK regarding their subject knowledge and confidence. His study found that only limited research was carried out in the UK, and this was at least 5 years old and not widespread across the regions. This research adds to the body of knowledge and focuses on the unique situation in initial teacher education (ITE) in NI with a view to providing a picture of MA amongst some of the ITE population and ways to improve the situation. Avoiding mathematics and numeracy related activities is not an option for those students who wish to become teachers especially those who have chosen Primary teaching.

Although there have been numerous research articles which consider MA, and substantial knowledge has been acquired, the area of teacher education has had limited research (Furner & Duffy, 2002). Pearson (2019) recommends that ITT in the UK should include exploring MA and using every opportunity to raise awareness of the issue of MA to make a difference, yet there is a limited body of knowledge on MA and pre-service teachers. There appears to be a particular dearth of research on this topic in NI, yet all student teachers go through the university route so it would be advantageous to find a pedagogy which increases subject knowledge, teacher's self-efficacy and improves confidence whilst also minimising MA.

Rethinking teaching approaches to allow more thinking time, using high quality resources which encourage greater depth, making the creativity and relevance of mathematics more obvious, and working in groups to explore concepts and challenges are all recommendations of the Pearson round table conference (Pearson, 2019). These are strategies I used in this research to extend the body of knowledge. To challenge the many negative perceptions about mathematics requires challenging the environment and a dismantling of traditional beliefs to affect change (Gonzalez, 2023).

2.10 Chapter overview

This chapter explored the literature relating to MA providing a context and background for the study. A definition of mathematics anxiety was examined, and the diverse presentations of MA were reviewed, including the types of phobia and anxieties. Understanding the different forms of anxiety is important and the definitions and links between trait, exam and mathematics anxiety were analysed and explained. The pathways to MA were presented in the context of the theoretical frameworks and the transmission of anxiety was discussed. It outlined how early experiences can influence life chances and future opportunities. The importance of number confidence was discussed and the gender differences which exist around the subject of mathematics was considered. The beliefs around the concept of a fixed and growth mindset ensued and the pathways to prevention and intervention investigated with the principles of resilience and self-belief.

The chapter further outlined the mathematics mastery pedagogy, the various interpretations of the pedagogy, the rationale behind the choice of the Singapore mastery and the structure of the lessons in my study. The gaps in the current research provided a rationale for this study which adds to the body of knowledge by considering pedagogy to overcome MA in the location of a teacher training college in NI.

3. Methodology

This project used a mixed method design to explore the impact of mastery teaching on the thoughts, feelings, and self-perceived competence of pre-service teachers as they completed a 10-week programme focused on the delivery of the NI Primary Mathematics curriculum. Arnold and Norton (2018) stated that Action research offers a framework of broad steps, which can guide research through practice with the precise steps varying between authors. This study was carried out using a model presented by Norton (2019) abbreviated to the IDETM'D acronym. This is a six-step framework which outlines the following steps:

- Identify a learning, teaching or assessment issue that is 'troublesome.
- Think of ways to investigate it
- Do it
- Evaluate it
- Modify your practice
- 'Disseminate the findings / outcomes.

3.1 Positionality: critical professional Inquiry

Researchers have beliefs, and forged by background and life-history, these are assumed to be an integral part of the research process (Cohen et al., 2007). The researcher is assumed to have a *position*, and this position affects the nature of the observations and the interpretations that they make. As a lecturer in a teacher training college and a former primary school teacher, my position is that through dialogue and reflection, the teacher is no longer the 'expert' who teaches but is a person who is taught through interaction with the students, in a joint learning process where all parties grow (Freire, 1993). As learning is a sign of growth, professional accountability is not determined by static possession of knowledge, but by the capacity to function in ever changing conditions (Lester & Mayher, 1987).

In this study, positionality was aligned with critical professional inquiry. Crotty (1998) states that while interpretivism seeks to understand, critical inquiry seeks to bring about change. This change can only come through an understanding of both what the current position is, and the desirable direction. Dewey's model of reflective practice outlines:

> *"...a meaning making process that moves the learner from one experience into the next with deeper understandings of its relationship and connections to other experiences and ideas* "(Dewey cited in Rodgers, 2002, p. 845).

As a teacher, I saw student-teachers in college discussing and displaying manifestations of MA and the lack of confidence which accompanied them. The desirable direction of change was to move students during their degree programme to a position of confidence in embracing the delivery of the mathematics curriculum. Achieving this goal relied on understanding the students' relationship and connections to their MA, as well as their experiences, and their beliefs about the subject.

The ontology of critical professional inquiry is based on relativism, in which reality is socially constructed through interactions with a variety of sources (Cohen, et al.,2018), including the media, institutions and society. Teachers may also be influenced by the methods in which they were taught (Korthagen, 1993), and this was my position. As someone who found mathematics difficult in school, I questioned whether there was a better way mathematics could be taught which was less abstract and easier to understand. In teaching, I taught mathematics the way I had been taught but knew that if I had found it difficult, so would other children. In line with Crotty (1998), I understood the position and the desirable direction to bring about change in pedagogy. To bring about change, engagement was necessary with external sources including investigation with pedagogies around the world which encouraged change and provided an alternative pedagogy to the familiar one experienced by myself and the current student-teacher population.

3.2 Transactional epistemology and a transformative paradigm

Transactional epistemology is an approach that links people and knowledge as inseparable (Dudovskiy, 2022) and suggests that it is important to assess participants' prior knowledge and experiences before commencing an intervention. In line with Dewey's (1933) model of reflection and practice, to move to a deeper understanding, I had to discover current ideas, concepts, and practices that allow me to form my own understandings of mathematics anxiety and of the mastery pedagogy, which I gradually reinforced through learning and experiences. This was applied to the project as students were also introduced to current ideas on the understanding and teaching of mathematics, different concepts, and practices to encourage their understanding as they practised and experienced the mastery pedagogy. Consideration was given to Dewey's (1933) 5 step model as there was a recognition of the problem, a search for information, reflection and evaluation of an alternative, a choice of pedagogy, and reflection on the outcomes.

Biesta (2010) suggested that experimentation is always an intervention, and that knowledge is about relationships, specifically between our actions and the consequences. As I developed my subject knowledge on mathematics mastery and implemented it into my teaching, I discovered my own anxieties and mindsets. In a transactional epistemology, knowledge is not a depiction of a static external world, but knowledge about the world "in function of our interventions" (Biesta, 2010: p495). Specifically, it represents a world that changes because of our interventions and people who change due to new knowledge, information, and experiences. My confidence increased as I acquired new knowledge, and my self-efficacy improved as I gained experience and developed my pedagogical understanding.

In this research, the function of the interventions was continually monitored, and my knowledge, information and experiences developed alongside that of the student-teachers. The development of my pedagogy was reviewed weekly as discussions during the class and measures each week at the end of the class gave me an insight into my progress and the feelings of the student-teachers. As students learned new skills and new ways of working, their self-reported confidence and competence were measured, and I was able to evaluate my own thinking and method of delivery. Jaworski (2004) highlighted this change by outlining the belief that the use of inquiry as a tool can lead to developing inquiry as a way of being when learners develop their practice.

Riyami (2015) referred to critical inquiry as a "transformative paradigm", with Mertens (2007: p. 213) arguing that a transformative paradigm enters every stage of the research process. The transformation during this research project was a gradual one and became more rapid and noticeable in the second iteration of teaching (see chapter 4.4). The concept of transformation has been a key objective of this study and is reported to be a feature of the reflective nature of action research which is described as: "a systematic multi-staged cyclical process, which aims to improve practice through the implementation of informed and incremental change" (Waghmare 2021 online), and to change and transform practices, the understanding of practices and the condition in which we practice (Kemmis, 2009).

3.3 Insider / outsider researcher

In the current project, my positionality granted me insider status as a teacher educator while also assigning me outsider status as a researcher. The intersectionality of these identities thus created different conditions for being an insider or outsider, which responded to the research context as I was developing my pedagogy alongside the students whilst at the same time evaluating the results of the mastery pedagogy on MA. According to Braun & Clarke (2013), a researcher is considered an 'insider' when they share attributes with the study participants. As a member of staff in the college in which I carried out the research, and a former primary school teacher, I shared some attributes with the participants. My occupation as a teacher-trainer might have granted me insider status as I am fully informed of the challenges of the teaching profession, and I assumed pre-service teachers would feel comfortable confiding in me as their class tutor about their MA.

However, I might also have been considered an outsider since a teacher-trainer can be perceived by students as an evaluator. It was essential that I was not perceived by my students as someone who was going to observe and evaluate their learning and practice during the research project. I regarded my positionality as being an inquisitive insider, but also as a coach helping to resolve issues with MA. I was also the person responsible for introducing mastery pedagogy and making decisions on the course context and this tension may have created assumptions for the students and their perceptions of my expectations.

The dichotomy of identity is difficult, as I was the lecturer of the students and a researcher looking at a problem of developing pedagogy to improve mathematics anxiety. As an insider researcher I was critically aware throughout this study that I should attempt to avoid making assumptions, especially that I did not use the information gathered to confirm my beliefs regarding MA and mastery teaching but considered the results objectively. I also had to be aware that the participants were free to give honest opinions and not just to give the answers they thought I was looking for, and this was strongly encouraged. The fact that some of the interviewees did give honest answers which were not always comfortable for me, reassured me that I had provided the environment for them to do so and thus decreased bias. I needed to be mindful of 'researcher bias', when personal values and experiences influence the research questions, design, and data collection procedures (Chavez, 2008) and the piloting of the questions helped with this area.

There are several advantages to being an insider researcher; having a greater understanding of the culture being studied, not altering the flow of social interaction unnaturally, and having an established relationship with the students which promoted both the telling and the judging of truth (Bonner & Tolhurst 2002). The insider-researcher can find it easier to have access to the participants and to build a foundation of trust, however an insider researcher must also be aware of the difficulties this access can bring regarding objectivity and reflexivity. Aristotle noticed that people are more likely to believe arguments that support their bias (Good, 2023) and being aware of this led me to frequently consider my bias towards mathematics mastery. One of the first steps taken to minimise researcher bias was the use of random sampling. My classes were randomly selected by administration and allocated to each tutor. The initial questionnaires measured the construct of each of the groups including gender, presence of MA, qualification level in the two distinct groups to ensure they were balanced. Blinded data collection was used to ensure the anonymity of the participants, but to also decrease bias and data was collected every week (See Appendix 1).

As a practitioner researcher, it is also important to use an appropriate lens to distance oneself from the familiar to make it strange and using a critical reflective lens (Brookfield, 2002) allowed me to be open to new questions whilst trying to guard against preconceptions, prior assumptions, and bias. By being aware of the potential for bias, I undertook steps to avoid researcher bias including asking broad questions of my participants before specifying, summarising the answers to them, and showing the respondents the results. Data can often be interpreted in many ways, and it was important that I considered what the data was really saying even when it did not give results to prove my theory or make it difficult to solve.

A researcher is considered an 'outsider' when he or she does not belong to the group to which the participants belong (Braun & Clarke, 2013), and as a tutor rather than a student I also belonged to this category. My positionality fluctuated at various times during the research depending on my insider or outsider status. Whilst there were times the pedagogy felt new, I also had to portray confidence and competence in it to ensure the students were assured in the knowledge and experiences they participated in. Mason-Bish (2018) stipulates that insider and outsider positionalities are dynamic and constantly changing depending on the context, which then determines participants' responses based on the positionality embodied by the researcher. As mastery pedagogy had not been taught in the college before, it wasn't just a new experience for the students, but it was also a new way of teaching for me and there were times when the dynamic was such that we were all learning together as I was experiencing new reactions to the way I was presenting the curriculum. I could relate to the sense of 'everything being different' in the first few weeks and in some ways, I also felt like a learner as I was teaching this for the first time.

3.4 Action research (AR)

Action research (AR) is a form of research that explicitly sets out to make a practical difference to the issue, problem or question being studied (Coleman, 2015), in this case the challenge of MA in pre-service teachers. As AR explores topics that are not just academically interesting, but also of personal, practical, or political concern, it crosses the boundary between academia and practice and places the researcher at the centre of the study itself (McNiff et al., 2003). In this study, I wanted to consider my pedagogy and analyse the effect I could have on pre-service teachers. If teachers are influenced by the way they were taught I wondered if a different pedagogy would be effective in minimising MA, creating a new influence and attitude towards mathematics. As Reason and Bradbury (2001) suggested:

> "[AR] seeks to bring together action, reflection, theory and practice, in participation with others, in the pursuit of practical solutions to issues of pressing concern to people, and more generally the flourishing of individual persons and their communities." (Reason & Bradbury, 2001: p.1).

AR offered the opportunity to interrogate and question experiences from the pre-service teachers, but also develop practice as research issues were identified and data collected weekly during the study to inform the decision making (Hine & Lavery, 2014). The research was an opportunity to create something new, connect to others, build communities of practice regarding mastery pedagogy, and find practical ways forward to support students who experienced elevated MA (Coleman, 2015).

AR has been described as an approach which encompasses a range of methods and tools that have some key characteristics (Coleman, 2015). Like critical professional enquiry, AR is a cyclical process of reflection and action, review, and evaluation. In the current research, this process is demonstrated in the two distinct blocks of teaching where reflection on the student view led to a review and evaluation of the teaching. Consideration of whether mastery pedagogy can alleviate MA was an appropriate subject for AR as it combined action and systematic reflection. McNiff and Whitehead (2010) outline the need for the researcher to be willing to act on the data especially if it shows that there are mistakes or a change in direction is necessary, and this research project reflected this in the changes which were made to the second iteration of teaching.

Reason and Marshall (1987) described action research as 'for me', 'for us', and 'for them' with three levels of focus representing 'multiple simultaneous attentions' (Marshall et al., 2011: p.245) and working collaboratively with others to co-enquire into questions of mutual interest; in this case, developing my own pedagogy and determining whether Mastery principles in teaching can help overcome MA in students in ITE manage symptoms of MA more effectively and thus provide a better outcome for the pre-service teachers and the children they will teach.

If AR is done in collaboration with other people, it is an emergent process rather than being fully planned (McNiff, 2017). Although there was a starting intention, the research proceeded through steps of action and reflection which indicated the learning and change that was involved, as assumptions were challenged, and new thinking was taken into action (see Figure 3 below).

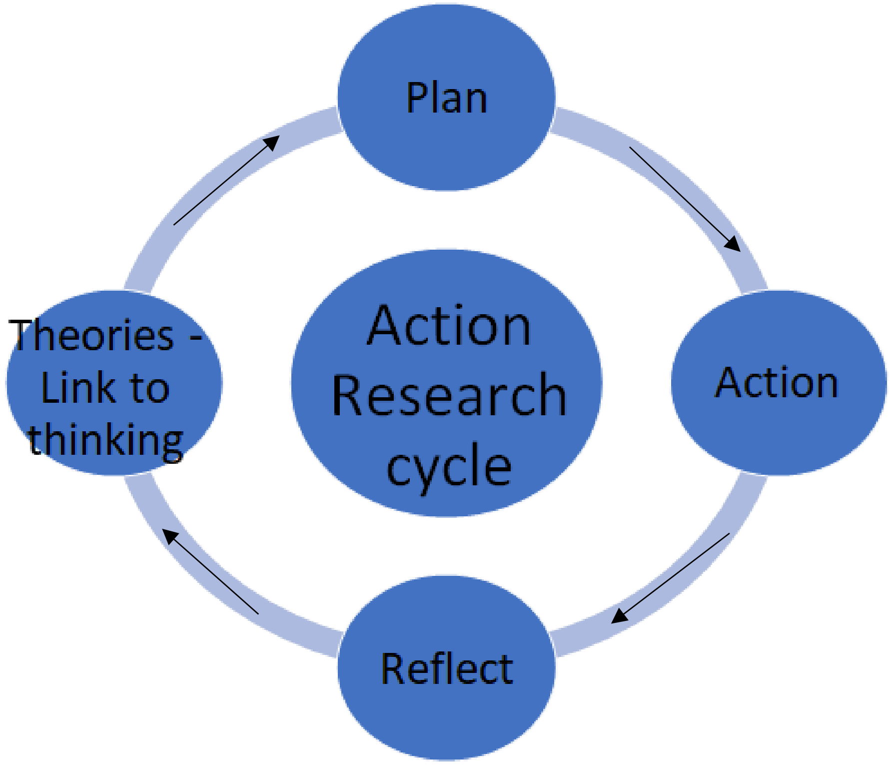

Figure 3   The action research cycle (adapted from Costley & Fulton, 2019)

3.5 Pedagogical action research (PedAR)

PedAR is a form of AR, which aims to develop, evaluate, and improve pedagogical practice with participatory or collaborative input (Cook, 2009). Norton (2009) uses the term 'pedagogical action research' to refer to research into the principles of learning and teaching that is undertaken within tertiary education, to distinguish it from the educational action research which is done at primary and post primary level. She also defines it through the idea that 'action' requires change resulting from the research, and claims it promotes methods that enhance the quality of teaching and learning in universities and further education institutions. Pring (2015: p.153) outlined that "action research is to be contrasted with theoretical research, its aim is not to produce new knowledge but to improve practice" however, Norton (2009: p.xvi) takes this idea a step further and outlines that the dual aim of PedAR is to improve practice AND contribute to knowledge:

> "Pedagogical action research is a systematic approach to investigate our own teaching / learning facilitation with the dual aim of modifying practice and contributing to theoretical knowledge" (Norton, 2019: p.1).

This project embraced the latter approach; its aim was to develop and improve my own practice and model pedagogy for future teachers. The project further contributes to the theoretical knowledge on MA amongst student teachers as most of the current research has been carried out with children (Ramirez et al., 2016) or already qualified teachers (Beilock et al., 2010). In addition, there is little research on overcoming MA in ITE (Mammarella et al., 2019), despite its impact on the children in the classroom (Beilock et al., 2010; Beswick, 2012; Bian et al., 2018). McNiff (2010) observed not just the practice-based nature but also the 'values laden' nature of AR and thus PedAR where problems concerning people, tasks and procedures need a solution. In the case of my research, I wanted to more effectively support student teachers who experience MA and to prevent children experiencing symptoms in the future (Beilock et al., 2010).

Reflexive practice, which goes alongside AR and PedAR, means looking at our own thinking, decision making and asking questions (Arnold & Norton, 2018). Looking at my own actions, course design, and the teaching and learning strategies can be 'unsettling' but the aim of this research was to unsettle my own views and keep the approaches, beliefs, and ways of seeing practice, under review (Pollner 1991). Somekh (2006, p.14) argues that "self-enquiry in action research is a matter of research quality" and it was important to acknowledge from the outset that the data does not have to prove that the intervention was effective (Arnold & Norton, 2018). It should not be used to demonstrate a straightforward cause and effect relationship (McNiff, 2017), but should help develop an understanding of personal, professional, practice.

3.6 Research design

The research context and my positionality influenced certain methodological decisions. I used a PedAR framework involving a cyclical process of planning, acting, observing and reflecting (Carr & Kemmis, 1986; Denscombe, 2014). Working with data in a PedAR project involved taking an integrated approach to make sense of the data using the three constructs of analysing data, authenticating data, and making sense of the data (McNiff, 2017). The development of using the findings from one method to inform the other worked to extend the breadth of the research by using different methods for different components of the inquiry (Burke et al., 2004).

This study consisted of a sequential mixed methods design containing two strands with an iterative nature and moving between quantitative and qualitative research methods to address the research question (Teddlie & Tashakkori, 2009). There was an initial preparation phase (Piggot-Irvine et al., 2016) which helped establish the presence and prevalence of MA among the cohort of students, followed by two 5-week teaching blocks with quantitative data collected before teaching started and after it had finished, as well as immediately after each teaching session. Between the two teaching blocks qualitative data was collected and the thematic analysis from these interviews was used to inform changes needed for the second block of teaching/action. Whilst using mixed-methods designs may be more time consuming than using a single method (Hall, 2020), the quantitative data was developed and deepened by the semi-structured interviews increasing the validity of the research and addressing biases that may sit with the adoption of a single methodological approach (Hall, 2020).

A summary of the structure of the project is included in Figure 4 below

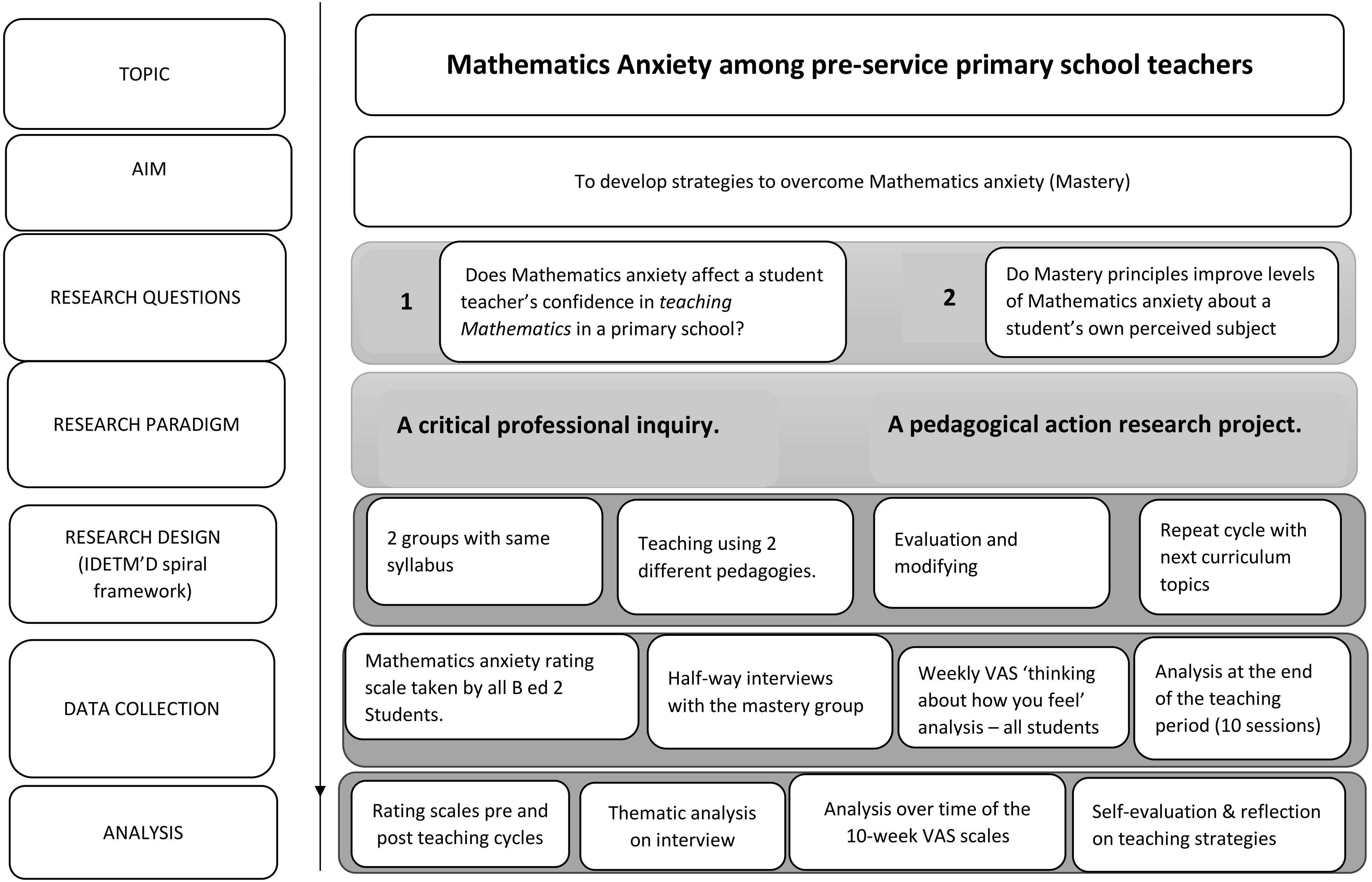

Figure 4 *My figure to illustrate the structure of the study*

3.7 Mixed Methods

Mixed methods research requires the integration of qualitative and quantitative data (Poth, 2018). In general, quantitative approaches are used alongside qualitative methods to explore and understand the meaning individuals or groups ascribe to a social or human problem (Creswell, 2009; Fee, 2012). The combination of both approaches in the current study fits well with the flexible nature of pedagogical action research (Norton, 2019; Creswell & Plano Clark, 2017) and my positionality of critical professional inquiry.

Mixed methods research allows researchers to 'generate previously inaccessible insights from the integration of qualitative and quantitative data and assumes that their collective contribution mitigates inherent weaknesses in either type of data' (Poth, 2018, p.28). The systematic cycle of information gathering, analysis and reflection (Lewin, 1948), is compatible with mixed methods through the integration of quantitative and qualitative methods to examine an issue building on the strengths of different methods (Johnson & Onwuegbuzie, 2004).

Although AR is sometimes associated with a constructivist worldview due to its exploratory nature (Stringer, 2014), its practical focus, and of this project, looks to intelligent action geared towards 'experimental problem solving' (Biesta, 2007) and is thus pragmatic. This experimental and intelligent problem solving should include a 'means and end,' in other words, judging material with respect to their function whilst evaluating how the end can be obtained (Biesta, 2007). In the case of this study, judging if the mastery materials and the action of using them can reduce mathematics anxiety.

Using a combination of empirical knowledge (derived from experience) and rational knowledge (from scientific reasoning) this study required multiple sources of evidence, therefore pragmatic epistemological principles provided a rationale for using both quantitative and qualitative data which was also influenced by Dewey's view of knowing as 'a way of doing' (Dewey, 1933), knowledge being created through action (Christ, 2010). Moreover, Christ (2010) argued that AR shares the same philosophy, methodologies, and design characteristics as mixed methods research.

3.8 Sampling and participants

The sample was opportunistic but purposive and consisted of students in their second year of a Bachelor of Education in primary education. The sample included 111 student teachers who were randomly allocated to two classes, each of which experienced a different teaching approach. Both groups followed the same curriculum, but in one classroom teaching was delivered through a mastery pedagogy (MP). Students in the other classroom experienced 'teaching as usual pedagogy' (TAUP) or a more traditional style of instruction. The students were made aware that they would all follow the same curriculum but depending on the tutor-group different pedagogies would be used to deliver the curriculum. All students received information to inform them of mastery principles and they were made aware that this term one group would receive their curriculum delivered through this pedagogy for the purposes of the research project and at a later stage the TAUP group would receive their instruction through a mastery pedagogy. The students received information on the project which took place in their normal numeracy class time. Students were offered the opportunity to swap classes if they did not want to be part of the mastery group, but none chose to do so.

3.9 Choosing and justification of instruments and methods of data collection

MA is multidimensional, and includes the physiological and affective, cognitive, and behavioural aspects (Liebert & Morris, 1967; Wigfield & Meece, 1988). MA can occur both in a testing or assessment context and in general mathematics learning (Hopko, 2003; Plake & Parker, 1982). The current study aimed to identify a measure for MA that captured the diverse elements of MA. The validity and reliability of data and the potential to compare it with similar studies and findings was also considered. Moreover, it was important to ensure that measures had been found to have good validity and reliability (Bastos et al., 2014). Consistently, Bastos et al., (2014) suggest that developing new instruments is only recommended when there are no other options for measuring the phenomenon in question, or when the existing ones have significant limitations. Norton (2019) also reinforced this idea stating that: "Wherever possible in carrying out your pedagogical action research study, it is a good idea to use instruments that are already published" (Norton, 2019: p.164). Measures were taken pre and post intervention, each week during intervention and interviews were undertaken at the mid-point of the intervention in this study. I investigated the instruments which were available and used a mix of previously published ones and developed some new ones and these will be discussed in the next section.

3.9.1 Quantitative pre- and post-intervention measures

Richardson & Suinn (1972) developed the Math Anxiety Rating Scale (MARS), but the measure includes a 98 five-point Likert-type scale and is therefore time consuming to use. Other scales have aimed to reduce the number of items. Rounds and Hendel (1980) for example, reduced the 98 item MARS to a 94-item scale, and Bessant (1995) used a reduced 80-item version of the MARS. Further revised versions (e.g. Hopko, 2003) contained American terminology which may have caused misunderstandings. Hunt et al., (2011) developed a UK scale to measure MA that included 23 items and that was piloted on a UK undergraduate population. More recently, Chinn (2020) developed the 'How I feel about mathematics scale' that included 32 items, however, this scale only measures mathematics anxiety. The study focused on MA but also teaching mathematics and therefore a measurement that included some index of how anxious students felt about teaching mathematics was required.

As well as anxiety about their own ability in the subject, it was important to measure student anxiety at teaching the subject. Therefore, the Mathematics Anxiety Scale for Teachers MAST (Ganley et al., 2019) was chosen because it generated two related indices of MA - general mathematics anxiety (GMA) and anxiety about teaching mathematics (ATM). The current study used the MAST with all student teachers in their second year of the ITE Bachelor of Education (primary) programme. Alongside the completion of this scale questionnaire, students were given an overview of Mastery teaching principles, a brief introduction to the research project and invited to consent to their data being collected (see Appendix 2 for the consent letter and the information given to students about the project).

3.9.2 The Mathematics Anxiety Scale for Teachers MAST (Ganley et al., 2019)

The MAST was administered electronically at the beginning and end of the research project. Previous studies have found the questionnaire to have good reliability and validity.

In this study students completed the MAST using online Google forms. The scale includes 15 items and for each of these students are asked to rate how well the item describes them on a 5-point scale (1= not true of me, 5 = very true of me), (see Appendix 3). The GMA includes n=9 items measuring emotionality (e.g., "I would start to panic if I had to solve challenging mathematics problems") ; worry (e.g., "I start to worry when I am given advanced mathematics problems to solve"); and social / evaluative (e.g., I would feel nervous if I had to figure out a mathematics problem in front of other adults) elements of MA generating a total score range from 9 - 45. The final six items measured ATM (e.g., I worry about making mistakes while solving mathematics problems in front of my class) and the score range is 6 - 30.

In addition to the MAST, students provided information about several added questions including their gender, subject specialism, and their highest mathematics qualification. The response to the last questions was to determine their mathematical knowledge for teaching (MKT) as formal mathematics educational experience is negatively correlated with MA (Hembree, 1990) and teachers with a higher MA have lower levels of MKT with more traditional beliefs about mathematics teaching and learning (Ganley et al., 2019).

3.9.3 Data collections during teaching Visual Analogue Scale (VAS)

To measure student feelings after each teaching session the study used a Visual Analogue Scale (VAS) (Begum and Hossain, 2019). It is a widely used data collection method due to its simplicity, adaptability, and speed of completion and it can be presented in several ways including as a numerical scale, a horizontal line, or as scales with descriptive terms along a line (Pagare, 2023).

The VAS was used to explore students' feelings as they experience different approaches to teaching and show good reliability and validity (Begum et al., 2019). Its aim is to quantify a characteristic or attitude that is believed to range across a continuum of values, and which cannot easily be directly measured. In the current study the VAS measured four constructs including anxiety (anxious, worried, relaxed), attentional control (focused, concentrated, distracted), understanding and mastery of the topic (understand, confused, mastered), and intrinsic motivation (satisfied, interested, happy) (see Appendix 1). After each teaching session, students were asked to rate online how they currently felt on a scale from 'not at all' through to 'extremely' for the three words or short phrases linked to each of the four constructs. This data was collected using an online platform called surveyanalytics.com which is a research platform to collect and analyse feedback or data. Student responses to the three items generated a score from 0-100 for each construct. Means for each construct were calculated from the three items. Individual links were shared with each student group every week. This link was sent out to each class member via Google Classroom using a Google form under 'assignment' which enabled them to submit an immediate response at the end of class.

Methodological advantages of this type of scale include high validity and high sensitivity, as slight changes in feelings and emotions can be detected easily (Reips & Funke, 2007). Online the data generated is automated, fast, and exact. The VAS was piloted by four participants (who were not part of the study) to ensure the links were active and the data generated would be easily accessed.

3.9.4 Mid-way through teaching - Qualitative Semi-structured interviews

Qualitative data provides a richer understanding of the perspective of the person involved in the research and offers more in-depth information to amplify questionnaire responses (Norton, 2019). For my qualitative data I used semi-structured interviews which included six core questions alongside prompts and follow-up questions on topics where further information was necessary for depth of understanding (See Appendix 4). The questions focused on general MA but also the confidence of the students in their ability to teach mathematics. Open ended questions are more useful in interviews as they encourage longer answers and maximise the chance of the interviewee giving full and accurate answers (Koshy, 2010), and these formed most of my questions. My interviews were developed from the constructs linked to those measured in the weekly VAS scales and followed these four targets: general MA, attentional control, self-efficacy (mastery) of the topic and intrinsic motivation in addition to considering the students' experience and opinions of the mastery pedagogy. The questions are outlined in Appendix 4.

Although interviews can provide rich and helpful data, they are time-consuming and difficult to conduct thus some piloting, and practice was needed before beginning any interview process (Kara, 2019). The interview questions were therefore piloted with four individuals who were not in the interview group. I considered the possibility of doing small group interviews to encourage discussion (Kleiber, 2004); however considering the stigma that some students may have about MA (Boaler, 2009), I felt that some might be less willing to be honest and open about their experience in front of their peers. I therefore carried out the interviews one-to-one online through Microsoft Teams. Although I had originally intended to carry out face-to-face interviews, the Corona-Covid 19 pandemic restrictions meant that interviews were conducted online, and the students were given the sample questions a week prior to the interviews. The interviews provided an opportunity for students to give detailed feedback on their experiences to date and their opinions to inform the second block of teaching.

I interviewed 12 participants from the mastery pedagogy group (Nine female and three male) and in addition to informing the second block of teaching, I used the qualitative data to enrich the quantitative data and triangulate some of the preliminary findings. The class were all given a copy of the research questions in advance and I asked for volunteers. As it is a sensitive subject, rather than selection I felt it was appropriate to ask for volunteers to ensure the participants were comfortable to be interviewed and I was aware this could have resulted in a small number of participants, however I wanted to ensure that anxiety levels were not raised by this process. By allowing self-selection in the interview participants, I was aware that there was potential for bias which could affect the generalisability of the responses (Heckman, 2010); however, the interview questions were given out in class a week in advance I asked the volunteer participants to discuss the interview questions with the other students at their class tables to enable a wider representation of responses. I had thirteen volunteers to be interviewed but one of the volunteers then withdrew, so I had twelve self-selected volunteers. Convenient times were arranged, and these participants were again informed of their right to withdraw and were given the interview questions again to consider and I arranged individual times for the interviews.

The interviews took an average of 45 minutes each (ranging in time from 14.21 to 37.41 minutes) duration. In addition, the interviewees had opportunities to discuss their feelings, opinions, and requests on the teaching to date and the subsequent block (see Appendix 4). Within each of the initial questions there was the opportunity to ask or probe further if an interviewee made a vague reference or outlined something. To ensure the interviewee was not led, these probes were usually very general and used prompts such as 'would you like to discuss that further' or 'would you like to explain what you mean / experienced.' At the end of the questions, the interviewee was given an open question to allow them to have the opportunity to talk and this question was usually 'Is there anything further you would like to discuss'? The interview structure is outlined in Appendix 4 but for the purposes of developing the second block of teaching, question 3 probed the student's feelings about the mastery approach and the teaching methods being used. Responses to these questions were used to inform the teaching in Block 2.

With the interviewee's permission, the interviews were recorded on a password protected device and transcribed after the interview. Although time-consuming, interview transcripts provided powerful data that supplemented the MAST questionnaires and the VAS weekly surveys (Koshy, 2010). The process was made shorter using Otter software for transcriptions, but this was not accurate, all interviews had to be checked and amended for accuracy. Following transcription, the interviews were uploaded into Quirkos software for coding and analysis.

3.10 The structure of the teaching programme

The structure of the teaching programme and the collection of data followed for the research project included two cycles of teaching, the pre and post intervention stages and the topics for teaching which are all included in this section. The topics taught each week and the data collected are outlined in Figure 5, and although group 1 and group 2 followed the same curriculum, the name of some of the topics varied depending on the pedagogy; for example in week 6 both groups were taught multiplication under the topic of coherence and commutativity, however the emphasis in mastery was on finding patterns whereas in the TAUP group the emphasis was more on the procedures in multiplication.

3.10.1 Pre-intervention stage, introduction, justification, and consent

This initial phase involved gathering data on MA with the student teachers in their second year in ITE. These students were studying the primary school curriculum with most of them being non-mathematics specialists. All students in the cohort completed the mathematics anxiety scale for teachers (MAST) (Ganley et al., 2019); all students were informed about mastery pedagogy, the research project and consent were obtained (see Appendix 2).

3.10.2 Block 1 teaching weeks 1-5

Having collected a baseline from the MAST, the students were split into two distinct groups for teaching (each group consisting of approx. 50-70 students). Both groups followed the same syllabus, but Group 2 continued receiving their curriculum through the traditional method teaching whereas Group 1 received their instruction through a Mastery approach (i.e., the intervention group). At the end of each lesson both groups completed a VAS scale (see Appendix 1) which measured their level of anxiety, their attentional control, their self-efficacy, and their intrinsic motivation at the end of the lesson (N=12 VAS scores overall for each participant in each group).

Following from a meeting with the tutors of both groups it was agreed that whilst both groups followed the same syllabus, there were distinct differences in the teaching methods; Mastery principles allowed the students to approach a familiar topic in a different way and rather than focus on recall, they learned through discovery, "knowing both what to do and why" (Skemp, 1976: p. 20) whilst encouraging flexibility using more than one approach to solve a problem and be able to choose an appropriate strategy (Russell 2000). The tutors communicated weekly to ensure that each week the same topics were being covered, and they shared knowledge on the methodology used in the teaching. At the end of the first iteration (5-week teaching cycle), a selection of 12 volunteers from the mastery group were interviewed about their experiences so far and any changes they would like to see in the teaching.

3. 10.3 Interviews

The findings from the interviews were used to inform and implement changes for the second cycle. This is the step where the data and teaching methods were analysed with the possibility of modifying practice (Norton, 2019). As the main intention was to bring about change in the form of improvement (Carr & Kemmis, 1986; Elliot, 1991; McNiff, 2017), it is at this point, prior to commencing the second cycle of teaching that change was considered. Whilst self-development or pedagogical improvement is a focus of this research, it is important to always remember that this aim does not usurp the needs of the students and the aim should always be to ensure understanding and teaching pedagogies which will be beneficial for the students own general mathematics anxiety (GMA) and their anxiety about teaching mathematics (ATM) alongside their ability in teaching children in their schools. The treatment of values is therefore especially important as this is where personal learning occurs in action research, according to McNiff (2017: p.9), the 'action' part of action research should be both "in-here" in one's own mind, and "out there" in the classroom with a personal transition, or transformative learning (Gravett, 2004). At this mid-way point in the project, the question I considered on my own reflection was 'What has changed within me?' as well as what has changed for the students?

3.10.4 Block 2 teaching weeks 6-10

During the second cycle of instruction, the students covered topics (Figure 5 below) which have been identified as ones that typically cause anxiety (Ganley et al., 2019), but as they were now more familiar with mastery principles and pedagogy, the expected level of mathematics anxiety diminished during these topics (NCETM, 2019). The second cycle had a familiar structure to the first one considering the 'five big ideas' of mastery (NCETM, 2017) and it followed the model for classroom work; whole class teaching, opener (familiar experiences), new concepts taught through the CPA approach, activity time of working in groups to explore, guided practice to consolidate, and discussion on higher order thinking (NCETM, 2017). The use of manipulatives was especially important in the CPA approach as students needed to be able to actively experiment with the resources in a real-life problem-solving situation.

<table>
<tr><td>Time Measures 1</td><td>Block 1:Weeks 1-5 of Mathematics Teaching</td><td>Interviews</td><td>Block 2: Weeks 6-10 of teaching</td><td>Time measures 2</td></tr>
<tr><td>Group 1 and Group 2 Consent
Time 1 Measures
1.National Numeracy strategy self-assessment
2. VAS using ‘Thinking about how you feel’ as it measures
Anxiety
Attentional control
Mastery of the topic
Motivation
3. Initial MAST
Mathematics anxiety Scale for teachers (Ganley et al. 2019)

<u>Teaching weeks prior to research weeks (All B Ed 2 students)</u>
Introducing the Numeracy curriculum
1.NI Curriculum and resources and explanation of the research project
2. National Numeracy strategy self-assessment
3.Teaching and learning theories- how young children learn
4.Understanding Numeracy and Mastery Principles</td><td>G1 Mastery Mathematics
G2 Teaching as usual
<u>Mathematics Topics</u>
<u>Week 1</u>: Fluency
G1 & G2 Visual Analogue Scale (VAS)

<u>Week 2</u> Variation and connections
G1 & G2 VAS

<u>Week 3</u> Representation and structure
G1 Using manipulatives
G2 Common errors
G1 & G2 VAS

<u>Week 4 Representation and structure 2</u>
G1 Bar modelling
G2 focus on manipulatives across key stages
G1 & G2 VAS

<u>Week 5</u> Mathematical language
G1 understanding terminology
G2 Context and content of language
G1 & G2 VAS</td><td>Semi- structured interviews with 12 students from G1

<u>Qualitative data analysis</u>

Sample questions (included in Appendix 4)</td><td>Group 1 mastery mathematics
Group 2 teaching as usual

<u>Mathematics Topics</u>
<u>Week 6</u> Coherence and commutativity
G1 through finding patterns
G2 Multiplication
G1 & G2 VAS

<u>Week 7</u> Fractions
G1 & G2 VAS

<u>Week 8</u> Decimals
G1 & G2 VAS

<u>Week 9</u> Percentages
G1 & G2 VAS

<u>Week 10</u> Linking fractions, decimals and percentages
G1 & G2 VAS</td><td>Time measures 2
1. VAS using ‘Thinking about how you feel’ as it measures
Anxiety
Attentional control
Self-efficacy
Mastery of the topic
Motivation
2. Final MAST
Mathematics anxiety Scale for teachers (Ganley et al. 2019)

<u>Quantitative data analysis</u>

Analysis of results
• Comparison of initial anxiety and final anxiety tests
• Weekly VAS
• Compare references to Interview transcripts</td></tr>
<tr><td colspan="5">Mastery teaching Principles include:
1. Whole class teaching, and 2. Lesson structure - <u>Opener</u>- Familiar experiences; <u>In Focus</u> (oral objectives); New concepts through CPA approach; <u>Activity time</u>- working in groups to explore <u>Guided practice</u>- further consolidation; <u>Mind workout</u> develop higher-order thinking through discussion, 3. How does this apply to children and how could this be used during teaching experience in school.</td></tr>
</table>

Figure 5 Topics for teaching

3.11. Ethical considerations

Elliott (1991) stated that ethics is not just a consideration for action research, but it underpins it and therefore this was an important part of this project. There is always the danger of exploiting the participants, and there are multiple ethical considerations such as power relationships, bias, choice, trust, confidentiality and doing no harm. Protecting participants from harm is not about physical harm in pedagogical action research but potential psychological harm in the form of self-esteem and confidence. As mastery is a new pedagogy and they were all starting at the same level, self-confidence grew, and the work done last year on growth mindsets was effective. I did however include signposting to counselling and to minimise any adverse effects.

Norton (2019) outlined that it is relatively easy to convince ourselves that the research on student-learning and teacher-teaching at university is for the greater good of improving both, but constant and careful consideration needs to be incorporated to ensure there is no abuse of power or bias towards presenting students, colleges, our subject department, and our own practices in an unfairly favourable light. Researching into learning and teaching practice within our own institutions raises several ethical dilemmas, and I was constantly aware that as a lecturer I had a certain amount of authority and power deriving from my intervention and research being part of their course. To address these issues, all the students in both groups were fully informed of the research project, including their right to withdraw at any time, and they were asked to provide written consent and assured that participation was voluntary. They were assured of the confidentiality of the data collection and storage processes, and these were outlined to them (Appendix 2).

Norton (2009) further indicated that it is important to consider if PedAR could potentially harm the learning and academic performance of the students and there is an inevitable tension between researching students' learning with the goal of improving it, while at the same time interfering with that learning with no guarantees that their learning will improve. Denscombe (2010) advocated that participants should not be adversely affected because of engaging in the research, and this is one of the reasons why this was a comparative quasi-experimental study with both classes continuing to follow the same syllabus but being taught using different methods.

There is another tension here I had to consider as influence is at the heart of action research because the practitioner wants to bring about change (McNiff & Whitehead, 2009). Cochran-Smith & Lytle (2007: p. 35) argued that 'all teaching is imposition', yet at the same time I wanted students to feel they had a real choice. Whilst students were asked to agree to take part in the research (without coercion) and were informed by being given sufficient information to make a judgement, there needed to be an option for them to decline without penalty or prejudice. Whilst they were given the option to remain in the class and follow the mastery curriculum without their data being used, they also had the option to decline the option of following the mastery principles style of teaching and join the 'teaching as usual' group instead. Ethically I also considered advantages and disadvantages for students, and it was agreed on a departmental level that during the next term, I would swap classes with my colleague so the TAUP group could also experience teaching through mastery principles.

A benefit to the students is that they received opportunities to be introduced to principles which developed their teaching skills, enhanced their confidence, and provided them with an alternative pedagogy. The students also encountered the latest research in MA and explored ways to identify and overcome it and learn the teaching styles featured in other countries. The activities included in the previous year's syllabus of growth mindsets encouraged them to appreciate and understand that changing mindsets in children and in adults is a gradual process which brings about different learning behaviours, which in turn create different learning outcomes for students (Dweck, 2007), and that relatively minor changes in teaching can change students' mathematical pathways or students' relationships with mathematics forever.

My research involved collecting data from participants and I applied for ethical clearance from Hope University prior to beginning my study (see Appendix 5). I also wrote to the principal of the college (the gatekeeper) to gain permission to carry out the project and to use the information (see Appendix 6).

Ethics, for an action researcher, goes beyond getting ethical approval, and there was a constant need to examine what was being done as ethical considerations emerged (Norton, 2019). Norton (2008) proposes that the action researcher should think ethically rather than merely go through an institutional ethics procedure. There was a need to re-visit ethical issues during this action research project and participants' feelings were checked at various stages (Norton, 2008). This was built into the cycles and participants were asked again for consent prior to interviews and a reminder of their right to withdraw before both teaching cycles. As a safe-guarding mechanism, the interviews commenced with a reiteration that the participant could withdraw at any time, may refuse to answer any questions which they do not wish to answer, and they were issued with an information sheet signposting them to student services and support for further help and guidance should they need it. All necessary reassurances and back-ups were taken during the interview recording, such as reassuring them that I was alone and no one else could hear their responses, and the recordings would be destroyed at the end of the project. Steps were also taken to ensure the interviewees' well-being, including asking them if they needed a break and assuring them of support. At the end of the interview, I provided the interviewee with the opportunity to add any additional information and offered to provide them with a copy of their answers.

A relatively new consideration in research is the ethical use of technology, especially transcription and coding instruments. Quirkos software is licensed to my institution and can only be accessed by password protected logins. I was assured by the research office in my college that it was ethically approved and safe to use. Using transcription software involved another consideration especially regarding general data protection regulations (GDPR). After consultation with the AI centre for tertiary education, I was assured that providing the transcription software is run entirely on a protected device and not stored by the transcription companies then it is GDPR compliant.

I have a responsibility to act with integrity and consider what is the most sensible thing to do in each context, or as Hammersley & Traianou (2012) refer to as ‘the situated nature of judgement’. In addition to the traditional framework, it was important in this study to ensure that the project was conceptualised as 'socially just' and supply help if required (Balogh, 2018 in Norton 2019 p 190) and this was always a consideration throughout the project.

3.11.1 Anonymity and confidentiality

On the study, I worked to ensure that confidentiality was maintained throughout. Students who took part had unique numerical identifiers when they supplied the questionnaires and the VAS scales. Whilst this ensured confidentiality, anonymity was not applied as it was important if I needed to recontact the participants to trace the journey of their MA. The college is small, and I targeted my research on classes within a particular year band. It would therefore be easy for some members of senior management to attempt to identify the participants, but all steps were taken to minimise this as much as possible. The interviews from Google Meet were video recorded during the meet and then the audio of this was uploaded to a file and Otter.ai software was used. Once the transcriptions were obtained these audio files were deleted.

Confidentiality means making clear to the students that the data would only be accessed by myself and other researchers in the team (including supervisors) although this too had difficulties, the fundamental principle is that individuals cannot be identified in any reporting of the study. BERA (2011: p.5) acknowledged the difficulties with confidentiality in an action research project when the lecturer and the researcher are the same person: 'Dual roles may also introduce explicit tensions in areas such as confidentiality and must be addressed accordingly.' (p.5).

3.11.2 Subjectivity and Bias

Hammersley (2011) outlined the importance of personal knowledge and judgement as necessary to make sense of data, but also outlined the presence of bias. The question of whether it is possible or desirable to set aside our own values and assumptions is debated, as these are a socio-temporal construction, and it is naïve to pretend otherwise. Hammersley (2011) indicated that the insider-researcher's own social and individual characteristics and influence may cause errors in the research which must be acknowledged as the researcher cannot totally divorce their own characteristics. Whilst reflexivity needs consideration, particularly when working with qualitative data, the impact of being a practitioner-researcher is acknowledged and although I attempted to reflect on my interpretations, subjectivity and bias are always present. Acknowledging my hypothesis, I continually tried to be guarded against preconceptions and assumptions which would not be consistent with the pursuit of knowledge. To protect the research from 'the negative effects of subjectivity' (Cohen et al., 2018 p. 26), the quantitative data was used alongside the qualitative data to minimise the risk (Bridges, 2001). To develop and enhance the information from the quantitative, Miles and Huberman (1994) indicate the features of qualitative data which contribute to the strength of the research: "as its focus on naturally occurring, ordinary events in natural settings, so that we have a strong handle on what "real life" is like" (Miles & Huberman, 1994: p.10); however bias may still be present.

3.12 Conclusion

The utilisation of mixed methods in this PedAR research project aimed to understand MA and to identify a pedagogy to address its core behaviours. The initial fact finding (MAST) in this study was to determine the position of students regarding the presence of mathematics anxiety, with the weekly data collection (VAS scales) providing the information on the process of change to highlight the desirable direction. Using semi-structured interviews to better understand findings from quantitative surveys, the integration of these methods did not just provide the existence of MA and its presentation over time during an intervention, but also gave some insights into the confidence, self-efficacy, and knowledge in this group of future teachers. The principles of critical inquiry included the interaction of current knowledge, personalising the knowledge and using equity and inclusion to transform and change (Jaworski, 2006). Using PedAR I was able to alter my pedagogy to model for them a mastery approach which gave an alternative to teaching using just a traditional approach. The data was analysed by coding, thematic analysis and assisted using transcription software which is described in the next chapter – chapter 4 data analysis.

4.Data Analysis

4.1 Analysing action research

There are several ways in which action research can be analysed and various authors have proposed multiple stages in AR (Bassey, 1998; Cohen et al., 2018). Finch and Mason (1990) identified distinct principles concerning analysis of data in the research process and stated that analysis is constantly taking place, which forms the basis for decisions about strategies. In this project, analysis was constantly taking place as the progress and teaching of the students remained the main priority and could not be compromised due to the research project. The preliminary forms of data analysis form the basis for later decisions to ensure they are situated and informed (Burgess et al., 2006), and the presence of MA formed the basis for the research. Decision making while collecting data should modify and sharpen the theoretical underpinnings grounded in data and is part of the PedAR process. Flexibility is needed during the research to encourage explanation and purpose behind the decisions, and this was evident in the second block of teaching. The process followed was aligned to Figure 6 (adapted from Arnold, 2016) where the problem was MA and the intervention and reviews were mastery pedagogy teaching. The discussion below outlines the methods used to analyse the data which emerged from the action research project. The quantitative and qualitative data were analysed separately and then integrated to arrive at the findings.

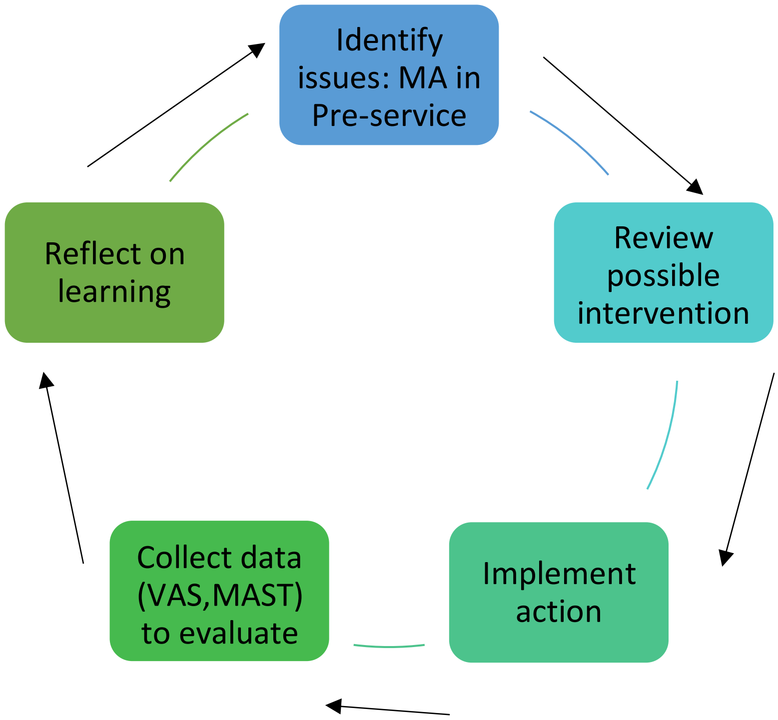

Figure 6 The process of identifying the issue and reflecting on the process. (Adapted from Arnold, 2016)

4.2 Parallel analysis and integration of the data

Following Onwuegbuzie and Collins (2007), data analysis followed a parallel mixed methods approach where the quantitative and qualitative data was analysed separately and then integrated to answer related aspects of the research question.

The respective sets of data are reported separately, and integration took place at the discussion stage (See Figure 7), so that analysis proceeded by focusing on answering questions by the appropriate data set, with the qualitative data used to enhance the interpretation of the quantitative data. The focus of the analysis was to understand the impact of the pedagogy of mastery versus teaching as usual, and any difference before (T1) and after (T2) the intervention on student teachers' anxiety and anxiety associated with teaching mathematics. The quantitative part of the study was dominant with the qualitative informing the teaching and then playing a key role in the final analysis.

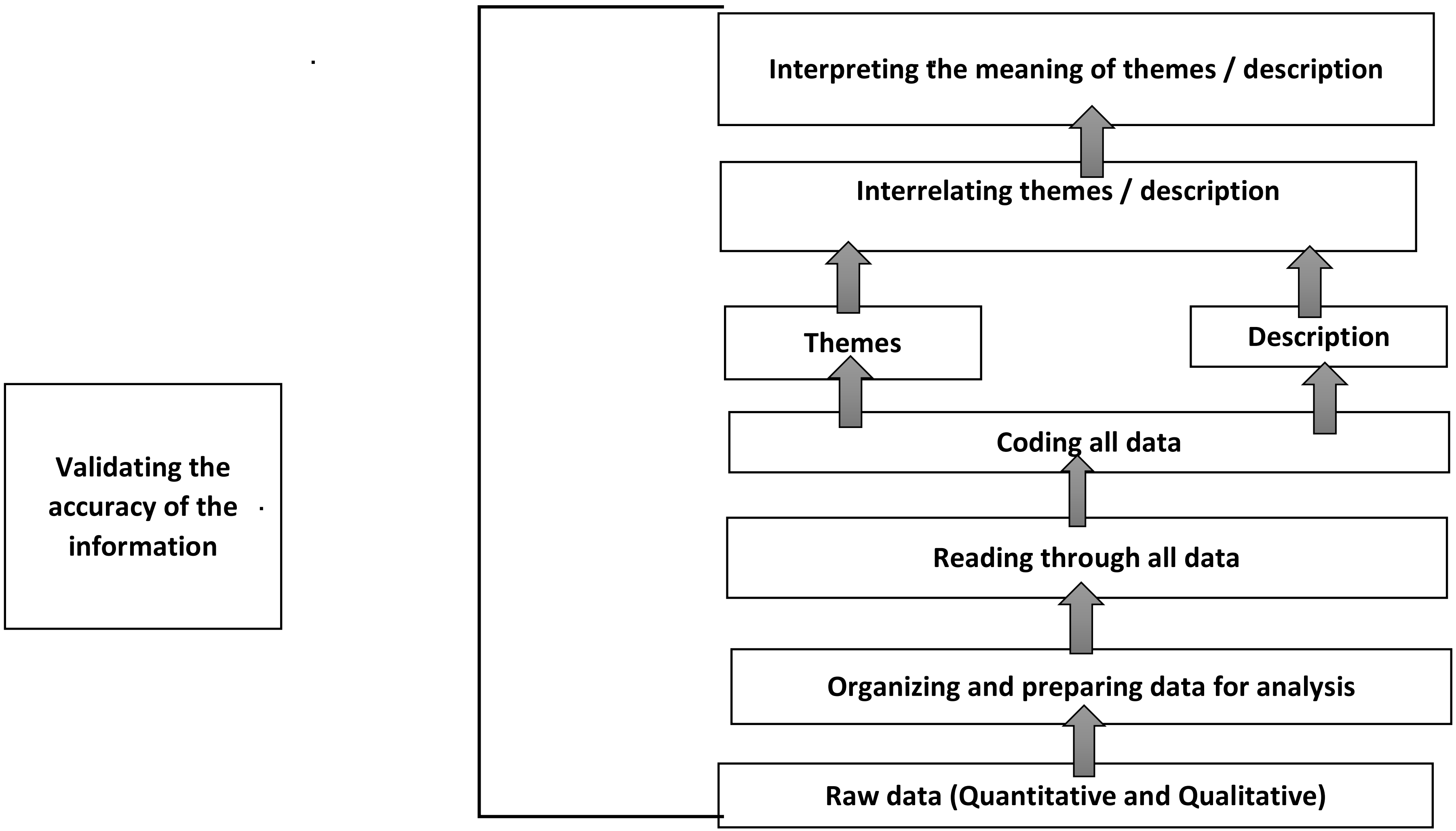

Figure 7 Data analysis in qualitative research (Creswell, 2009: p.185)

4.2.1 Exploring group differences in mathematics anxiety and anxiety about teaching mathematics before (T1) and after (T2) teaching

At Time 1 (T1) there were 111 participants across four classes; 57 in Group 1 (MP intervention group) and 54 in Group 2 (TAUP). SPSS software highlights that the statistics calculated for each analysis are based on the cases with no missing or out of range data for any variable. T1 calculations are therefore based on 109 participants, as there were two participants who did not fully complete the questionnaires and there were several data fields missing. Both participants were in the TAUP group, and their incomplete submissions were removed, which reduced the T1 numbers to 57 (MP group) and 52 (TAUP group). During the 10 weeks, attendance at class reduced and was particularly poor towards the end of the intervention which was just before the Christmas break. The final MAST questionnaire (T2) had fewer responses than the initial questionnaire (T1). At T2 this number had reduced to 81 participants: 50 in group 1 (MP) and 31 in group 2 (TAUP).

4.2.2 Student-reported anxiety at Time 1

Table 1 shows the mean scores at Time 1 and Time 2 for the two groups MP and TAUP. Table 2 shows the division of this information by gender. Preliminary analysis looked at Time 1 (pre-teaching experience) anxiety scores to explore associations between mathematics anxiety and anxiety about teaching mathematics. In addition, it considered whether Time 1 scores were different between groups and gender.

Considering the association between mathematics anxiety and anxiety about teaching mathematics, the analysis showed that at T1 these two measures were positively associated ($r = .75$, $p < .001$), indicating that students who reported increased self-reported symptoms of mathematics anxiety also reported more self-reported anxiety about teaching mathematics (see Figure 8).

Further analysis considered whether there was a difference in group or gender between groups at T1 for mathematics anxiety, and anxiety about teaching mathematics (see Table 2). Considering mathematics anxiety, a two group (MP versus TAUP) and two gender (male versus female) analysis using a repeated measures ANOVA showed a main effect for gender ($F(1,108)=9.709$, $p<.002$). This showed that females self-reported more mathematics anxiety compared with males, (see Table 2). There was no main effect of group ($F(1,108)=0.00, p=.984$) and no interaction between group and gender ($F(1,108)=.781$, $p<.05$), suggesting that there were no differences in mathematics general anxiety between groups, and that within both groups females reported more anxiety compared with males.

Considering anxiety about teaching mathematics at T1, the analysis similarly showed a main effect of gender ($F(1,108)=11.720$, $p<.001$), with females self-reporting more anxiety about teaching mathematics compared with males, (see Table 2). There was no main effect of group ($F(1,108)=0.005$, $p=.947$),or an interaction between group and gender ($F(1,108)=.074$, $p=.786$), indicating that anxiety about teaching mathematics did not differ between groups, and that within both groups females reported more anxiety about teaching compared with males.

Table 1 Means and standard deviations (SD) for self-report mathematics anxiety, and anxiety about teaching mathematics at T1 and T2 for the mastery pedagogy (MP) and the teaching as usual pedagogy (TAUP) groups separately and combined.

		Mastery Group (MP)		Teaching As Usual Group (TAUP)		Both groups	
Measures	N	Mean	SD	Mean	SD	Mean	SD
Mathematics Anxiety							
Time 1	57	23.75	8.94	24.65	9.28	24.18	9.07
Time 2	50	23.82	8.61	26.74	8.02	24.94	8.46
Teaching anxiety							
Time 1	52	18.93	5.69	19.02	5.93	18.97	5.78
Time 2	31	18.52	5.11	19.84	5.27	19.02	5.18
Total anxiety (Calculated by adding the means for each group in each block - Total anxiety 1 = MA 1 + TA1 and repeat for each group and time).							
Time 1	109	42.68	13.87	43.67	14.17	43.16	13.95
Time 2	81	21.17	5.89	22.81	6.0	21.8	5.95

Table 2 Means and standard deviations (SD) for self-report mathematics anxiety, and anxiety about teaching mathematics at T1 and T2 for the mastery pedagogy (MP) and the teaching as usual pedagogy (TAUP) groups between gender.

	Mastery Group (MP)				Teaching As Usual Group (TAUP)				Both Groups			
	Male (N: T1 =13; T2=9)		Female (N: T1=44, T2=41)		Male (N: T1=12, T2=6)		Female (N: T1=40, T2=25)		Male (N: T1=25, T2=15)		Female (N: T1=84, T2=66)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Mathematics Anxiety												
Time 1	20.31	7.72	24.77	9.10	18.5	8.01	26.5	8.91	19.44	7.75	25.6	9.0
Time 2	18.67	5.15	24.95	8.85	23.00	7.43	27.64	8.03	20.4	6.3	25.97	8.58
Teaching anxiety												
Time 1	15.85	4.26	19.84	5.78	15.42	6.17	20.1	5.49	15.64	5.16	19.96	5.61
Time 2	15.67	3.43	19.15	5.32	17.33	4.08	20.44	5.41	16.33	3.66	19.64	5.30

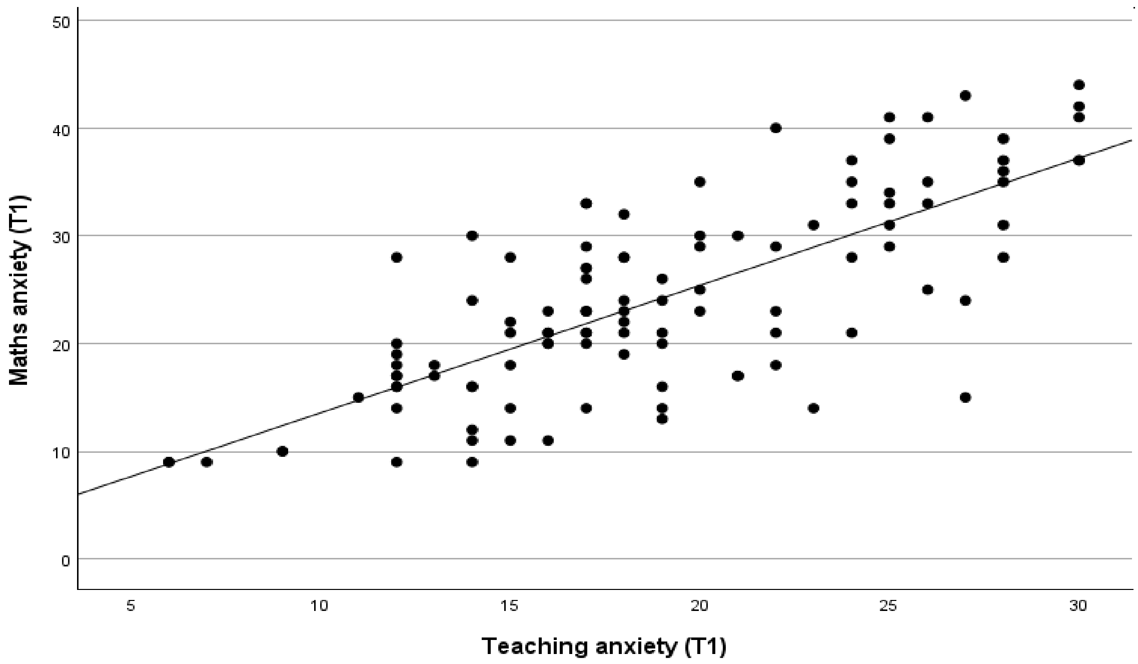

Figure 8 Graph showing the association between anxiety of teaching mathematics and general mathematics anxiety at T1

4.2.3. Comparing T1 and T2 scores on mathematics anxiety and anxiety about teaching mathematics between groups

Analysis explored whether student reports of mathematics anxiety, or anxiety about teaching mathematics decreased for the MP group compared with the teaching as usual (TAUP) group. Any interactions between group and time were explored using planned comparisons that focused on within group differences across time. In these analyses, the p-value was adjusted to address multiple comparisons ($p < .025$).

A repeated measures ANOVA for two Group (MP versus TAUP) and two Time (T1, T2) was carried out to explore potential change in generalised mathematics anxiety between T1 and T2 for each group This analysis showed no main effect of time ($F(1,79) = .02$, $p = .89$) or group ($F(1,79) = 1.79$, $p = .19$), see Table 1. The time by group interaction was also non-significant ($F(1,79) = .44$, $p = .51$). The results indicated that student self-reported mathematics anxiety did not change over time for either group (see Figure 9).

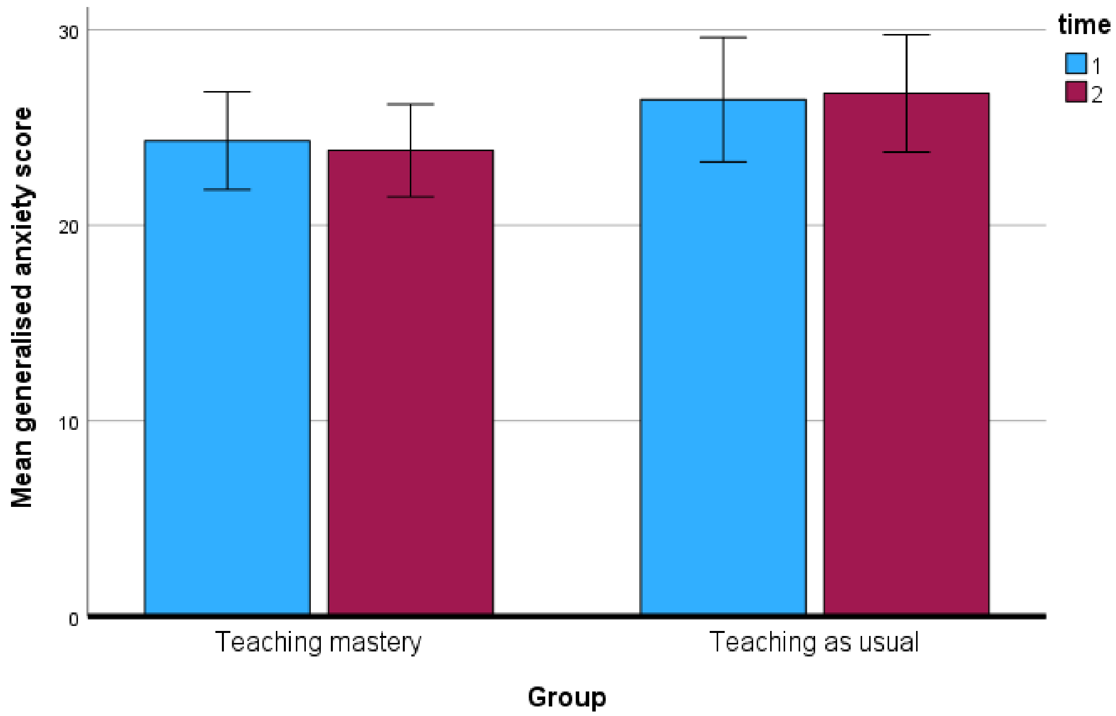

Figure 9 T1 and T2 generalised mathematics anxiety between the two groups

A repeated measures ANOVA for two Time (T1, T2) was carried out to explore potential change in anxiety about teaching mathematics between two Group (Mastery versus TAUP). This analysis showed no main effect of time ($F (1, 79)=1.16$, $p = .28$) or group ($F(179)= .958$, $p = 0.331$). The time by group interaction was also not significant ($F(1,79)=.169$, $p=.682$). The results indicate that student self-reported anxiety about teaching mathematics did not change over time for either group (see Figure 10).

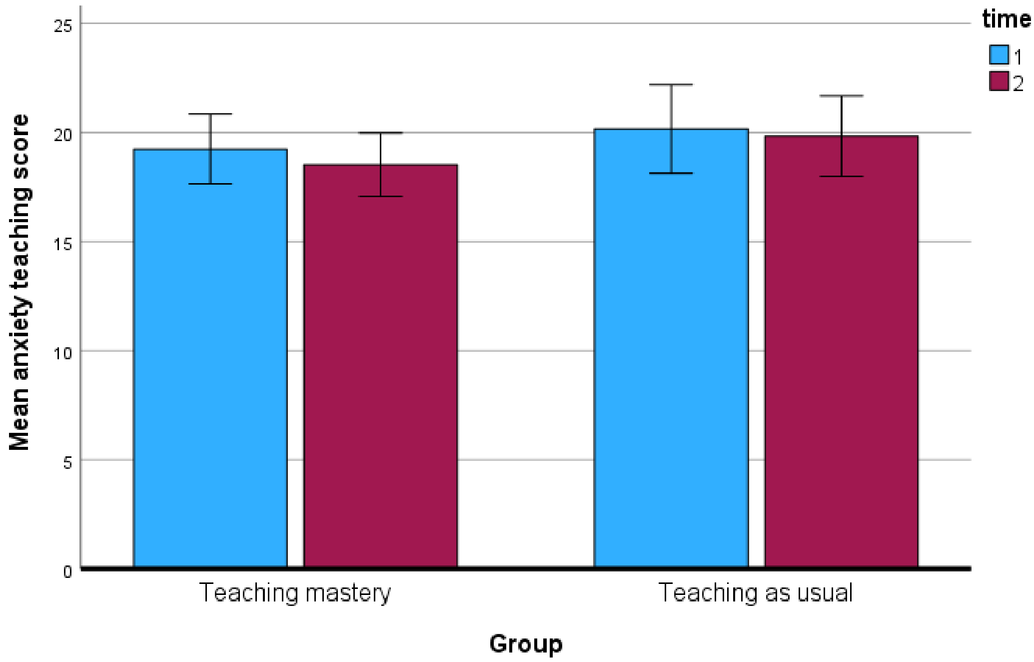

Figure 10 Anxiety about teaching Mathematics for each group and at each time point

4.2.4 Understanding change in the learner experience during teaching

It was anticipated that there should be increased positive change across the ten teaching weeks in the MP group versus TAUP group with respect to student self-reported efficacy, anxiety, attention, and motivation, as measured by the VAS

N=109 students were asked to complete the 12-item VAS scale after each of the ten teaching sessions in both the MP and TAUP groups. Analysis focused on mean VAS scores (mastery, anxiety, attention, and motivation) following teaching in the first five teaching weeks (Block 1) compared with the mean score in teaching weeks six to ten (Block 2) for each group. It was anticipated that the

MP group would show positive change between Blocks 1 and 2, and this change would be less evident in the TAUP group. Further analysis considered whether mathematics anxiety and generalised anxiety questionnaire scores students completed before teaching were associated with mean VAS scores in Blocks 1 and 2. Individual VAS scores in each of the ten weeks are also presented in Tables W for the MP group and Table X for the TAUP group for descriptive purposes (in Appendix 7).

Across each of the four VAS scales positive change would be reflected in lower anxiety scores in Block 2 compared with Block 1, and higher scores in mastery, motivation, and attentional control between blocks. It was anticipated that every participant would be included in all analyses, however, attendance and associated completion of the VAS scale at the end of each teaching session was variable between students, and lower overall in Block 2 compared with Block 1. The total mean number of VAS scales (out of 10) completed across the ten teaching sessions was 6.96 (SD=2.30, range=0-10). The mean number of sessions completed in weeks 1-5 (Block 1) was 3.81 (SD=1.20, range = 0-5). The mean number of sessions completed in weeks 6-10 (Block 2) was 3.16 (SD=1.45, 0-5).

4.2.5 Exploration of attrition and anxiety

There was a significant level of attrition in this study. Analysis considered whether there was a relationship between student attendance in lessons and self-reported anxiety and anxiety about teaching before the study started. Considering heterogeneous attrition, in which the attrition effect is different for separate groups it is notable that attendance in the MP group decreased from 57 to 50 students from the first to the final week of the data collection. In contrast, attendance in the TAUP group decreased from 52 to 31 students.

Considering differential attrition, the factor under consideration was whether the attrition was higher amongst students who were already mathematics anxious. Exploration of the relationship between attendance and anxiety before teaching started showed that generalised anxiety or anxiety about teaching mathematics was not associated with the number of lessons attended in either group.

Figure 11 shows that there was no significant association between attendance and generalised mathematics anxiety for either the MP (r =0.070) or the TAU (r =0.046.) groups . Figure 12 shows that there was no significant association between attendance and anxiety about teaching mathematics for either the MP (r =0.108) or the TAU (r =0.069)groups.

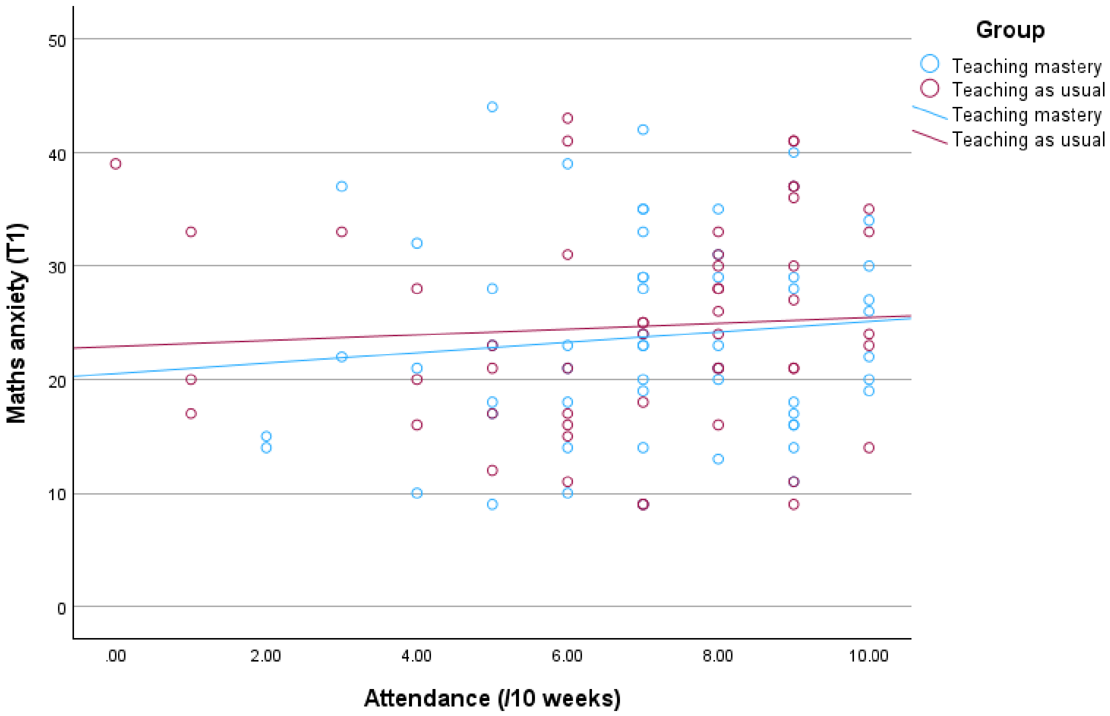

Figure 11 between attendance and mathematics anxiety in the mastery pedagogy and teaching as usual groups at time 1 (T1; before teaching began)

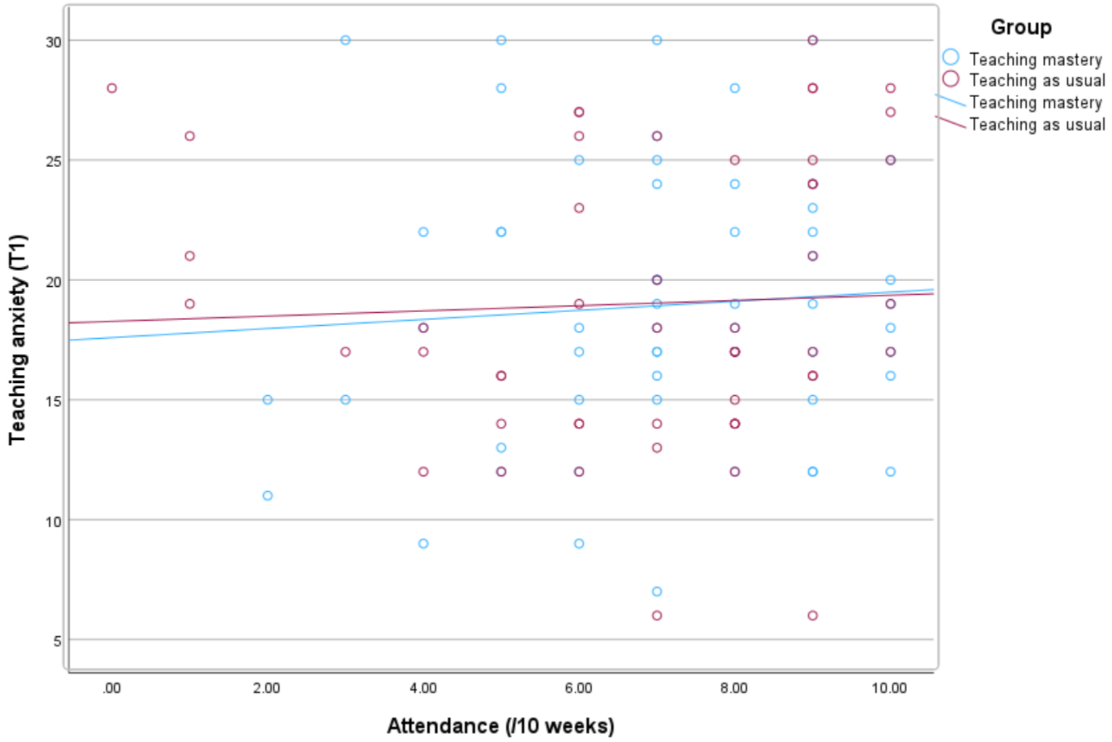

Figure 12 Association between attendance and anxiety about teaching in the mastery pedagogy and teaching as usual groups at time 1 (T1; before teaching began).

To address issues with attrition in the analysis and to ensure that students had experienced mastery teaching for most teaching weeks, the primary analysis focused on students who completed at least 4 (4 or 5 /5) VAS scales in both blocks (i.e., in weeks 1-5 and 6-10). This analysis included 39 /109 students, 19 students in the MP and 20 students in the TAUP group.

Secondary analyses presented in Appendix 7 included N=68 students who completed at least 3 (3 or 4 or 5 /5) VAS scales in both blocks, 34 in each of the mastery and TAU groups. The final analysis looked at the N=94 students who completed at least 2 (2 or 3 or 4 or 5 /5) VAS scales in weeks 1-5 and weeks 6-10, n=57 in the mastery group and n=52 in the TAU group. Analyses therefore included three separate repeated measures ANOVAS for two Group (Mastery, TAU) and two Block (Block 1, Block 2), for each mean VAS score (mastery, anxiety, attention, motivation). (12 in total; see Table 3). Primary analyses are presented below (Table 3).

The mean VAS scores primary and secondary data

Table 3The mean visual analogue scale VAS mastery, anxiety, attention, and motivation scores for primary and secondary data (students who respectively completed at least 4, at least 3 or at least 2 teaching sessions) in Blocks 1 and 2 for the mastery pedagogy (MP) and teaching as usual pedagogy (TAUP groups

VAS scales	Primary analysis (N=39)				Secondary analysis 1 (n=68)				Secondary analysis 2 (n=94)			
	Mastery (n=19)		TAU (n=20)		Mastery (n=34)		TAU (n=34)		Mastery (n=49)		TAU (n=45)	
	Block 1 Mean (SD)	Block 2 Mean (SD)	Block 1 Mean (SD)	Block 2 Mean (SD)	Block 1 Mean (SD)	Block 2 Mean (SD)	Block 1 Mean (SD)	Block 2 Mean (SD)	Block 1 Mean (SD)	Block 2 Mean (SD)	Block 1 Mean (SD)	Block 2 Mean (SD)
Mastery	63.53 (10.17)	68.25 (15.26)	73.64 (14.25)	72.29 (16.09)	64.07 (10.76)	66.57 (15.1)	73.66 (13.76)	72.83 (16.06)	62.47 (10.19)	65.37 (13.84)	73.61 (14.23)	75.31 (16.25)
Anxiety	32.23 (11.58)	30.18 (16.85)	32.49 (20.19)	32.06 (19.65)	30.77 (12.2)	31.78 (17.54)	31.74 (19.84)	29.23 (20.46)	31.93 (13)	32.84 (17.24)	33.36 (18.72)	28.10 (19.85)
Attention	75.03 (10.93)	75.30 (14.44)	82.09 (13.01)	82.19 (13.32)	76.81 (11.7)	76.18 (14.53)	81.82 (12.23)	83.27 (12.31)	75.30 (11.87)	74.71 (13.48)	80.51 (11.49)	83.11 (11.96)
Motivation	72.34 (9.27)	72.18 (15.72)	80.60 (14.0)	77.23 (15.51)	74.02 (10.64)	71.88 (16.36)	81.32 (12.61)	78.42 (15.72)	74.09 (10.47)	71.59 (14.89)	78.64 (13.05)	78.73 (14.92)

4.2.6 Primary analysis for VAS scores in Blocks 1 and 2: Students who completed at least 4 VAS scores in each block

Mastery VAS scores. Considering the primary analysis, where students completed 4 or 5 sessions in each block. Analysis for mastery scores showed no effect of Group (F(1,37) =2.74, p=.11) or Block (F(1,37) =1.27, p=.27), indicating that there was no difference in mean mastery VAS scores between groups, or between blocks 1 and 2.

The interaction between Group and Block approached significance (F(1,47)=4.32, p=.05) meaning that there is a 95% probability that the results found in the study are the result of a true relationship/difference between groups being compared. Planned comparisons found that while the MP group showed significant positive change between blocks (p=.022), this difference was not evident for the TAUP group. The mean mastery VAS scores and standard deviations for the MP (n=19) and TAUP (n=20) groups for students who completed at least 4 teaching sessions in Block 1 and Block 2 are shown in Table 3 and Figure 13.

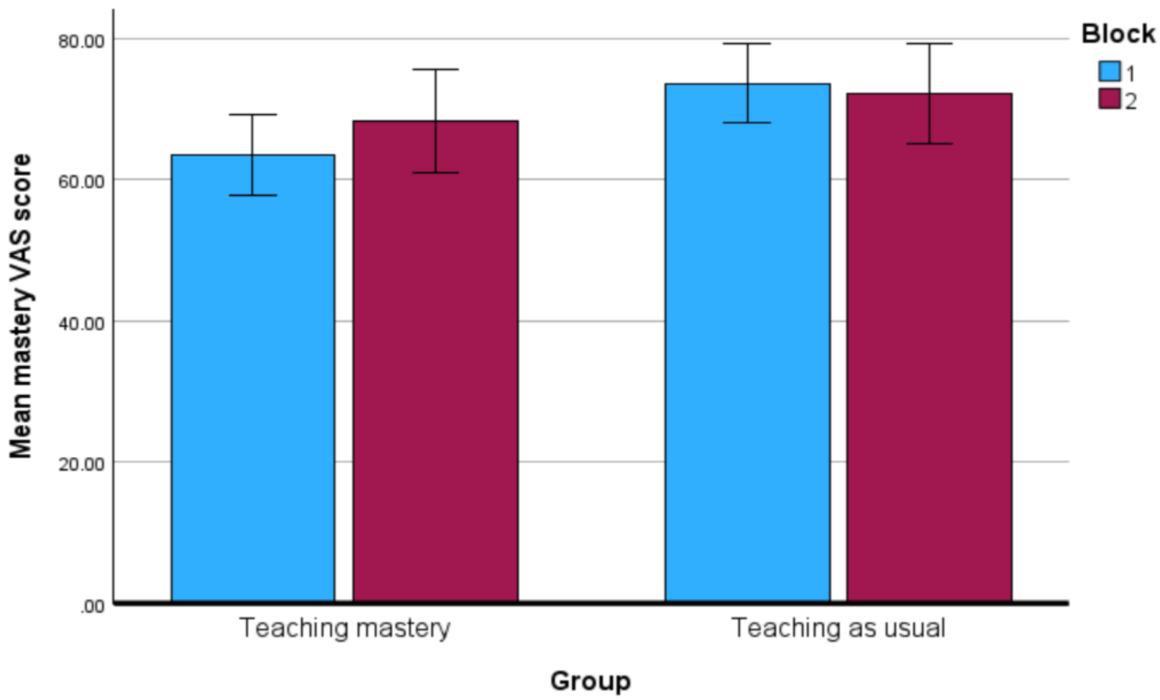

Figure 13 The mean mastery VAS scores and standard errors for the Mastery (n=19) and TAU (n=20) groups for students who completed at least 4 teaching sessions in Block 1 and Block 2.

Anxiety VAS scores. Considering the primary analysis, where students completed 4 or 5 sessions in each block, analysis for anxiety scores showed no effect of Group ($F(1,37) = 0.042$, $p = .839$) or Block ($F(1,37) = .402$, $p = .530$), indicating that there was no difference in anxiety VAS scores between groups, or between blocks 1 and 2. The interaction between Group and Block was also not significant ($F(1,47) = .170$, $p = .682$) (See Figure 14 and Table 3)

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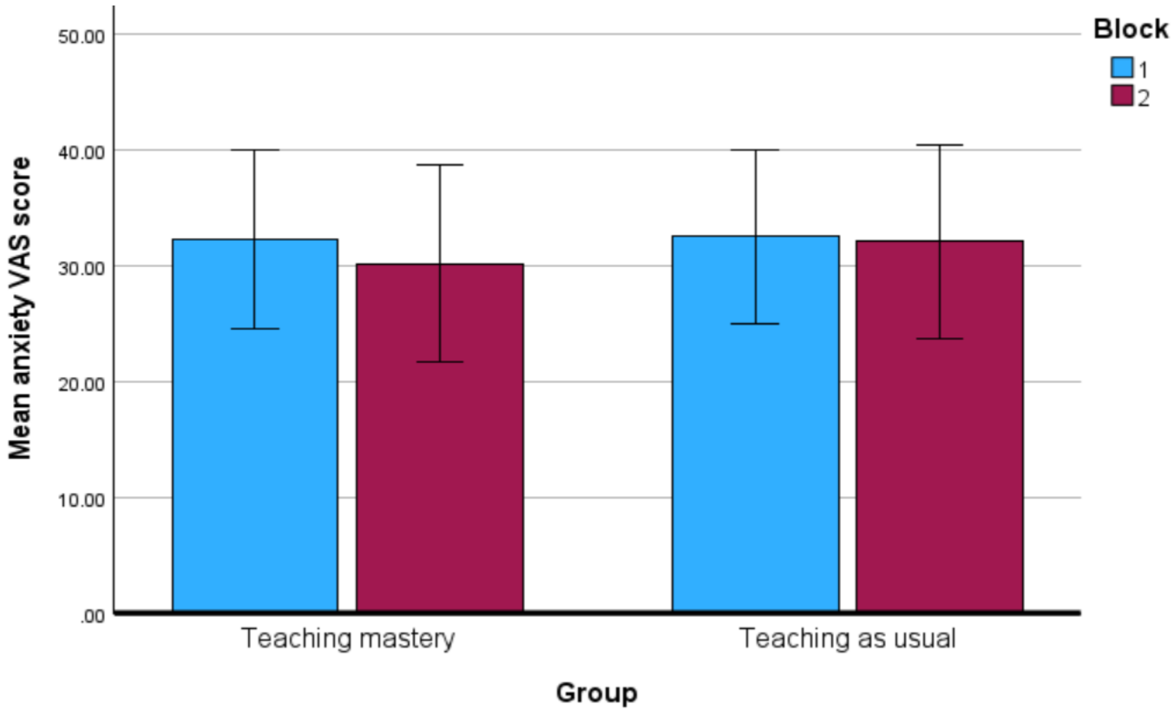


Figure 14 The mean anxiety VAS scores and standard errors for the MP (n=19) and TAUP (n=20) groups for students who completed at least 4 teaching sessions in Block 1 and Block 2.

Attention VAS scores. Analysis for attention scores showed no effect of Group (F(1,37) =3.159, p= .084) or Block (F(1,37) = .017, p=.896), indicating that there was no difference in attention VAS scores between groups, or between blocks 1 and 2. The interaction between Group and Block was also not significant (F(1,47)=004, p=.950), (see Table 3 and Figure 15).

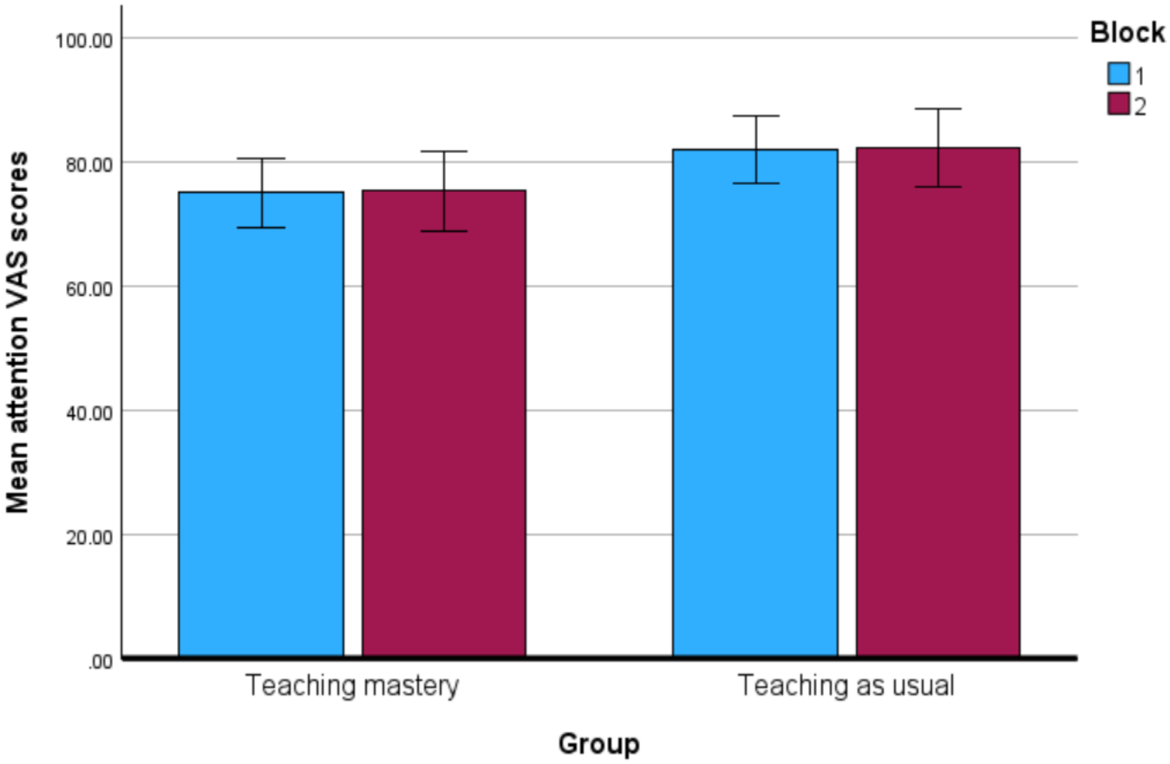


Figure 15 The mean attention VAS scores and standard errors for the MP group (n=19) and TAUP group (n=20) groups for students who completed at least 4 teaching sessions in Block 1 and Block 2.

Motivation VAS scores Analysis for motivation scores showed no effect of Group ($F(1,37) = 2.691$, $p= .109$) or Block ($F(1,37) = .935$, $p=.340$), indicating that there was no difference in motivation VAS scores between groups, or between blocks 1 and 2. The interaction between Group and Block was also not significant ($F(1,47)=.770$, $p=.386$), (see Table 3 and Figure 16).

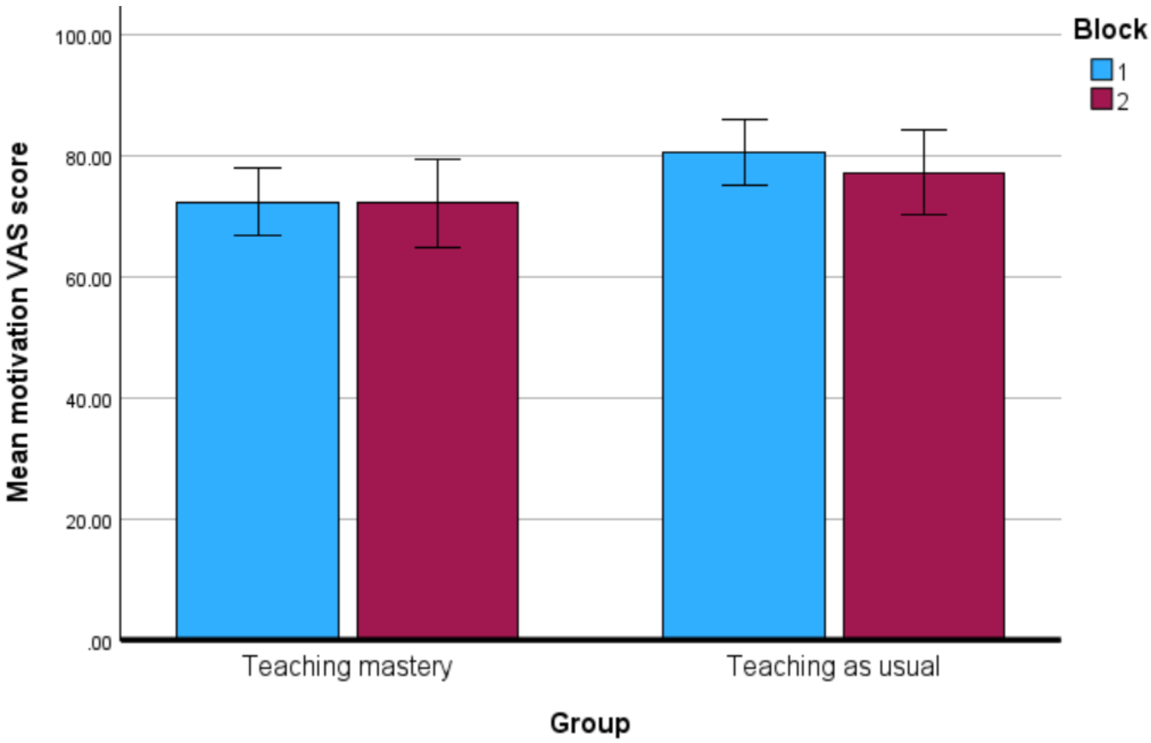


Figure 16 The mean motivation VAS scores and standard errors for the motivation (n=19) and TAU (n=20) groups for students who completed at least 4 teaching sessions in Block 1 and Block 2

4.2.7. Comparing MA and anxiety about teaching mathematics during teaching

Further analysis considered whether students who reported increased feelings of generalised mathematics anxiety or anxiety about teaching mathematics before teaching also reported less mastery and motivation, lower attention, and more anxiety during the teaching itself (as reported in Blocks 1 and 2). A positive correlation is measured on a 0.1 to 1.0 scale. Values > .5 indicate a strong association, those between ±0.30 and ±0.49 a moderate association, and those < .3 a weak association. The stronger the positive correlation, the more likely the association. (Connolly, 2007)

Table 5 shows moderate positive association between Block1 generalised mathematics anxiety and teaching mathematics with mastery / perceived subject knowledge and a moderate negative association with anxiety. The association between Block 1 generalised mathematics anxiety and teaching mathematics with motivation was small but significant. Links between Block1 generalised mathematics anxiety and teaching mathematics with attention was not statistically significant. In addition, Table 4 indicates that the associations were similar when looking at links between pre-intervention anxiety and student reported experience during teaching for Block 1 or Block 2. Appendix 7 shows the data separately for each group, highlighting that the associations were consistent between both the MP and the TAUP groups.

Table 4 Pearson's correlations between generalised mathematics anxiety and anxiety about teaching mathematics with mastery, motivation, attention and anxiety during the teaching itself in Blocks 1 and 2.

	Visual analogue scale							
	Mastery		Anxiety		Attention		Motivation	
	Block 1	Block 2	Block 1	Block 2	Block 1	Block 2	Block 1	Block 2
Generalised mathematics anxiety	-.30**	-.37***	.52***	.42**	-.86	-.18	-.21*	-.24*
Teaching mathematics anxiety	-.31**	-.39***	.46***	.43***	.18	-.17	-.26**	-.28**

*p<.05, ** p<.01, ***p<.001

4.2.8 Summary of the Quantitative data

The main aim of this analysis was to consider the difference between the two teaching groups over a 10-week intervention and to consider the student experience in learning via weekly differences in the four constructs. The analysis showed that when comparing group differences for each construct between Time 1 and Time 2, the results do not show any statistically significant changes across the block of teaching. There was some indicative data which showed a positive change in feelings of mastery between blocks in the MP group, which was not evident in the TAUP group.

4.3 Approach to data analysis (Qualitative)

The process of thematic analysis involved a series of stages, following the model for thematic analysis set out by Braun and Clarke (2006), that comprises familiarisation with the data, generating initial codes, searching for themes, reviewing potential themes, defining, and naming the themes and producing the report. Creswell (2009: p.185) noted that 'preparing the data for analysis, conducting different analyses and moving deeper into understanding' is like ‘peeling back the layers of an onion’ for qualitative researchers and a step-by-step approach is useful.

Koshy (2015) advises that there is no single way for analysing qualitative data but for the data analysis to be effective, there is a need to be systematic. Familiarisation with the data occurred many times as the initial information was collected, it was considered prior to uploading it to the transcription software and continuously re-read during transcription to check for accuracy. After familiarisation, the data was assigned codes in the Quirkos analysis software (Quirkos 2021). The codes were systematically reviewed and grouped to create themes. The naming of the themes was also a systematic process which is described in the next section. Although Norton (2019) suggested that using digital tools for qualitative analysis may separate the researcher from intimately interacting with the material, I found that the process encouraged familiarisation and intimate interaction rather than preventing it.

4.3.1 Familiarisation, Coding and Defining Themes

Transcription was assisted by using Otter.ai (Otter 2020) software which is a transcription application using artificial intelligence and machine learning to develop speech to text. Otter.ai (2020) turns voice conversations into notes, and Otter software was used to transcribe student interviews. Whilst no transcription tool is perfect, Otter.ai (2020) takes about five to six minutes to transcribe a 15-minute audio file and all transcripts were checked and adjusted to address minor inaccuracies. The transcripts were then uploaded to an online software for coding called Quirkos (2021). Quirkos (2021) is a software package for the qualitative analysis of text data. It provides a graphical interface for the themes of analysis and ‘to identify areas of similarity’ (Braun & Clarke, 2012: p.63). Quirkos (2021) was chosen as it is a simple to use, graphical software programme to assist with qualitative analysis. Colour coding is used so key phrases become distinguishable and allow recurring codes to be identified, collected, and grouped.

The security in Quirkos (2021) ensures that not only is it password protected but it encrypts research projects using end to end encryption. Quirkos

(2021) is limited to text only data and it does not support multimedia, audio, or video data; thus my recorded interviews had to be read, transcribed, and re-read checking for accuracy before uploading. Quirkos (2021) has limited use for statistical analysis, therefore it accepts text data in a narrative form without any quantitative values added or coding done. It is designed for smaller scale projects which use dozens rather than hundreds of sources, although it may have limited feature sets, it is flexible with data sets, and it is compatible with other data analysis programmes (Quirkos, 2021). My college had recently invested in this software, so it was readily available, and for my small number of interviews, ease of use and variety of data retrieval formats, I considered it suitable for the qualitative part of my analysis.

4.3.2. Analysis of the interviews

The nature of the Quirkos (2021) software permitted combining codes to form new themes and create a visual representation to illustrate which were most common or reoccurring and thus was helpful in considering the students comments and grouping them into the appropriate themes.

The transcripts were analysed to determine what changes to the teaching were suggested or implied (see Appendix 4, Question 6). Individual sentences were initially colour coded in Quirkos (2021) according to my interpretation of their meaning. Often a sentence was assigned to more than one code, because it had overlapping meanings. as it may have applied to more than one area. For example, students reporting negative feelings about mathematics often also reported feelings of MA and those who reported confidence in their mathematics ability often reported positive feelings about mathematics. Such statements were assigned more than one code. Altogether sixteen codes emerged during this stage of the analysis. Similar codes were then grouped into five themes as an efficient means of accounting for all the data. For example, code A more manipulatives, code B hands on activities, and code F active learning, were all grouped to form the theme of Practical Classes. The themes and contributing codes are presented in Table 5 and discussed further in the next subsection.

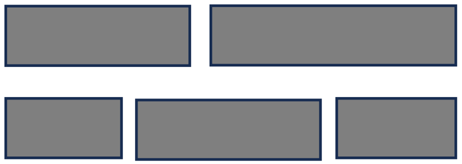
1. Divide data into sections	2. Identify patterns	3. Define codes	4. Identify themes
 Data was read and transcribed. It was then uploaded into Quirkos and reread sentence by sentence. In the context of the sentence the various pieces of data were assigned to a category. Categories were created and colour coded to correspond to the message in the data.	"More manipulatives, more active, more hands on stuff that's what you want" (participant G). "Make sure you've got the hands on first before you move too quickly to the abstract." (Participant I). "Sometimes the PowerPoints can be quite confusing" (Participant A), "Give us more time to engage in practice, the mastery approach" "ways to bring it into my lesson and more ways of like applying it to say a Key Stage one classroom and then how to apply it to a key stage two" (Participant F). keep up with the practical aspect of the class, definitely give us more time to, engage in practice, see videos or examples of the mastery approach,(Participant E)	Code A: More manipulatives Code B: Hands on activities Code C: Application and transfer Code D: Teacher modelling Code E: Slow down the rate Code F: Active learning Code G: Explain the Jargon Code H: Revision of last week's activities Code I: Break the information down Code J: Explain new terminology Code k: Use videos of actual teaching Code L: More repetition needed Code M: more time for context Code N: More revision time needed to learn and practice Code O: Practical demonstrations Code P: Mindset	**Theme 1 – Practical classes** Code A: More manipulatives Code B: Hands on activities Code F: Active learning **Theme 2 – Class Context** Code D: Teacher modelling Code k: Use videos of actual teaching Code C: Application and transfer Code O: Practical demonstrations **Theme 3 – Time** Code E: Slow down the rate Code M: more time for context Code N: More revision time needed to learn and practice **Theme 4 – Language** Code G: Explain the Jargon Code J: Explain new terminology Code P: Mindset **Theme 5 – Recap and Revision** Code H: Revision of last week's activities Code L: More repetition needed Code I: Break the information down

Table 5 Coding from Quirkos software using the model adapted from Braun and Clarke (2012)

4.3.3 Examples of codes developing into themes

Some students said they would like increased use of manipulatives / practical resources (coded as manipulatives / pink) in class, more active lessons (active learning coded in purple), and more practical activities (practical activities coded in blue) :(See table 6). "More manipulatives, more active, more hands-on stuff that's what you want" (participant G). This was coded under manipulatives and under practical activities. "Make sure you've got the hands on first before you move too quickly to the abstract." (Participant I).

These codes of manipulatives, active learning, active lessons, and practical activities were all grouped together to form the main theme of 'Practical classes. Similarly, when students stated that they would like to see more teacher modelling, more videos, transfer of information to the class context and more classroom application of the approach, these ideas were grouped under the theme of 'class context.' Exemplars of this theme included the following: "I'd say make it a little bit more context embedded," (participant A) "ways to bring it into my lesson and more ways of like applying it to say a Key Stage one classroom and then how to apply it to a key stage two" (Participant F).

Some of the students referred to having more time to work through activities, additional sessions in mastery or the timing of each segment and this was listed under the theme of 'time.' For example, "Give us more time to engage in practice, the mastery approach" (Participant E). As mastery was an original approach for the students, several expressed a need to understand the terminology, jargon and concepts, these ideas were grouped together under 'language', "Sometimes the PowerPoints can be quite confusing" (Participant A), "Sometimes I need things explained to me more than once" (Participant H).

As the concept of mastery pedagogy was new, some students stated that they would need to revisit some of the teaching in their own time or would like a recap at the start of each lesson and I have called this theme 'recap'. "I have to take time out and I have to break it down" (participant H).

Overwhelmingly, the areas which students requested were an increase in the use of practical activities (including the use of manipulatives and active learning) and an increase in practical application to include either modelling or seeing the teaching in context through video or discussion. Other themes which were used to change the teaching, and which came from the interviews included doing a recap at the start of the lesson of the main teaching points, allowing more discussion time and simplifying the mathematical language.

4.3.4. How the analysis informed teaching

As the second block of teaching was influenced by the changes made due to the interviews, and both blocks were measured via the VAS scales, it is important to understand how the first block of teaching was different from the second and thus yielded changes in the data.

Students generally reported in the interviews that although they understood their own subject knowledge better, they did not feel confident in how to apply this to their teaching. They wanted to increase their confidence to teach the topics and to decide if using mastery principles was the best way for them to do so. The student's request for more active learning and less theory occurred as they were now familiar with the structure and concept of mastery. As mastery pedagogy was a new approach for them, initially there was a period of adjustment and understanding, and the first few weeks necessitated a certain amount of theory, whereas it was now timely that the second block could focus more on classroom implementation and lesson structure as the students requested from the interviews. Indications from the quantitative data suggest that the students in the MP group started from a lower level of confidence than the TAUP group as they were aware they were following something new. It was outlined to them at the beginning of the study that they would be following a different pedagogy and were given the option to change teaching groups if they wished. None did however and they stayed in the group which was following the mastery pedagogy. In the second block of teaching when the changes outlined occurred, their anxiety decreased, and mastery increased.

4.3.5 Practical activities

As some students stated that they would like more time for practical activities, it was important that students came to class prepared and a 'flipped classroom' model was further refined to allow more time in class for activities to enable the students to develop familiarity with the new pedagogy. Following on from their interview suggestions, each week the thinking and theory behind the teaching along with sample videos of the application of the topic was sent out. This ensured that those students who wished to read or view information about the topic could prepare before coming This was developing my pedagogy alongside that of the students as I was adapting and learning to provide a model of teaching which fulfilled their needs. Each week the conceptual understanding was sent out with the links to reading, theory and other areas of Numeracy which ensured I focused carefully on the conceptual requirements of each topic.

In the mastery approach, procedural fluency and conceptual understanding are developed in tandem because each supports the development of the other (see chapter 2 figure 2). The prior experience of the students in numeracy and my own previous experiences were focused mostly on procedural learning. As mastery was a new pedagogy and the students were unfamiliar with the structure of the lessons, the theory behind mastery and the format, these factors contributed to the first block of teaching being quite explanatory and theory driven however, considering the feedback from the interviews, the second block involved more interaction, discussion, and practical activities. The students were given the opportunity to develop mastery and confidence by practically applying the theory and the lesson structure.

4.3.6 Context and language

The skills required to be able to understand the concepts presented were also discussed. Students had requested in the interviews that they would like to see the learning in context; how mastery would apply to their teaching in school and for them to see it working. This was done through a variety of media including reading, video demonstration and podcasts. In the second block of teaching, the sessions were designed to follow the mastery pedagogy more closely where the teacher leads back and forth interaction, including questioning, short tasks, explanation, demonstration, and discussion, enabling pupils to think, reason and apply their knowledge to solve problems (NCETM, 2022), as the students were now more familiar with the theory and were ready to implement strategies with developments from their suggestions for change.

Students reported that the new terminology and language was something they had not experienced previously as mastery required them to use precise mathematical language to communicate their reasoning and thinking effectively. In addition to becoming familiar with this language themselves, they needed to develop their confidence in ensuring they could explain it appropriately in their teaching and encourage children to use appropriate mathematical language. Using the appropriate, specific mathematical language ensures that confusions are eliminated and there is a clearer understanding. Developing mathematical language is one of the principles of mathematics mastery and an important skill for the student teachers to develop.

4.3.7 Revision and revisiting

In Block 2, the lessons started with a short revision of the materials that had been sent out for preparation and a cursory discussion to clear up any misunderstandings or explain terminology which was not understood or may have caused confusion. This was in response to the student request from the interviews, but also to facilitate the 'flipped learning' model and aligned to Bruner's spiral curriculum (1960) and Ebbinghaus's forgetting curve (Murre & Dros, 2015).

An obvious shift was occurring which became apparent in the interviews, as the students were beginning to appreciate that with mastery the focus was no longer about finding an answer to a question but was shifting to explanations of what they did and an appreciation of understanding. Explanation of thinking and understanding became the focus of the lesson rather than a focus on the right answer and the conclusion. For some students this was uncomfortable (2/12), and they were more secure with the formulaic approach, which was the familiar. For most of the student interviewees (10/12), they reported that the innovative approach was starting to become clear, and most were eager to learn more. Even the students who were more comfortable with the traditional approach reported that they wanted to continue with mastery as they had an open mind, and while the style of teaching may not have been the most suitable for them, they acknowledged that not all children learn the same way.

> “I can see why some people might want to stick to the straightforward stuff, but that's what everyone knows. But then I think this mastery stuff could be the way forward just makes everything seem a lot easier. Not that there's one way to do and stuff it allows people to think more outside of the box.” (Participant G).

In summary, the second block of teaching had amendments which were informed by the interviews. These amendments resulted in material being sent out prior to class to allow for more time in class for additional activities, a recap and revision at the start of every lesson and an explanation of the vocabulary and language being used. The lessons included teacher modelling and video demonstrations prior to students engaging in practical activities. The amendments to the teaching were important, not just to improve pedagogy, but to contribute to the students’ knowledge, understanding and the method of instruction.

4.3.8 Linking themes across data sources

There were four constructs under consideration; the student’s own mastery of the subject i.e. their perceived knowledge of the subject, the anxiety levels they experience when doing mathematics activities, their level of attentional control, and their motivation for doing the subject. When considering the four themes from the VAS data; Anxiety, attentional control, mastery or understanding of the topic and motivation, these concepts were included in the interview questions and this information in the interviews was used to strengthen the same themes from the quantitative data.

Regarding ***mathematics anxiety,*** 9/12 of the interviewees reported to having negative feelings about mathematics (Participants A, B,C,E,F,G,H,K,J) ranging from "I am a failure" (Participant C) to "mostly just nervous about it" (Participant A) , and 8/12 used the term "maths anxiety". Of the 9 students who reported negative feelings about mathematics, 6 of them used the term "maths anxious" ("Even as a child I was anxious about it" Participant H) and two others reported anxiety in teaching other subjects as well (example participant C stated "I make everything harder than it is").

All 12 of the interviewees reported increased concentration, ***attention*** and focus but the reasons for this varied; for some it was because it was new and they had to concentrate to understand and learn (participants E,F,H,I); for more it was because they were interested (participants A,C,D,G,J,k,L); and for others it was fear in case they were asked a question and would be embarrassed if they had not been paying attention (Participant B).

Regarding ***mastery*** of the subject, all the participants reported that they felt their subject knowledge had increased, that mastery exposure would change their way of teaching, and their own development was changing. The responses varied from "I've realised that you don't need to make everything completely difficult it can be as simple as it says" (participant C), "I am seeing the different elements of mathematics and I'm starting to click" (Participant F) and Participant H summed it up by saying "It made me feel that I can actually do this".

For ***motivation,*** most of the students reported that they were motivated to learn due to the novel and practical nature of mastery:

"Instead of us just sitting there passively listening. So, I think the practicality of it really does help" (participant K). But some also admitted that for the first two weeks they were not motivated at all as the concepts were new. It was only after they started to understand the thinking of mastery and the practical elements of it that they were motivated to learn: "when we get into class and it is active, it allows us to practise it more and to do it with other people" (Participant A).

All 12 reported positive comments about their experiences to date ranging from "I am really enjoying mastery" (participant C) to "I am a big fan of it" (participant B).

Although it was only after the first 5 weeks of teaching, half of the students (6/12) commented positively about the flipped classroom model and how the use of manipulatives helped promote conceptual understanding and would affect their teaching: "The different materials and manipulatives have really, really changed how I would teach the mastery side of things." (Participant A).

There were also several unexpected statements which came from the interviews, and I had not anticipated in my questions. The first was how a teacher can influence the attitude of a child for a lifetime. While this has been discussed in many research papers (Boaler 2009; Beilock et al., 2010) and was one of the motivating factors for this pedagogical research project, I did not expect to find so many participants recount experiences without being directly asked. 9/12 of the interviewees referred to this factor and reinforced how important it is that a teacher has the right mindset for teaching numeracy and influencing children: "the teacher made a big, makes a big difference to a child" (Participant C) "The whole reason I passed my GCSE was because one of the teachers" (Participant E) "never really had like, had a good teacher" (Participant A)

Another issue which came up in the interviews was the idea of gender and how teachers in mathematics classes in schools often treat boys and girls differently, with different expectations and attitudes: "there was only six girls in my class... the boys never seem to have an issue with it. But I think whenever I was doing mathematics in primary school, that I think I just was kind of brushed it to the side" (participant F). Although this was prevalent in the literature, it was not asked as a direct question, and I had not anticipated that students would discuss it. This reinforces research by Devine et al., (2012) where gender differences made in school can influence long term outcomes.

4.4 Integration and interpretation

Although the main aim of the qualitative data was to inform the teaching for the second block to bring about change, this change takes the form of intervention, as different approaches to the data can raise different theoretical perspectives (Norton, 2004). The qualitative data was considered again at the end of the study as a critical addition to the quantitative data. The integration of the qualitative and quantitative data sets took place post-interpretation of the individual data sets.

To consider the constructs individually, a comparison is made between the group who experiences TAUP and those experiencing a MP. Whilst significance was not always reached from the statistics, some trends started to emerge (see Appendix 7).

The TAUP group started the study with a higher level of self-reported mastery. In discussion this may have partly been contributed by the knowledge that the TAUP had experiences in most of the areas they were going to be taught, whereas the MP group were aware that they were going to experience something new and different which may have caused a lack of confidence. This was reinforced with a comment from participant B: "I suppose as the weeks go on, my maths anxiety would definitely go down and my confidence in my mathematics definitely was up."

Over the course of the study, the anxiety levels in the TAUP group was consistent, however over time the anxiety levels appeared to show a trend towards decreasing for the MP group. Considering attention, over the course of the intervention, the TAUP group remained consistent in this area, whereas there appeared to be an increase in the MP group (See Table 4). The students reported that their focus and attention was initially low due to their uncertainty in a new pedagogy. Consistently, during the interviews, several students report that their attention and focus is increasing as they are becoming more familiar with the structure of the lessons: "I would say I've become a lot more concentrated because I have been a lot more interested in the mastery side of things. So, I'd say that's definitely improved over the first six weeks" (Participant

A); “you keep us involved definitely adds to my focus and obviously keeps me more clued in” (Participant B).

Motivation is another area that the qualitative interviews demonstrated increase over time. Whilst initially the students were uncertain of a new pedagogy and did not understand it, they reported that by week 5-6 they were starting to see the potential in the fresh style of teaching, and they were motivated to learn more about Mastery teaching. “I would say more focused I would say it is down to the fact that I think it's quite interesting in what we're learning” (Participant D), “I'm probably focusing more because I'm actually interested in what's been taught” (Participant G), “the whole idea that there's more than one way to work things, though, doesn't have to be so rigid. Mathematics can be fun, and it can be interactive. There are different ways to do a thing” (Participant J), “I also quite like the idea of being practical so we're not just passively listening. I actually like physically doing things so when you give some of the questions to try ourself” (Participant k), “this year, I really have to focus because it’s so new, but I like the challenge of like, if you miss anything, you could just come be completely confused “ (Participant C).

Norton (2019) cautions that interviewees do not always give honest and unbiased answers when talking face-to-face, comparing the anonymous weekly VAS answers with the interview answers may mitigate this to some degree and I found this a useful way of recapping the data from the interviews.

4.5 Summary

This chapter has presented an analysis of the quantitative and qualitative data generated for this study. The design of the study influenced by Creswell (2009) and the models used for analysis from Braun and Clarke (2006 & 2012) were discussed. The first set of quantitative data analysed was from the MAST questionnaire (Ganley et al., 2019) which was generated pre and post intervention. MA and anxiety about teaching mathematics were considered and these were compared for both groups. A repeated ANOVA measure found there were no significant changes over time in student self-reported anxiety and anxiety about teaching mathematics.

Semi-structured interviews from twelve volunteers from the MP group provided guidance for the second block of teaching. The main changes signposted more practical elements in class, more time to consider the new learning, recap and revision of the theories at the beginning of each class, a focus on the language of mathematics and application of what mastery teaching would look like in a classroom. This data was revisited at the end of the study and the data was compared to the weekly VAS data to enrich the findings and link the themes.

The second set of quantitative data was an analysis of the weekly VAS data. Due to high levels of attrition, primary and secondary data was analysed. The primary data found that the MP group reported positive change to their mastery / self-reported knowledge between Block 1 and Block 2 and this was significant; however, this was not the case for the TAUP group. The primary analysis for anxiety found no significant change however descriptively the week-by-week mean VAS indicated decreased anxiety for the MP group but slight change for the TAUP group. The attention scores showed no significant change for either group and the motivation scores whilst not significant, showed decreased motivation for the TAUP group but no change with the MP group. The secondary analysis can be viewed in Appendix 7.

5 Discussion

The current research represents a novel intervention that aimed to utilise a mastery teaching intervention with pre-service teaching to reduce student feelings of their own mathematics anxiety and anxious thoughts about teaching this subject. The study used a group design to compare student reports of anxiety before and after the teaching module in an MP intervention and where change was compared with students in a TAU group. In addition, the study used an innovative approach to measure student thoughts and feelings about their teaching experiences, including anxiety and related constructs (attention, motivation and self-efficacy), as they moved through the teaching module (presented here as difference between the first five and last five teaching weeks (i.e., Block 1 and Block 2 respectively).

Alongside this quantitative approach the study included a qualitative element based on action research to provide an additional student perspective of mastery intervention. This qualitative data was also used in the current research design to inform teaching in the second half of the module. Comparing measurements before and after teaching, it was anticipated that students in the MP group would report decreased mathematics anxiety and less anxiety about teaching mathematics compared with the TAUP group. In addition, it was expected that changes in anxiety and related constructs would decrease more in the MP group compared with the TAU group as students moved through the module. Moreover, it was predicted that positive change would be reflected in student narratives.

5.1. Key findings

The results showed that student self-reported mathematics anxiety and anxiety about teaching mathematics did not change over time in either the MP or the TAU group. In addition, the results found that there was no significant change in either generalised anxiety or anxiety about teaching mathematics before and after the intervention in either group. The results further showed that students who reported increased anxiety before teaching also reported more anxiety, less motivation and less self-efficacy during teaching, as reflected in associations with combined scores for the first five and last five weeks of teaching. Analysis of the measurements of student reports of anxiety, self-efficacy, attention and motivation the results did show some group differences. To ensure the integrity of the intervention, primary analysis focused on comparing students in the MP and TAUP who had attended for at least four out of the five weeks in each teaching block. Analysing combined data from the first five weeks of teaching and compared with the second five weeks, students in the MP group reported significantly more mastery, and this difference was not evident in the TAUP group. There were no significant changes between teaching weeks with respect to student reports of anxiety, attention or motivation in either group.

Further analyses showed that students who reported increased feelings of mathematics anxiety also reported more anxiety about teaching mathematics. Similarly, students who reported more anxiety before the module began also reported more anxiety during teaching, as well as less mastery and motivation. These results are reflective of other research which considers the association of mathematics anxiety and performance (Ma, 1999; Smith, 2010; Dowker et al., 2016). In addition, consistent with previous findings, females self-reported more MA and more anxiety about teaching mathematics compared with males. This is comparable with other studies which have considered the gender effects in mathematics anxiety (Beilock et al., 2010; Devine et al., 2012; Ganley & Lubienski, 2016; Buckley, 2016).

Qualitative data from the interviews with the MP group indicated that students reported favourably on their experiences with mastery. Five main themes emerged from the data to inform the teaching, and these were the practical nature of mastery, the context of the teaching, the time frames of the classes, the language of mastery and remembering and recapping the learning. Some students reported that they did not all feel it was the best way for them to undertake mathematical activities, but they felt it was useful to understand the pedagogy and an alternative way to teach children.

In addition, the qualitative data considered the four constructs from the VAS scales and whether the interviews supported the quantitative data. With respect to student reports of anxiety, most of the students who were interviewed reported having negative feelings about mathematics and explicitly used using the term "maths anxiety". In contrast to the quantitative data, all the interviewees reported increased attention, focus and concentration, but there were assorted reasons for this. Some of the students reported that they had increased attention as they were interested in the new pedagogy, whereas others reported increased attention as it was new and demanded more focus. As it was a new and unfamiliar pedagogy, they reported to pay more attention in case they were asked a question, and they would not want to appear foolish.

Similarly, regarding mastery or self-reported subject knowledge, all the interviewees reported increased subject knowledge and a consideration to changing their teaching in future placements. Some students further reported a better understanding, others reported they could now see the connectedness topics; however, a small number said that they were more comfortable with using previously learned formulae for their own calculations. Even these students however, appreciated understanding mastery as their future pupils may need a different approach than what they had traditionally learned. Most of the students reported that they were highly motivated to learn due to the novel and practical nature of mastery.

The qualitative data converged with respect to student reports and narratives around mastery, interview narratives did not generally converge with the qualitative data on all constructs, however, it is important to remember that the interviews were carried out after the first teaching block.

5.2 Consideration of secondary analyses

Due to high levels of attrition, secondary data was used and analysis of the secondary data considered students who had attended 3 or more sessions in each block (analysis 1) and those who attended 2 or more sessions (analysis 2; see Appendix 7). The results of the secondary analysis (1) indicated that mastery, attention and motivation were overall higher in the TAUP compared with the MP. The results of secondary analysis (2) similarly showed that overall student reports of mastery, attention and motivation were greater in the TAUP compared with the mastery group. In addition, this analysis found that students in the TAUP group reported less anxiety in the second half of the module compared with the first, and this difference was not evident in the MP group.

Collectively, these analyses suggest that across the module (i.e., comparing Blocks 1 and 2) students experienced increased mastery if they attended more classes in the MP group, and decreased anxiety in the TAUP if they attended fewer of the classes.

5.3. Links with previous research

There have been several pieces of research which provide evidence that some pre-service teachers lack confidence and competence in mathematics, both in terms of how they learn and how they could teach (Bolden et al., 2013), In the current study all students in the college took the National Numeracy self-assessment (see Figure 5) which indicated self-reported MA. The initial MAST has no cut-off point to indicate elevated anxiety. The mid-point of the questionnaire can be used to indicate how many students report that concerns and worries were “somewhat” “generally” or “very true” for them. Data showed that 39% and 59% of student mean scores were above this mid-point for general mathematics anxiety and teaching mathematics respectively.

Evidence suggests that trainee teachers bring the views they gained at school based on their own learning and curricula (Xenofontos & Andrews, 2012). Although these views are not always consistent (Dreher et al., 2016), Zhand and Wong (2015) proposed that many teachers already possess a set of beliefs and myths about mathematics before entering the classroom. During the interviews it was clear that many student teachers were bringing views from their own school experiences and were able to express how this affected their feelings about mathematics. It is this complexity of teacher’s beliefs and anxieties which contribute to the attitudes, firsthand experiences, and expectations they hold. Teacher’s beliefs are intrinsically combined (Holm & Kajander, 2012) and become crucial in shaping classroom practice (Beswick, 2012) therefore it is important that this study discussed these beliefs and encouraged the student teachers to appreciate they could change.

5.3.1. Subject knowledge and confidence in ability

Although the entry requirements for all entering the initial teacher primary training programme in this college is a minimum of GCSE mathematics, there is evidence that this does not guarantee content knowledge and confidence to teach the subject in a primary school (Askew et al., 1997; Henderson, 2012; Day & McKechan, 2015), and this was evident by all the student-teachers having achieved the required entry qualifications yet some still expressed in class having anxieties about their subject knowledge. It has been argued that improving teachers' mathematical knowledge base will lead to better teaching (Alexander et al., 1992; Ma, 2010), however despite the NI primary curriculum being skills based (CCEA, 2006), most of the interviewees outlined that they had more exposure to procedural understanding and preparation for examinations than understanding problem solving and multiple representations.

The current findings provide some evidence that a mastery approach can increase a student's confidence in their knowledge of the subject. This finding fits with further studies which have found that mastery learning programmes have a positive effect on students (Kulik et al., 1990), can help develop teacher strategies (Boylan et al,. 2018), can develop problem solving skills (Drury, 2018), and can change teacher beliefs (Boyd & Ash, 2018). This work extends these findings to demonstrate that the approach can be used to impact pre-service teachers as well as experienced teachers.

The study did not show that the focus on mastery reduced anxiety in pre-service teachers as there is no 'one-size-fits-all' approach (Hunt, 2020) . There have been many studies on overcoming MA considering various constructs. Geist (2010) promoted critical thinking and relating mathematics to real life, Sun and Pyzdrowski (2009) found active learning improved learning. Placing less emphasis on computational speed (Geist, 2010; Furner & Berman, 2003) and organising students into cooperative learning groups (Geist, 2010) have all shown to influence MA. Other research shows various interventions including mindful diaphragmatic breathing, cognitive restructuring, expressive writing and systematic desensitisation (Geist, 2010). Developing a mathematical mindset (Boaler, 2016) and building up mathematical resilience (Johnston-Wilder et al., 2020) all have shown some effect, and whilst this intervention did not generalise the related constructs, the results of the study fit with a growing focus on pedagogy in the classroom. This preliminary data speaks to agendas from CCEA (Owens, 2019) and from government policy from the Education authority (DENI, 2009 & 2011).

5.3.2. Gender issue and stereotyping

Whilst mathematics anxiety is known to start in early primary school and affect more girls than boys (Hembree, 1990), the findings of this research found gender differences as females self-reported more MA than males and more anxiety around teaching mathematics. Koch (2018) found that MA increases with age and the MA of pre-service teachers typically increases when they become in-service teachers. This study aimed to effect positive change in pre-service teachers to influence this possible trajectory. As negative attitudes of mathematics-anxious teachers have a strong influence on same-gender children (Beilock et al., 2010) and a high percentage of our primary school teachers are female (this study began with 84 females and 25 males), traditional stereotypes could be reinforced (Soni & Kumani, 2015). During the interviews, some of the student-teachers noted their own experiences of gender stereotyping and how teacher anxieties can affect the child's confidence and increase child MA, Boylan et al. (2017) identified both teacher beliefs and weak subject knowledge as contributors to poor teaching. The student views expressed in the current study are consistent with the view that there is an urgent need to ensure pre-service teachers have a solid knowledge of mathematics, good teaching strategies and methods to reduce their own and their students' mathematics anxiety (Boylan et al., 2017).

5.4 Strengths and limitation of the current study

Oancea and Furlong (2007) suggest four criteria to evaluate action research:

transparency in design and reporting, trustworthiness (validity), paradigmatic considerations and contribution to knowledge. These four criteria are now considered in the context of this project by exploring the strengths and limitations of this study.

5.4.1 Strengths

Action research does not necessitate using the same indicators of research rigour that more positivist methods might use (Arnold & Norton 2018). One of the strengths of this study was the design which allowed some exploration of one route (mathematics mastery pedagogy) to increase self-efficacy in trainee teachers. Mixed methods research often uses parallel forms of reliability and triangulation and the use of this method allowed an in-depth analysis of the thoughts and feelings of students with the qualitative data complimenting the quantitative data. The reporting of both data sets using a parallel followed by an integrated approach (Onwuegbuzie & Collins, 2007) ensured transparency both in design and reporting.

The use of a control group (TAUP) strengthened the internal validity of this study. Both groups were similar in their populations and were randomly assigned class groups. The existence of confounders threatens internal validity (Navarro & Foxcroft 2022), although with random allocation which happens in organising the groups, confounders are distributed randomly and evenly through the groups. In support, the MAST questionnaire demonstrated similarities in the anxiety scores within the groups, and similar gender divisions.

External validity relates to the generalisability or applicability of the findings. This study considered the effects of mastery on MA in a group of university students and the data was generated from the developments of a specific group, in a specific cohort in one college, with the focus of the study considering pedagogy within the university. Considering the specific nature of teacher training in NI, it cannot be said that the results would generalise or have some applicability across the UK. Action research is about developing practice in a particular context rather than creating generalisable rules for other practitioners (Arnold & Norton, 2018), thus generalisations around drawing conclusions from a small sample would not apply to the population as a whole;

however, it may have replicability in this specific context with an understanding that there will be variations in the changes made to the teaching.

In this study the results are specific to this group of students, however this study could be replicated across year groups and across teacher training colleges in the province and could bring changes to the wider pedagogy of numeracy teacher training in NI. The results of the study may have some applicability to student teachers more broadly as this group of students are representative of a sample of students who would typically be in this training college. Diverse groups of student teachers may give different suggestions for change and therefore repeating this investigation would enable a demonstration of the extent to which the results are replicable and generalisable to student teachers in different contexts (McAteer, 2013). The research could be replicated with other cohorts and in other teacher training colleges considering pedagogical changes.

As the role of the teacher is significant in developing attitudes and engagement to mathematics (Gough, 1954; Gunderson et al., 2012; Maloney & Beilock, 2012), additional ways to build and improve pre-service primary school teachers' confidence and decrease their own levels of MA is considered in this research and mathematics mastery as a possible contributor to this field has been discussed.

One of the contributions to knowledge has been to highlight the pedagogy for future teachers as an alternative way to teach children who may not respond well to a traditional pedagogy and may need an alternative approach to enable them to succeed and not experience the failure which can lead to MA (Boaler, 2006). This project has empowered this group of future teachers with an alternative pedagogy they can offer.

There have been numerous articles of research published which considers MA (Mammarella et al., 2019), and although substantial knowledge has been acquired in recent years, an area which has been highlighted as needing further investigation has been the area of teacher training (Furner & Duffy, 2002) with only limited research carried out in this area. There is a significant lack of research on mathematics mastery in NI, perhaps because mastery pedagogy is not widely known in schools and many schools retain the traditional resources and methods which have been in use for a long time. This project has contributed to the growing field of research on MA and ways to alleviate it and highlights the specific circumstances in NI.

5.4.2 Limitations

This research took place during the Corona virus Covid-19 pandemic which had an unprecedented effect which is still to be understood. Teaching quickly went from in-person classes to online, and this cohort of students began their university experiences from behind a screen. The data from this study was collected as lockdown regulations were slowly lifting, and as the world was gradually coming out of a crisis, all anxieties may have been heightened. There were still restrictions in place regarding isolation when someone tested positive, only working in selected groups, wearing masks in class, etc. For this reason, all interviews were held online, which may also have affected their responses. This may explain in-part the levels of attrition and may contribute to increased anxiety levels, but the full effects of the pandemic are still being considered in research.

One of the limitations of the MAST states that "there is no clear cutoff determined for what constitutes evidence that a person is 'high' in math anxiety" (Ganley et al., 2019: p.13) and an arbitrary cutoff of the midpoint is used, but this should not be used as evidence for a certain percentage of student teachers exhibiting high levels of mathematics anxiety. The MAST was used to determine MA using this midpoint criteria for mean scores however this anxiety was not levelled into high or low levels of anxiety. Whilst it may be useful to determine the level of MA this is not a fixed measurement, and levels of anxiety can vary from topic and situation (Chinn 2020) as was seen in this study (see weekly reported anxiety levels in Tables W and X - Appendix 7).

The interviews informed the second iteration of teaching and gave early indications of student feelings on the mastery teaching to date. Interview data had significant merit in highlighting findings from the quantitative outcomes. It would have been stronger, however, if a second round of interviews had taken place at the end of the study when students had experienced the suggested changes, and were asked about their feelings after the changes were implemented. This was not done due to timetabling and college organisation of the term, however, it is something which should be consider in similar research projects in the future. Moreover, future research should focus on teacher experience in the classroom with students in the MP group compared with those in the TAUP. This approach would allow an investigation into the longer-term impact of the MP intervention on teacher anxiety and classroom practice.

VAS scales are used mostly in studies for comparisons with repeated measurements at different points in time as a part of monitoring (Sung & Wu, 2018). One of the major advantages of using a VAS scale is that it is easy and quick to use. When perceived as a continuum and can be easily used to calculate an arithmetic mean, however users may have difficulty finding the point on the line that best applies to them (Klimek et al., 2017). Electronic VAS may increase this difficulty of finding the point on the line which applies to them, and therefore it may be less accurate than is desired. Weighing up the pros and cons, the electronic VAS was still considered to be the best option to deliver quick and reasonably accurate information weekly as students had access and familiarity with electronic devices and could complete a VAS at the end of class with relative speed and ease. The electronic version of the VAS also ensured that analysis was also quick and accurate. As all the students were completing the VAS scale and understood it reflected their feelings about the class they had just experienced, the bias of being in a particular group did not appear relevant to the students.

Experimenter bias is another area which should be considered as it is introduced by an experimenter whose expectations about the intervention's outcome can be subtly communicated to the participants in the experiment. Whilst there were attempts to overcome this by explaining to the students that we wanted to see which style of teaching was best (Rosenthal, 1967), it cannot be ruled out that the students assumed that because my classes were being taught through a mastery pedagogy this was my preference and therefore, it was reflected in their positive answers towards mastery Any research project needs to consider the researcher's subjective involvement in the project and in the data collected. As outlined in Chapter 3, my ontology of critical professional inquiry was based on my interactions with a variety of sources, and my epistemology was influenced by communities of practice including how I was taught. I was influenced by my understanding of mastery and how the explanations of concepts appeared very logical to me. Bringing many previous influences with me to this project and coming to the project as an insider / outsider researcher brought difficulties, but the focus must be the transformative paradigm of pedagogical action research.

During this project, my own teaching transformed as I increased my knowledge and understanding of how others interpret the pedagogy of mathematics mastery and adapt it to their teaching. Whilst it has influenced how I will deliver my course in the future, I am also aware that I must consider societal needs. The pedagogy of mathematics mastery may have improved my understanding and there were some indications that some students benefitted from teaching in this way, however, ultimately the pedagogy they will use will be heavily influenced by the school and the context in which they will teach.

Recommendations for intervention research indicate that participants should be blind to the group they have been allocated to (see Zabor et al., 2020). In the current study, however, as their blinding was not possible because student feedback on the pedagogy was needed, and they were aware this was not the way they were normally taught. This could be overcome in the future with a different year group as first year students would not have experienced university and therefore would not have a preconceived idea about typical approaches to teaching.

6. Contribution to the field

Mathematics anxiety has been cited as a common reason for underachievement (Ashcroft & Kirk, 2001). Research has consistently demonstrated links between MA and mathematics outcomes (Szczygiel, 2021; Zhang et al., 2019; Ma, 1999). This study considered implementing mastery approaches for the reduction of mathematics anxiety in pre-service teachers. Its primary aim was to significantly decrease students' MA and anxiety about teaching mathematics, significantly decrease students' anxiety and increase their attention and motivation through teaching, as well as their perception of subject knowledge and feelings of competence and self-efficacy around the subject. The study further aimed to utilise qualitative data to inform the second block of teaching and revisit it to gain further insight into the quantitative data.

The results showed no significant change in the pre and post intervention data measuring MA and anxiety about teaching mathematics. Weekly measures indicated some advantages of the mastery approach to teaching compared with teaching as usual. Specifically, the mastery group reporting increased perception of subject knowledge and feelings of competence and self-efficacy in the last five weeks compared with the first five weeks and this change was informed by the qualitative data to make changes to the teaching.

This pedagogical action research project looked at the evidence to educate professionals on a new way to teach. The project also asked the participants to consider its relevance to their needs and environments. Regarding the value of this research, being explicit about what has worked in a particular context may resonate with other practitioners or create a desire within us to ascertain if a similar project would work with another group. This is harnessing relatability (Bassey, 1981; Dzakiria, 2012) and produces understanding which can be shared beyond the localised to open discussion and debate with others (McAteer, 2013). The current research project represents an ambitious research design that aims to consider the pedagogy of mathematics mastery as a means of reducing mathematics anxiety and anxiety about teaching mathematics in student teachers. It provided a preliminary exploration of accepting that MA is more widespread than perhaps students realised, and it is not linked to ability or intelligence, but has links with confidence and self-efficacy. It highlighted the benefits of mastery pedagogy and the advantage of introducing it to pre-service teachers in NI. Specifically, it found that student teachers defaulted to teach the way they had been taught and this approach was not always successful. They appreciated that there are differences in the way people learn, and the mastery pedagogy provided them with an alternative pedagogy.

Attitudes and motivation are important because they determine how much people choose to engage with mathematics. In many countries the society has a shortage of mathematically educated people (Hannula et al., 2014) and if this trend is to be changed it needs to begin with primary education so children will be prepared for the world of the future, and they will be contributors to the economy and society, therefore targeting future teachers is important. The hypothesis on the value of a mastery pedagogy would require strong data to persuade school leaders that it would be useful to consider change, however this study provides a starting point for this discussion. Many of the strategies to alleviate MA are sound pedagogy which can be embedded in a mastery approach to make mathematics more accessible for pre-service teachers (and in the future the children they will teach) who may be mathematics anxious.

The context for the current study links to future teachers to acknowledge and recognise their own MA and how it can potentially affect the children they will teach. All pre-service primary teachers entering ITE in this college now undertake the MA self-assessment and mathematics competence online tests (National Numeracy, 2014) as many of them have not encountered mathematics in an educational setting for a few years. This approach can result in reinforcing confidence in ability or highlighting areas for development. All students are signposted to additional support in mathematics if required and this is done in a sympathetic and confidential way. Moreover, a clearer understanding of MA in future teacher training would enable the introduction strategies that they can use and strategies they can employ for themselves and the children they teach to help them understand and reduce their anxiety – this could include using the growth zone model, and relaxation techniques (Lee & Johnston-Wilder, 2018).

The quality of our education system is dependent above all, on the quality of our teachers. What student-teachers bring they carry through and it impacts their experiences in training and in the classroom. Well-structured, appropriately organised training can lead to changes in practice, improvement in institutional level and significant improvements in student achievement (Pedder and Opfer, 2010) and can try to address negative feelings before they go out to the classroom.

Pedagogy is also important as not all children learn in the same way and teachers should be armed with a variety of ways to attempt a problem so that mathematics is accessible for all children. By employing mastery principles, early years professionals now receive more support to develop mathematics talk, as this can support creative thinking and engagement with the subject (NCETM, 2022). In addition, mastery pedagogy promotes collaborative problem solving and mathematical discussion with an emphasis on the importance of regular work in groups to explore concepts and challenges (NCETM, 2022). For example, a key mastery principle is being explicit about what has worked and being able to express this to harness relatability (Dzakiria, 2012) and produce understanding. Promotion of mindset may be a factor to consider as people can be self-fulfilling, so if they believe they cannot do something they will probably be right (Dweck, 2016). As role models, teachers and pre-service teachers need to be encouraged to have the confidence to accept that they may not be able to do it yet, and the same will apply to children in their future classrooms to highlight that mathematics is for everyone (Boaler, 2019).

6.1 Future direction of research

Teacher anxiety with mathematics need to be addressed through initial teacher education programmes, as well as through continuous training and professional development to ensure they present the right attitudes. Teachers need to use the most effective methodologies in the mathematics classroom and to ensure they have good subject knowledge (Liu, 2016; Perry, 2004; Sloan et al., 2002). Whilst there have been case studies and research carried out in England on the effectiveness of a mastery pedagogy (Boyd & Ash, 2017 2018; EEF, 2015), there is limited research on the effectiveness of varying pedagogy in NI and how it would contribute to teacher subject knowledge and confidence. Research needs to be undertaken to find pedagogies which give an alternative to procedural teaching to take account of conceptual understanding.

Given the recognised positive impact of mastery pedagogy around the world (OECD 2010, & 2023; Burghes, 2011; Vignoles & Jerrim, 2015; Boyd & Ash, 2018), understanding, and using mastery pedagogy may enable our student teachers to graduate with an understanding of pedagogies and skills which will enable them to be effective teachers wherever they work. Further research is needed on the impact of mastery pedagogy in its various forms and how it would align with the ethos and values enshrined in the NI curriculum.

Currently, there are no known interventions which prevent the onset of MA, but some recent research has found that non-generic environmental factors contribute more to MA than genetic factors (Koch, 2018). A wider study involving other cohorts in this teacher training college or a trial in other teacher training colleges would provide richer data to add to the findings of this study. Running the intervention over a longer time, extending beyond training into the classroom, and interviewing the participants more frequently, would allow for a clearer understanding of the impact of MP in teacher training and beyond. If the long-term results and additional research indicate that mastery is important in reducing MA and promoting more conceptual understanding, then it would be important that a version of this research is produced which is accessible for practitioners and is presented to them through professional development opportunities.

While this study outlines the potential to minimise MA by providing an alternative pedagogy for teachers, MA is a much wider challenge and has implications across society. Businesses, parents, carers, government, the media and wider society all have their part to play in breaking down entrenched perceptions of mathematics. As demand grows globally for problem solvers and creative thinkers, there needs to be a collective effort to encourage more number-confident and resilient citizens for the future if we are to compete on a global stage.

7. References

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8. Appendices

Appendix 1 VAS Scales

THINKING ABOUT HOW YOU FEEL RIGHT NOW

Instructions to the student: The scale below consists of words describing different feelings and emotions. Rate each word or phrase by drawing a vertical line on the scale below to indicate the extent you feel that way RIGHT NOW.

I FEEL ANXIOUS

Not at all A little Moderately Extremely

0---100

I UNDERSTAND THIS TOPIC

Not at all A little Moderately Extremely

0---100

Satisfied

Not at all A little Moderately Extremely

0---100

FOCUSED

Not at all A little Moderately Extremely

0---100

CONFUSED ABOUT THIS TOPIC

Not at all A little Moderately Extremely

0---100

Interested

Not at all A little Moderately Extremely

0---100

DISTRACTED

Not at all A little Moderately Extremely

0---100

WORRIED

Not at all A little Moderately Extremely

0---100

I CONCENTRATED

Not at all A little Moderately Extremely

0---100

RELAXED

Not at all A little Moderately Extremely

0---100

HAPPY

Not at all A little Moderately Extremely

0---100

I HAVE MASTERED THIS TOPIC

Not at all A little Moderately Extremely

0---100

Notes:

Notes on the Visual analogue scale – to be completed after every session

The scores for anxiety, attention, motivation, and self-efficacy are made up of the three constructs, making a possible score range for each (and after each session) from 0-300

1. Anxiety = ANXIOUS, WORRIED, RELAXED (REVERSE SCORED)
2. Attentional control = FOCUSED, CONCENTRATED, DISTRACTED
3. Mastery = I UNDERSTAND THIS TOPIC, CONFUSED ABOUT THIS TOPIC, I HAVE MASTERED THIS TOPIC
4. Intrinsic motivation = Satisfied, interested, happy

Appendix 2 Consent letter and consent form

Title of research: **The development of pedagogical Mastery approaches to increase mastery and reduce Mathematics anxiety in student teachers using action research**

To: All B Ed 2 students
Research project: Consent

Dear Student,
I am currently undertaking research as part of my Educational Doctorate project in Liverpool Hope university, and I am interested in considering if the teaching of Numeracy through Mastery principles contributes to reducing Mathematics anxiety amongst students in their first and second year of initial teacher education.
I would really appreciate your participation in this research, which will be voluntary, and you have the right to withdraw at any time during the project.

At the beginning of the research, you will be asked to fill out a short questionnaire on your attitudes and feelings towards Mathematics. Each week over ten teaching weeks you will be asked to fill out a short rating scale at the end of class recording how you felt this week in class doing the activities and how you feel about mathematics and your learning. During the class, I may observe and make field notes on the sessions as part of the data collection process. Midway through the project I will be inviting a few students to volunteer to be interviewed to further clarify any points I have noted from the weekly rating scales. This interview will be short and will take place with only you and me present. It will be audio recorded for this research, and all data will be kept secure in a password protected computer and destroyed at the end of the research. Prior to including it in the research, I will share the interview transcript with you to ensure I have represented your answers appropriately and fairly.

After the 10 weeks teaching you will be asked to fill out a final Questionnaire on your feelings and confidence on Mathematics.
It is important to stress that this research is Pedagogical action research project, which means I am examining my own practice and the principles involved in Mastery teaching not testing nor examining student ability.

Participation in the project is voluntary, and you will not be penalised nor at any disadvantage if you decide not to take part. You can withdraw at any time during the project and request your data to be deleted. Confidentiality will be maintained, and your identity will be protected. You have the right to request any information collected from you and I will share my findings with the participants at the conclusion of the project.
Thanking you in anticipation of your participation

Best regards

A.G. Parks

If you are Happy to take part in the research, would you please complete the form below

Consent to take part in research

I ……………………………………………………….voluntarily agree to participate in this research study.

- I understand that even if I agree to participate now, I can withdraw at any time or refuse to answer any question without any consequences of any kind.
- I understand that I can withdraw permission to use data from my interview any time until the research is completed, in which case the material will be deleted.

- I have had the purpose and nature of the study explained to me in writing and I have had the opportunity to ask questions about the study.
- I understand that participation involves filling out a weekly rating scale, up to 3 questionnaires, and if selected, a semi-structured interview.
- I agree to my interview being audio-recorded and my written questionnaires being used for Data collection as well as any relevant observations during the course of the 10 weeks during class time.
- I understand that all the information I provide for this study will be treated confidentiality and all protocols have been followed.
- I understand that in any report of this research, my identity will remain anonymous. This will be done by changing my name and disguising any details of my interview which may reveal my identity or the identity of the people I may speak about.
- I understand that anonymised extracts from my interview may be quoted in the thesis, and any future publications including published papers or conference presentations.
- I understand that if I inform the researcher that myself or someone else is at risk of harm, they may have to report this to the relevant authorities – they will discuss this with me first but may be required to report with or without my permission
- I understand that signed consent forms and original audio recordings will be retained in a secure location locked in a filing cabinet or on a password protected computer until the end of the research project with only the researcher having access to this data.
- I understand that a transcript of my interview, in which all identifying information has been removed, will be retained for two years from the date of the exam board
- I understand that under freedom of information legislation I am entitled to access the information I have provided at any time while it is in storage as specified above.
- I understand that I am free to contact any of the people involved in the research to seek further clarification and information.

Research: Mrs Geraldine Parks

Academic supervisors from Liverpool Hope university

Dr Owen Bardon

Dr Julie Hadwin

Dr Veronica Poulter

Signature of research Participant *Date*

………………………………………………….

……………………

I believe the participant is giving informed consent to participate in this study

A.G. Parks

Signature of researcher *Date*

Appendix 3 MAST

Mathematics Anxiety Rating Scale for Teachers (MAST) (Ganley et al. 2019)
Questions will be answered using a 5-point rating scale (1= not true of me at all, 2= generally not true of me, 3= somewhat true of me, 4= generally true of me, 5= very true of me)

Questions 1-11 correspond to General Mathematics anxiety (GMA) using 3 subscales
Questions 12-19 correspond to Anxiety about teaching Mathematics (ATM)-------

Emotionality

1. My Palms start to sweat if I have to do a difficult Mathematics problem
2. I get butterflies in my stomach when I do Mathematics problems
3. I would start to panic if I had to solve challenging mathematics problems
4. I get a sinking feeling when I think of trying to solve Mathematics problems

worry

5. When I see a complicated Mathematics problem, I feel overwhelmed
6. Feelings of anxiety interfere with my ability to solve mathematics problems
7. My mind goes blank when I am about to start a challenging mathematics problem
8. I start to worry when I am given advanced Mathematics problems to solve
9. I feel self-conscious if I don't know how to solve a mathematics problem right away.
10. I get nervous when I think my Mathematics ability is being evaluated
11. I would feel nervous if I had to figure out a mathematics problem in front of other adults.

Anxiety about teaching Mathematics

12. I worry about making mistakes while solving Mathematics problems in front of my class of children.
13. I would be nervous teaching mathematics to children in a higher level than I am used to teaching.
14. I would feel uncomfortable if another teacher / peer observed me teaching a mathematics lesson.
15. When I am teaching, I avoid going into depth about Mathematics concepts I don't feel comfortable with.
16. I would feel uncomfortable if a student asked me to explain why an advanced mathematics strategy works.
17. It makes me nervous to solve a mathematics problem in front of my class if I haven't already figured out the solution.
18. I worry about not being able to answer student's questions about mathematics on the spot.
19. I would be anxious if my principal / tutor observed my class, particularly during Mathematics time.

(*Ganley considered that there were some repetitive items in this scale and the removal of 2,5,18 and 19 did not change the results of the scale, so this 15 point simplified version was used in this research.*

Appendix 4 Sample questions for interviews

Core Questions	**Example prompts**
Preamble 1. General feelings about Mathematics How did you feel about your own mathematics skills and ability before starting on the Mastery programme?	How did you feel about mathematics in primary school? How did you feel about Mathematics in post primary? When did you notice a change in your feelings about Mathematics? Can you pinpoint what caused this change?
2. *(Linked to confidence)* How do you feel about your confidence in your own Mathematics ability now?	Can you discuss this further /pinpoint what improved your confidence / what might develop your confidence?
3. *(Question linked to the pedagogy in general and to motivation)* Feelings about the mastery approach Are there any teaching methods we have been using which were particularly useful in helping you to enjoy the subject? Are there any teaching methods we have been using which you felt didn't help you to enjoy the subject?	Is there anything in particular you wish to discuss regarding Mastery principles of teaching?

4. Focus and concentration *(Linked to attentional control)* Is your concentration in class more or less focused as you are working through the topics?	Can you discuss further why you think this is the case and what is improving / diminishing your concentration.
5. Mastery of the subject knowledge Are there any areas where your own subject knowledge has developed?	What has developed your subject knowledge?
6. *General information* Application to becoming a teacher Have the past 5 weeks changed the way you might teach Numeracy in primary school in future?	Can you discuss further how you think you would teach the topics covered to children in primary school? Why would you use that approach?

Appendix 5: Ethical approval

LIVERPOOL
HOPE
UNIVERSITY
Est. 1844

Liverpool Hope Research Ethics

Home   Your Research   Username: 17010778

Latest Notes for this Application (by parre on 2021-06-03 18:13:01)

The revisions have been comprehensively addressed and I am pleased to approve the application. Good luck with the project.

Section 1 Your details

a **Researcher**

Geraldine Parks
(17010778)

b **Title of Proposed Project**

The development of pedagogical mastery approaches to increase mastery and reduce maths anxiety in student teachers using pedagogical action research.

c **Programme Title and Level of Study**

EDUCATION

d **Research Dates**

I confirm that I wiill not start my research before ethical approval has been given

Appendix 6: Gatekeeper's letter

Dear XXXXXXX,
As you know, I am in the process of completing the Doctorate in Education programme at Hope University in Liverpool. I am now at the stage of beginning the dissertation element and I write to seek your permission to conduct the research in XXXXXXXX.

My area of interest lies in initial teacher education, and teachers. I am focusing on the important levels of mathematics anxiety (and lack of numerical confidence) in student teachers and how this can be diminished / overcome. It is my intention to conduct Pedagogical action research project 'The development of pedagogical mastery approaches to increase mastery and reduce mathematics anxiety in student teachers using pedagogical action research'.
With your permission, the research will take place during this current academic year and will involve a series data collection method. I intend to do a baseline mathematics anxiety questionnaire (electronically) with the b Ed 2 primary students in the first term to establish the presence of mathematics anxiety.

This will be followed by 2 x 5-week teaching cycles where 2 of the classes will be taught their course content through Mastery Principles and the other classes will be taught the same content through 'teaching as usual' pedagogy. Each week all the classes will complete (electronically) a short VAS scale which will measure 4 things that week – their anxiety on that week's topic, their attentional control, their understanding of that week's topic and their intrinsic motivation.
Between the 2 teaching cycles there will be a small number of students invited for interview (invitations will be given to those who demonstrated high levels of mathematics anxiety at the start of the project and / or those who have indicated they really wish to discuss it) to evaluate the teaching and to see what changes need to be made prior to the next iteration. I stress, this is to evaluate my own pedagogy and NOT to test or evaluate the students.

During the entire research process, I can assure you that I will adhere to the British Educational Research Association's [BERA] 'Ethical Guidelines for Educational Research' (2018) along with the ethical guidelines provided by the Hope University. All data collected will be treated with the utmost confidentiality and to ensure the personal anonymity or each participant they will log reply to the questionnaires using a student number. In this project confidentiality is assured but I need to be able to track the progress of mathematics anxious students and thus will use a number for identification rather than their names. Participation in the study will not have any bearing upon any aspect of assessment of each participant during this year and students will only have their data included if they give permission for this. Participants will also be allowed to withdraw from the research in full, or part at any point but obviously not from class.

There are implications for this project – if the data shows that a new pedagogy is best for teaching Numeracy to student teachers and reduces or alleviates mathematics anxiety, then it may affect our discussions on future pedagogy in Numeracy. The Mastery principles have changed the pedagogy for teaching Numeracy in Singapore, Shanghi, Finland and numerous countries with the results being evident in PISA and Timss. Since 2014 Mastery principles have also been introduced through Mathematics Hubs in England. It is not widely known in Ireland (North or South) so this project will hopefully contribute to 'new knowledge.'

If you have any queries concerning the nature of the research or are unclear about any aspect of the study, please contact me in person or by email at XXXXXX If you are happy to proceed, I would be most grateful if you could inform me of the same.

Thank you for your interest and support in this work.

Yours sincerely,

Geraldine Parks

Appendix 7 Additional information on analysis

Appendix 7 contains additional information on analysis. It begins with tables W and X which are the weekly VAS descriptive statistics for each group, the mastery pedagogy group (MP) and the teaching as usual pedagogy (TAUP) group. The Appendix then outlines the secondary analysis linked to attendance; VAS scores for Block 1 and Block 2 for participants who completed at least 3 VAS scores in each block (secondary analysis 1), and analysis for participants who completed at least 2 VAS scores in each block (secondary analysis 2)

Table W Weekly VAS summaries Descriptive statistics Group 1 Mastery

	Anxiety		Motivation		Attention		Mastery	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Week 1 N=49	34.82	16.16	75.27	14.70	73.53	14.62	61.05	14.59
Week 2 N=47	32.20	17.81	74.94	17.43	74.48	16.26	63.35	17.93
Week 3 N=45	27.33	14.49	76.73	13.54	76.24	16.02	66.61	14.89
Week 4 N=35	32.03	17.16	73.79	14.32	76.25	14.77	63.18	14.73
Week 5 N=47	32.76	17.04	69.04	13.94	74.01	14.30	60.35	16.80
Week 6 N=39	34.42	20.05	72.20	17.00	74.98	17.18	63.27	18.18
Week 7 N=46	25.17	17.33	75.72	16.69	78.24	14.71	73.20	16.04
Week 8 N=42	39.47	21.43	67.46	17.47	72.19	15.66	58.08	18.62
Week 9 N=31	31.91	23.02	69.28	19.61	73.61	17.02	65.23	21.17
Week 10 N=21	24.46	18.83	77.25	14.98	79.24	14.13	75.63	14.90

Table X Weekly VAS summaries Descriptive statistics Group 2 – Teaching as usual.

	Anxiety		Motivation		Attention		Mastery	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Week 1 N=47	34.82	20.23	78.4	14.26	80.72	14.26	72.15	18.01
Week 2 N=28	37.51	22.31	78.27	23	76.17	16.21	71.82	16.61
Week3 N=36	29.74	22.05	82.23	13.42	81.58	14.0	74.88	15.26
Week 4 N=36	29.74	22.05	82.23	14.42	81.58	13.98	74.88	15.26
Week 5 N=45	33.19	23.81	76.72	20.21	81.35	15.3	72.16	19.12
Week 6 N=36	30.46	26.48	79.9	19.77	86.61	13.74	75.92	21.24
Week 7 N=40	25.27	22.05	80.1	15.64	83.6	13.65	77.87	18.89
Week 8 N=41	25.89	20.31	78.3	15.74	82.62	13.74	73.45	18.3
Week 9 N=21	36.27	23.46	76.59	20.07	79.06	18.07	69.65	19.07
Week 10 N=27	28.95	20.95	76.74	16.02	82.01	13.69	73.54	20.71

Appendix 7.1: Secondary Analysis 1 (VAS scores for Block 1 and Block 2 for participants who completed 3 or more sessions)

Secondary analysis 1 considers group differences in mastery, anxiety, attention, and motivation VAS scores. For students in the TAUP Group (N = 34) and the MP (N = 34) who completed 3, 4 or 5 sessions in each block.

Mastery VAS scores. Considering the secondary analysis (1) where students completed 3, 4 or 5 sessions in each block. Analysis for mastery scores showed a significant effect of Group ($F(1,37) = 6.22$, $p = .015$), indicating that mastery scores were greater overall in the TAU group M = 73.25 compared with the MP group M = 65.32. There was no significant effect of Block ($F(1,37) = 0.462$, $p = .499$), indicating that there was no significant difference in Mastery VAS scores between Blocks 1 and 2. The interaction between Group and Block was not also significant ($F(1,47) = 1.82$, $p = .182$). The mean mastery VAS scores and standard deviations for the MP (n=34) and TAUP (n=34) groups for students who completed at least 3 teaching sessions in Block 1 and Block 2 are shown in Table 3 (chapter 4); see also Figure 17 below.

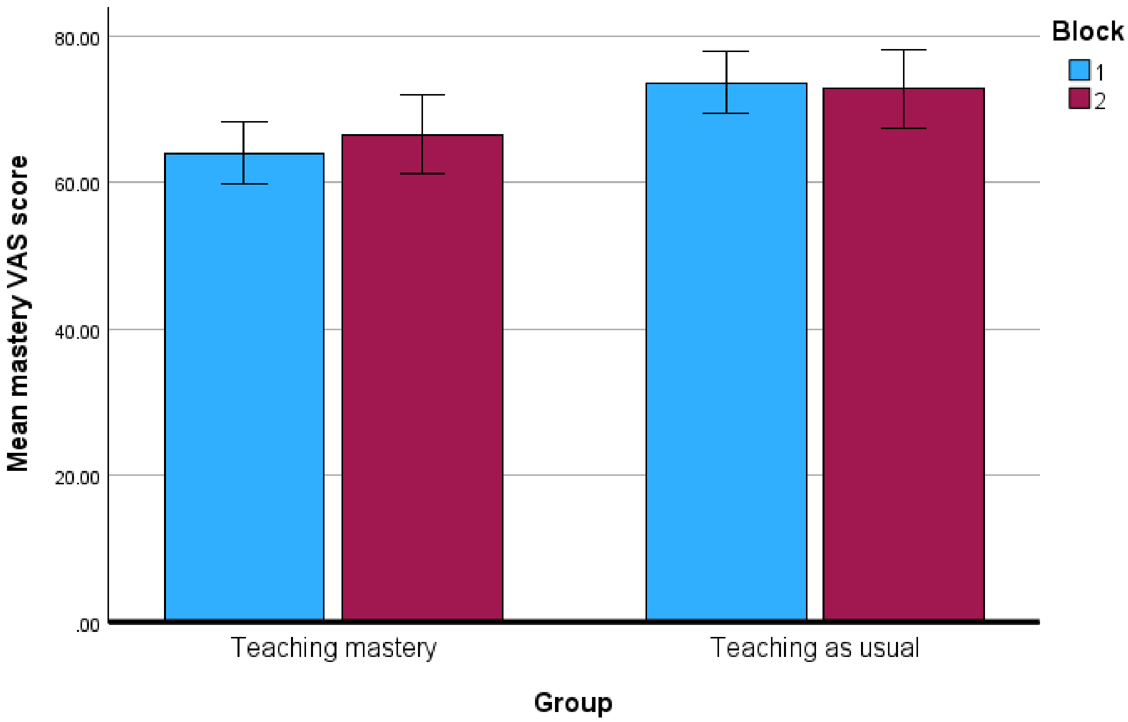

Figure 17 The mean Mastery VAS scores and standard errors for the MP (n=34) and TAUP (n=34) groups for students who completed at least 3 teaching sessions in Block 1 and Block 2.

Appendix 7.1.2 Secondary Analysis 1 Anxiety VAS

Anxiety VAS scores. The analysis for anxiety scores showed no effect of Group ($F(1,37) = 0.039$, $p=.845$) or Block ($F(1,37) = .230$, $p=.633$), indicating that there was no difference in Anxiety VAS scores between groups, or between Blocks 1 and 2. The interaction between Group and Block was also not significant ($F(1,47)=1.262$ $p=.265$). The mean anxiety VAS scores and standard deviations for the MP (n=34) and TAUP (n=34) groups for students who completed at least 3 teaching sessions in Block 1 and Block 2 are shown in Table 3 (Chapter 4) and Figure 18 below.

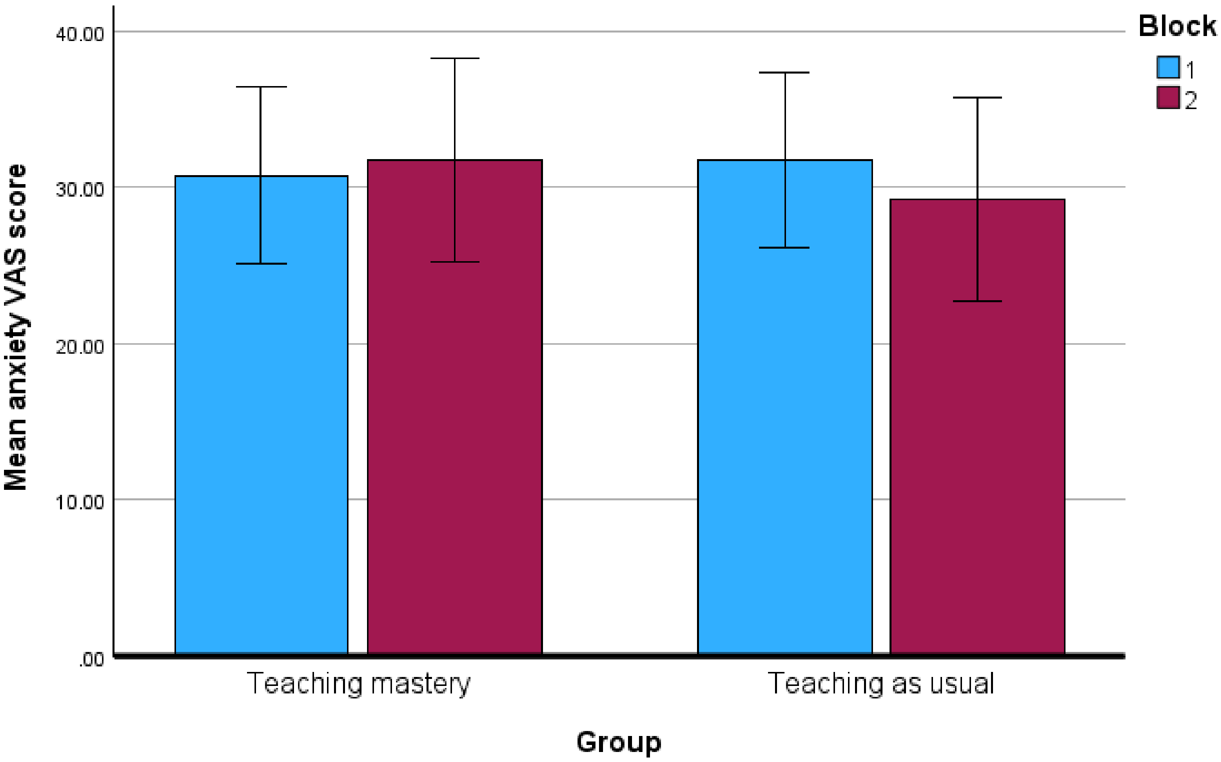

Figure 18 The mean Anxiety VAS scores and standard errors for the MP (n=34) and TAUP (n=34) groups for students who completed at least 3 teaching sessions in Block 1 and Block 2.

Appendix 7.1.3 Secondary analysis 1 Attention VAS

Attention VAS scores. Analysis for attention scores showed a significant effect of Group ($F(1,37) = 4.28$, $p = .042$), highlighting that the mean attention score was greater for the TAU Group Mean= 82.55 compared with the MP Group M = 76.50 The effect of Block was not significant Block ($F(1,37) = .017$, $p = .684$), indicating that there was no difference in reported attention VAS scores between Blocks 1 and 2. The interaction between Group and Block was also not significant ($F(1,47) = 1.08$, $p = .303$. The means for attention for each Group and in each Block are shown in

Table 3 (Chapter 4), see also Figure 19 below.

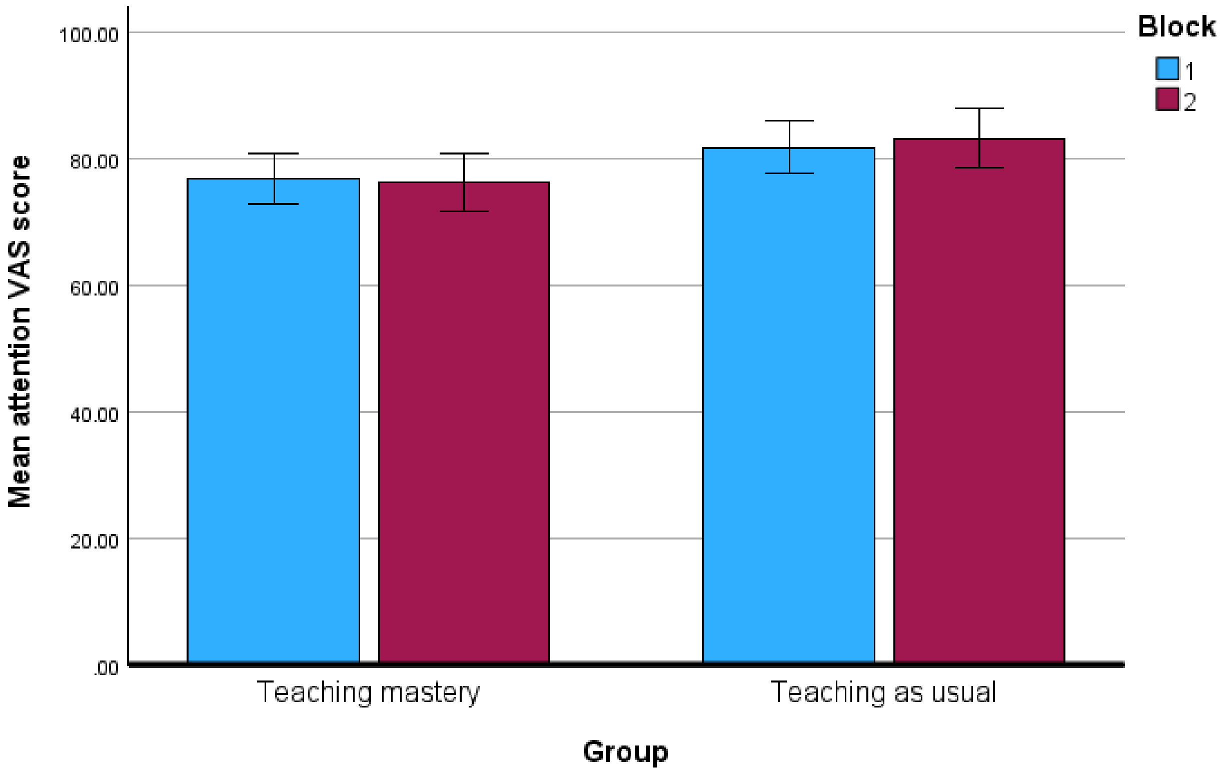

Figure 19 The mean attention VAS scores and standard errors for the MP (n=34) and TAUP (n=34) groups for students who completed at least 3 teaching sessions in Block 1 and Block 2.

Appendix 7.1.4 Secondary analysis 1 Motivation VAS

Motivation VAS scores Analysis for motivation scores showed a main effect of Group, indicating that overall motivation was greater in the TAU Group(M = 79.87) compared with the MP group (M = 72.95 (F(1,37) = 4.95, p= .03). The main effect of Block (F(1,37) = 3.35, p=.072) was not significant, indicating that there was no difference in Motivation VAS scores between blocks 1 and 2. The interaction between Group and Block was also not significant (F(1,47)=.078, p=.781), see Table 3 (Chapter 4) and Figure 20 below.

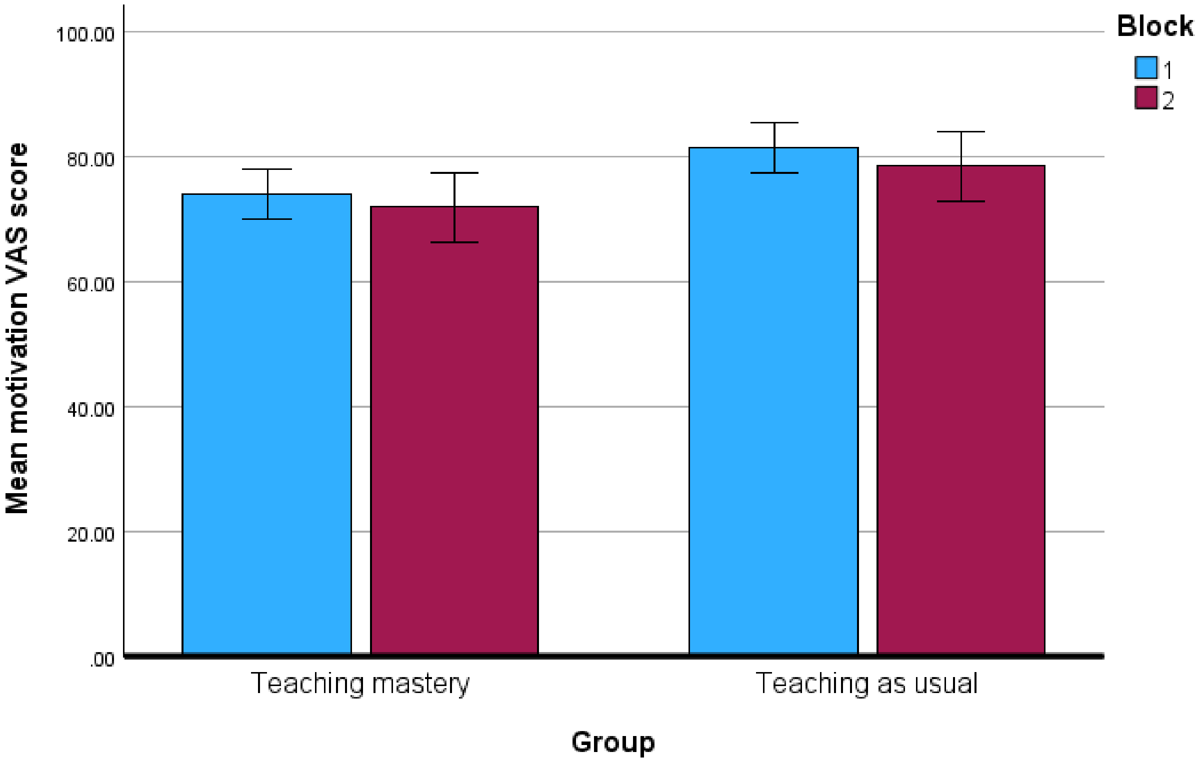

Figure 20 The mean motivation VAS scores and standard errors for the MP (n=34) and TAUP (n=34) groups for students who completed at least 3 teaching sessions in Block 1 and Block 2.

Appendix 7.2: Secondary Analysis 2 (VAS scores for Block 1 and Block 2 for students who completed at least 2 VAS scores in each block).

Mastery, anxiety, attention, and motivation VAS scores. This analysis represents the secondary analysis (2), where students in the TAUP Group (N = 45) and the MP Group (N = 49) completed 2, 3, 4 or 5 sessions in each block.

7.2.1 Secondary analysis 2 Mastery

Mastery VAS scores. Analysis for mastery scores showed a significant effect of Group ($F(1,92) = 16.85$, $p = < .001$), indicating that students in the TAU Group (M = 74.46) reported more mastery overall compared with students in the MP Group (M = 63.92) The main effect of Block was marginally significant, ($F(1,92) = 3.67$, $p = .059$). It indicated that descriptively Mastery was higher overall in Block 2 M = 70.34 compared with Block 1, (M= 68.04) but because $p > .05$ the difference is only indicative and not statistically reliable. The interaction between Group and Block was also not significant ($F(1,92) = .247$, $p = .62$). The mean mastery VAS scores for the MP (n=49) and TAUP (n=45) groups for students who completed at least 2 teaching sessions in Block 1 and Block 2 are shown in Table 3 (chapter 4) and Figure 21 below.

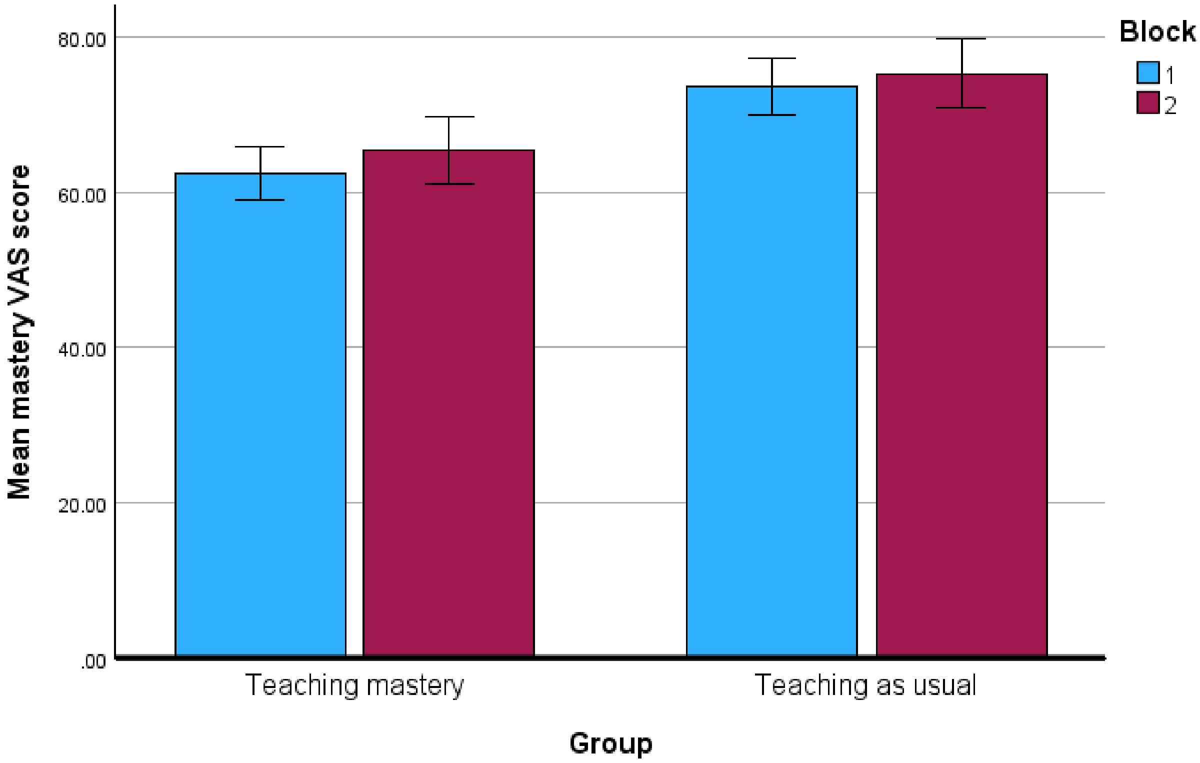

Figure 21 The mean mastery VAS scores and standard errors for the MP (n=49) and TAUP (n=45) groups for students who completed at least 2 teaching sessions in Block 1 and Block 2.

7.2.2 Secondary analysis 2 Anxiety

Anxiety VAS scores. The analysis for anxiety scores showed no effect of Group ($F(1,92) = 0.257$, $p = .613$) or Block ($F(1,92) = 2.24$, $p = .138$), highlighting that overall anxiety did not differ between Group or Block. The interaction between Group and Block was significant ($F(1,92) = 4.51$ $p = .036$). Because the focus of interest was on change within groups over time (between Blocks), two planned comparisons used paired-sample t-tests to compare differences between Blocks separately for the TAU and the MP groups (adjusted $p = .025$). This analysis showed that for the MP there was no difference between Blocks ($t(48) = .437$, $p = .664$) $M = 32.33$). Analysis for the TAU group indicated that students reported less anxiety in Block 2 ($M = 28.10$ compared with Block 1 ($M = 33.36$ $t(44) = 2.62$, $p = .012$). For the TAU group, this would suggest that if students attend fewer classes in the latter stages of teaching, they experience less anxiety.

The mean mastery VAS scores for the MP (n=49) and TAUP (n=45) groups for students who completed at least 2 teaching sessions in Block 1 and Block 2 are shown in Table 3 (Chapter 4) and Figure 22 below.

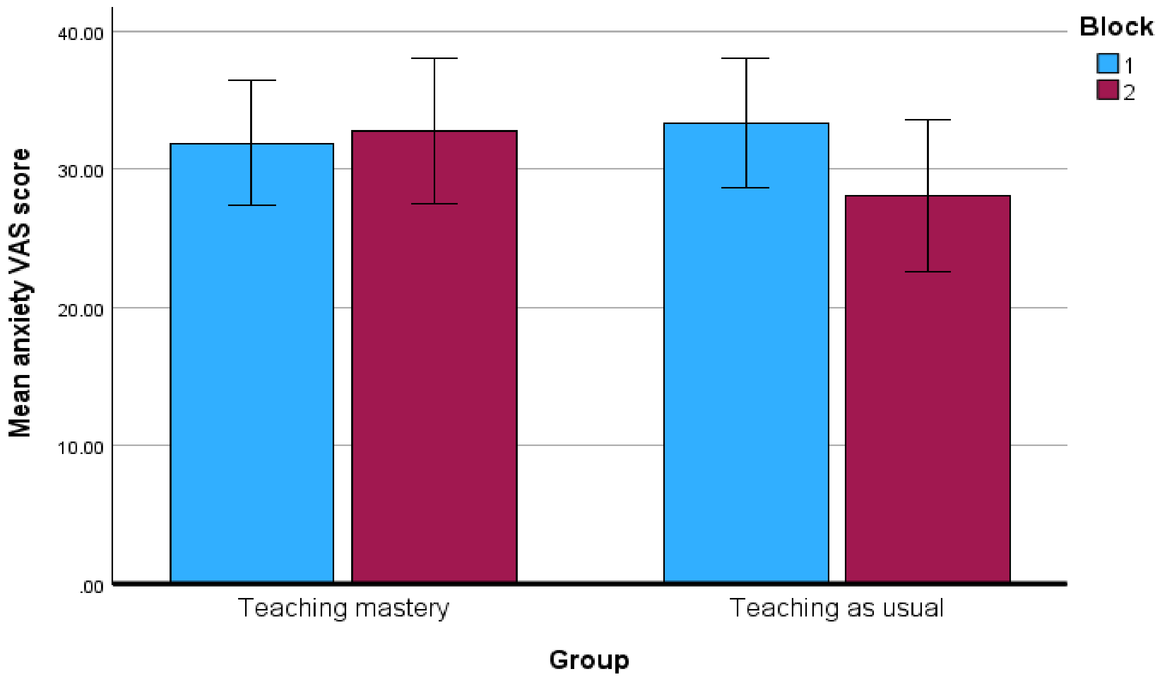

Figure 22 The mean anxiety VAS scores and standard errors for the MP (n=49) and TAUP (n=45) groups for students who completed at least 2 teaching sessions in Block 1 and Block 2.

7.2.3 Secondary analysis 2 Attention

Attention VAS scores. Analysis for attention scores showed a significant main effect of Group where the TAUP self-reported higher levels of attention overall (M = 81.81 compared with the mastery group F(1,92) =8.6, p=.004). The main effect of Block was not significant (F(1 92) = 1.02, p=.316), indicating no difference in reported attention for Block 1 and Block 2. The interaction between Group and Block was also not significant (F(1,47)=2.58, p=.112) Table 3 (Chapter 4) and Figure 23 below show the means for attention for each Group and Block.

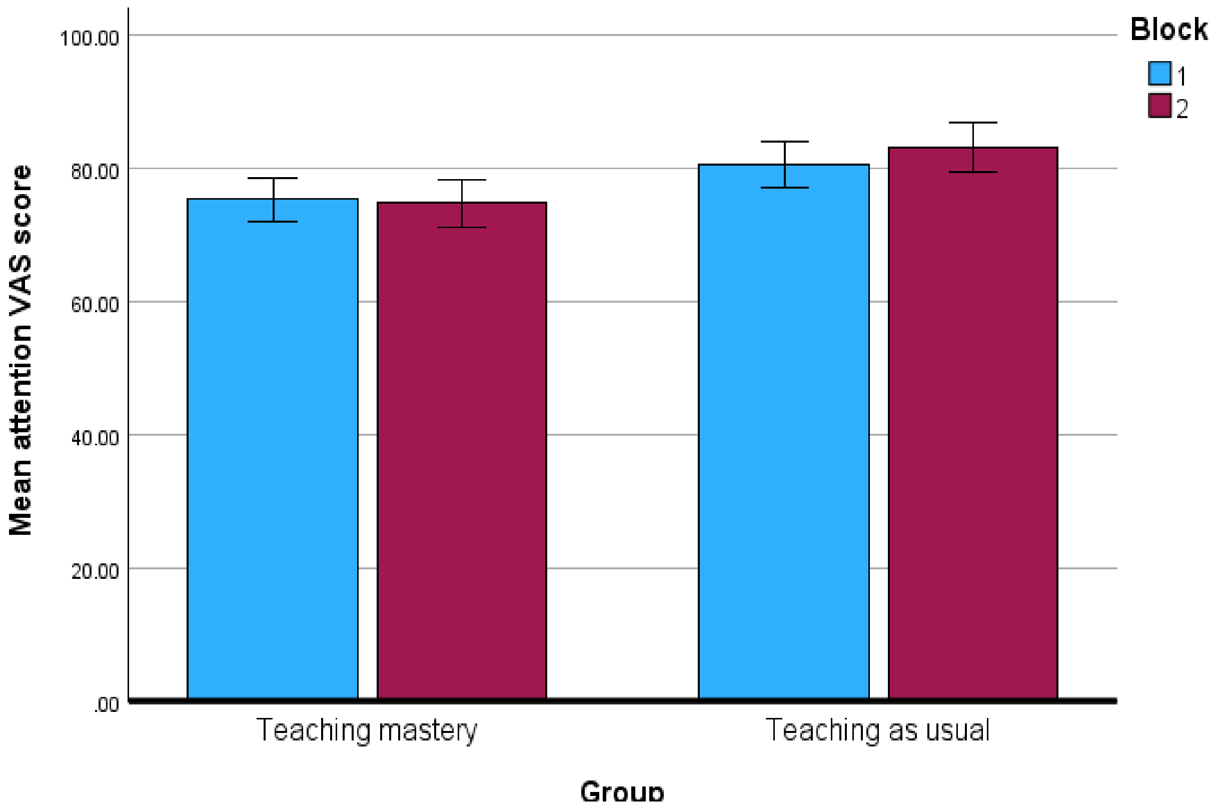

Figure 23 The mean attention VAS scores and standard errors for the MP (n=49) and TAUP (n=45) groups for students who completed at least 2 teaching sessions in Block 1 and Block 2.

7.2.4 Secondary analysis 2 Motivation

Motivation VAS scores The analysis for motivation scores showed a significant effect of Group ($F(1,92) = 5.57$, $p= .02$), where motivation was greater overall in the TAU Group ($M = 78.69$) compared with the MP Group ($M = 72.84$). The main effect of Block was not significant ($F(1,92) = .936$, $p=.336$), highlighting no difference in motivation VAS scores between Blocks 1 and 2. The interaction between Group and Block was also not significant ($F(1,47)=1.09$, $p=.30$), see Table 3 (chapter 4) and Figure 24 below.

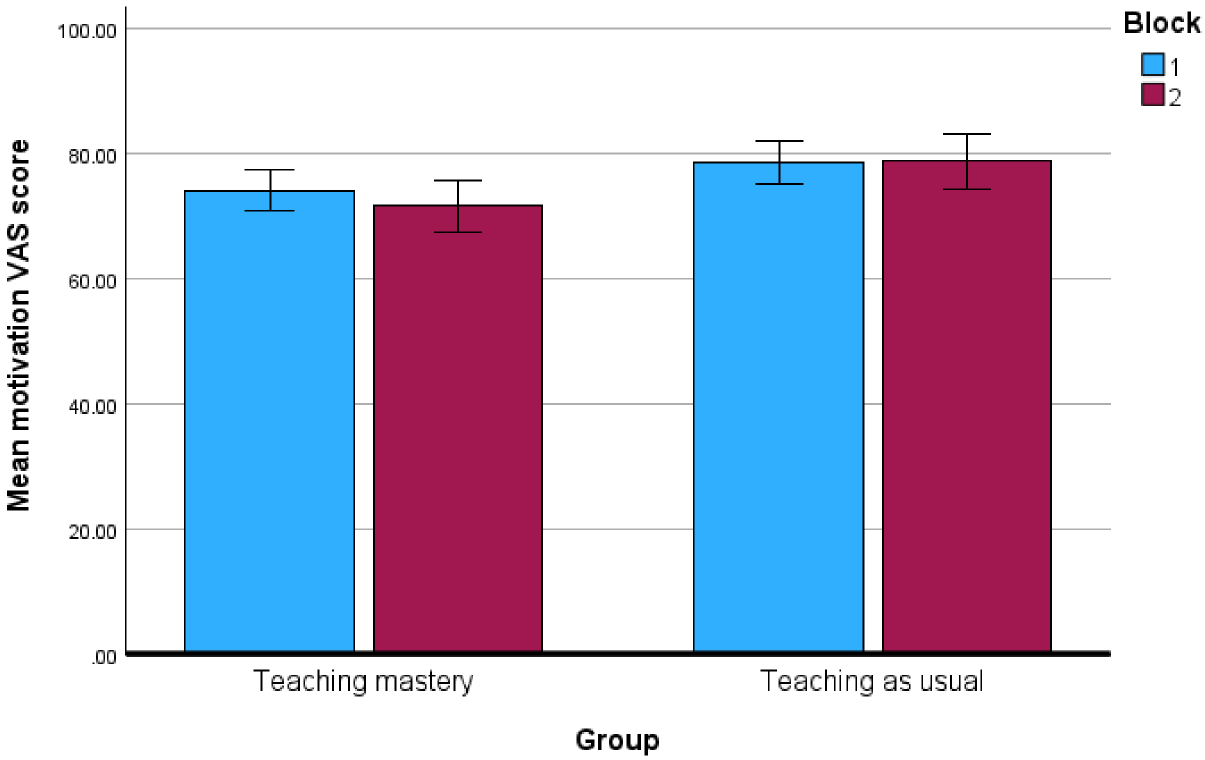

Figure 24 The mean motivation VAS scores and standard errors for the MP (n=49) and TAUP (n=45) groups for students who completed at least 2 teaching sessions in Block 1 and Block 2.

Appendix 8: Pearson's correlations between generalised mathematics anxiety and anxiety about teaching mathematics during the teaching in Block 1 and 2

Table Y Pearson's Correlations between generalised mathematics anxiety and anxiety about teaching mathematics with mastery, motivation, attention and anxiety during the teaching itself in Blocks 1 and 2 for the mastery group.

Group 1 Mastery pedagogy Group (MP)

	Visual Analogue scale							
	Mastery		Anxiety		Attention		Motivation	
	Block 1	Block 2	Block 1	Block 2	Block 1	Block 2	Block 1	Block 2
Generalised Mathematics anxiety	-.22 P=.11	-.17 P=.26	.47*** P=<.001	.22 P=.12	.00 P=1.0	-.06 P=.71	-.24 P=.08	-.05 P=.74
Teaching Mathematics anxiety	-.27* P=.05	-.21 P=.16	.408*** P=.002	.28* P=.05	-.17 P=.21	-.05 P=.73	-.27* P=.04	-.10 P=.499

*p<.05, **p<.01, ***p<.001

Table Z Pearson's Correlations between generalised mathematics anxiety and anxiety about teaching mathematics with mastery, motivation, attention and anxiety during the teaching itself in Blocks 1 and 2 for the teaching as usual pedagogy group.

Group 2 Teaching as usual pedagogy Group (TAUP)

	Visual Analogue scale							
	Mastery		Anxiety		Attention		Motivation	
	Block 1	Block 2	Block 1	Block 2	Block 1	Block 2	Block 1	Block 2
Generalised Mathematics anxiety	-.45** P=.001	-.62*** P=<.001	.57*** P=<.001	.62*** P=<.001	-.20 P=.17	-.38** P=.009	-.2 P=.18	-.47** P=.001
Teaching Mathematics anxiety	-.38 ** P=.007	-.59*** P=<.001	.51*** P=<.001	.57*** P=<.001	-.17 P=.24	-.34* P=.02	-.24 P=.1	-.48*** P=<.001

*p<.05, **p<.01, ***p<.001