Exploring the Impact of a Targeted Mediated Learning Intervention on the Mathematical Ability of Grade 5 Learners Experiencing Mathematical Difficulties

Belinda Cooke: 2288309

Supervisor: Professor Zaytoon Amod

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

A research project submitted in partial fulfilment of the requirements for the degree of Masters in Educational Psychology in the Faculty of Humanities, University of the Witwatersrand, Johannesburg, 15 March 2024

DECLARATION

I declare that this research project is my own, unaided work. It has not been submitted before for any other degree or examination at this or any other university.

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ABSTRACT

This preliminary investigation took place in a South African private remedial school and presents the case study of three Grade 5 learners experiencing mathematical difficulties. The study aimed to establish whether a 12-week mediated learning intervention (Feuerstein (2009) From Unit to Group (FU2G)) would have an impact on the learners' mathematical ability as well as on their deficient cognitive functions related to mathematics. The sample included three learners, a teacher trained in the FIE-Basic programme, and a remedial teacher responsible for remedial mathematics classes with the learners. Class mathematics test marks and scores from mathematics-related Wechsler Individual Achievement Test, Third Edition (WIAT-III) (Wechsler, 2009) subtests were used as a measure of mathematical ability before and after the intervention. Data was also collected through semi-structured interviews with both teachers and the completed FU2G instrument booklets. A qualitative assessment of deficient cognitive functions related to mathematics was based on the Feuerstein list of deficient cognitive functions. Qualitative evaluation of the participants' performance on the WIAT-III subtests before and after the intervention was not notably different. Due to considerable difference in the content of each term's class mathematics assessments, qualitative interpretations of the participants' mathematics class test marks were not pursued in the findings. The findings revealed that the FU2G intervention resulted in some positive changes in each learner's deficient cognitive functions related to mathematics. The learners' WIAT-III subtest performance as well as these positive changes are discussed in relation to each participant's learning difficulties and neurodiversity. Overall, the participating teachers had a positive perception of the use and benefits of the mediated learning experience intervention.

Keywords: From Unit to Group Instrument, Feuerstein Instrumental Enrichment, Mediated Learning Intervention, Mathematical Learning Difficulties

ACKNOWLEDGMENTS

I would like to convey my appreciation to the following people, without whom this research would have not been possible:

To the school principal and educators who willingly participated and guided me along the way, this research was not possible without your openness to try and without the wealth of experience you readily shared with me. Thank you for opening the doors of your school to see if we could learn something new together.

To my supervisor, Professor Zaytoon Amod, your guidance, unconditional help, and support throughout this process has helped me grow. I am truly grateful for the depth of your expertise and experience I was fortunate to learn from.

To the three Grade 5 learners, it was you who ultimately made doing this research possible. Although I never met you, I am grateful for your willingness to be part of something new and for showing up and giving it your best shot. I admire your commitment, your eagerness to learn, and your spirit.

To my family who have walked this road with me. Thank you for your unconditional love and support, for your on-going encouragement, and for giving me the space to finish what I started, and finish well.

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CHAPTER ONE: INTRODUCTION

This case study, a qualitative preliminary investigation, aimed to explore the potential impact of the Feuerstein From Unit to Group (FU2G) Instrument on mathematical ability and cognitive functioning related to mathematics among a small group of learners experiencing mathematical difficulties. The study also sought to understand teachers' perceptions related to mediated learning prior to and after the intervention. The study took place in a private remedial school based in Johannesburg, South Africa, one of few schools in the country to implement Feurestein's instrumental enrichment tools and a mediated learning programme. A purposive sampling strategy was pursued to identify and recruit three Grade 5 learners experiencing mathematical difficulties and two teachers were identified as highly suitable for the study due to their specific remedial training and training in the FIE-Basic programme. The research procedure included pre- and post-intervention stages. The Feuerstein FU2G mediated learning intervention was implemented over a 12-week period with the three learners by a specialist teacher trained in the FIE-Basic programme. Given the small sample size and case study approach, all data was interpreted qualitatively.

Research Aims

This preliminary investigation aimed to explore the potential of a targeted Feuerstein mediated learning intervention to impact mathematical ability among a small group of learners experiencing mathematical difficulties. Further, the study explored whether such an approach to teaching key mathematics concepts was beneficial to the learners' overall cognitive functioning related to mathematics.

Rationale for the Study

It is commonly acknowledged that there is a mathematics crisis in South African education with research indicating that South African scholars underperform in mathematics relative to their peers in both developed and developing countries (Reddy et al., 2016; Spaull & Kotz, 2015). Mathematics is a critical ability for the future workforce of the country as a means out of poverty and a way to realise the government's inclusive economic development plan, which is dependent on science, technology, and innovation. Literature and research indicate one key area for poor mathematics achievement stems from poor basic numeracy skills being taught and attained in the early years of schooling. Given the hierarchical manner in which mathematical ability develops, it is essential to address this gap in basic numeracy for any opportunity to improve mathematics outcomes in secondary and tertiary phases of education.

A consideration to addressing learning gaps in numeracy is based on the theory of structural cognitive modifiability and mediated learning experience (SCM-MLE) (Feuerstein, 2000). SCM-MLE challenges the traditional notion that 'intelligence is fixed' and offers a more positive outlook for all learners, especially (although not exclusively) for low-achieving and special needs children. This theory is based on the assumption that the cognitive system has plasticity and is able to be modified. Supporting literature exists on the effectiveness of MLE in education settings; however, there is limited local literature on MLE and mathematics. A remedial school environment offers the opportunity for a small, in-depth study. This preliminary investigation was set in such an environment and has the potential to contribute to future research among other South African school populations also in need of basic numeracy skill development and/or remediation. While literature and research exist on the challenges facing the development and acquisition of mathematical ability, there is very limited local research related to possible ways of addressing the situation.

Research Questions

The following research questions were explored in this study:

i. Is there a change in the mathematical ability among a group of Grade 5 learners following a 12-week targeted mediated learning intervention?

ii. Prior to the mediated learning intervention, how do teachers describe each learner's observed mathematical ability with particular reference to Feuerstein's cognitive functions?

iii. Following the intervention, how do teachers describe each learner's observed mathematical ability with particular reference to Feuerstein's cognitive functions and the mediated learning instrument?

iv. What are teachers' perceptions related to the use and benefits of mediated learning prior to and after the intervention taking place?

Outline of Chapters

This research report consists of five chapters. Chapter One provides contextualisation for the research. It outlines the main objectives of the study as well as the significance of this study, which is presented particularly as it pertains to the South African context. This chapter concludes with the proposed research questions for the study.

Chapter Two offers a definition of mathematical ability based on literature and further reviews the literature related to numeracy as foundational to the development of mathematical ability as well as other influencing factors. It also includes literature related to the measurement of mathematical ability. The theoretical framework of this study, Feuerstein's theory of structural cognitive modifiability and mediated learning, is then outlined. This is further expanded with literature related to deficient cognitive functions and Feuerstein's instrumental enrichment programme. An exploration of both international and South African literature on studies related to Feuerstein's instrumental enrichment, mediated learning, and other mediated interventions targeting early numeracy among at-risk populations is explored.

Chapter Three describes the specific methods used to conduct the study. This chapter begins with a description of the sample, instruments utilised, and research design. Thereafter, the specific procedure, ethical considerations, and data analytic techniques adopted for this study are presented.

Chapter Four presents the findings of this study. Three main findings are shared in relation to the research questions. The case study methodology allowed for the identification of general findings across the sample group as well as for a deeper understanding of these findings in the context of each learner.

Chapter Five forms the discussion and conclusion of this research report. It makes links between literature and the findings of this study and identifies possible gaps in research. This is followed by some discussion on the limitations encountered in the study. Recommendations are presented together with some elaboration on how this study may influence the remediation of mathematical difficulties. A discussion of future research opportunities in this area in the South African context is also provided.

CHAPTER TWO: LITERATURE REVIEW

Introduction

In this chapter contextualisation for the research is provided, starting with a review of the literature in the areas of mathematical ability and the factors that can affect its acquisition and development. The theoretical framework of this study, Feuerstein's theory of structural cognitive modifiability and mediated learning, is then outlined. This is further expanded with literature related to cognitive functions and Feuerstein's instrumental enrichment (FIE) programme. Finally, an exploration of both international and South African studies related to FIE, mediated learning, and interventions targeted at numeracy development are explored. A review of literature related to the measurement of mathematical ability is also included.

Mathematical Ability: What Does It Entail?

Although there is no ideal benchmark to describe or measure mathematical ability (Karsenty, 2020; Tosto et al., 2015), it is understood that mathematical ability is a human construct that can be defined cognitively or pragmatically (Karsenty, 2020). *Cognitive definitions* are used when considering mathematical ability from a theoretical perspective and this can then be defined as the ability to obtain, process, and retain mathematical information (Krutet͡skiĭ, 1976; Vilkomir & O'Donoghue, 2009), or it can be defined as the capacity to master new mathematical ideas and skills (Koshy et al., 2009). *Pragmatic definitions* are usually used when considering mathematical ability from the perspective of identifying learners' potential or assessing learning outcomes, such as the ability to perform mathematical tasks and to effectively solve given mathematical problems (Karsenty, 2020). These definitions are both general in nature and can be broken down into a number of parts, which may not be mutually exclusive to either definition.

Krutet͡skiĭ (1976) offers one of the most widely acknowledged and accepted definitions of mathematical ability, suggesting that it is made up of the capability to: use formal language and operate within formal structures of connections; generalise; think in a logical-sequential manner; perform shortcuts while problem solving; switch thinking directions; move flexibly between mental processes; and recall previously acquired concepts and generalisations. Although there is a widely accepted opinion that associates mathematical ability with intelligence, the relationship remains elusive. Xin and Zhang (2009) found some evidence that fluid intelligence is positively correlated with the ability to solve realistic mathematical word problems; however, mathematical ability goes further than number sense, arithmetic, and word problems.

Measuring and Evaluating Mathematical Ability

Over time it has become understood that using a standard IQ test is not an appropriate tool for evaluating mathematical ability and a shift has been made towards aptitude tests, such as the widely known Scholastic Aptitude Test – Mathematics (SAT-M). Despite the various criticisms of such aptitude tests and other psychometric assessments, they remain the predominant method to assess mathematical ability among learners (Karsenty, 2020). In a systematic review of empirical evidence from 34 quantitative studies (Tosto et al., 2015), the most common tests to assess mathematical performance were the Wide Range Achievement Test 3rd edition/revised (Wilkinson, 1993), the Woodcock-Johnson Test 3rd edition/revised (Woodcock et al., 2001) and, the Wechsler Individual Achievement Test, 2nd edition/numerical operation (Wechsler, 2001). Standardised tests such as the Wechsler Intelligence Scale for Children (WISC) (Wechsler, 2003) and Adults (WAIS) (Weschler, 2008) were also noted to be among the more frequently used measures.

Criticism regarding the credibility of such psychometric assessments, especially related to mathematics, includes that a single assessment result may be greatly influenced by the test taker's anxiety or fatigue, prior training and practise on similar tests, and the focus of such psychometric assessments on quantitative rather than qualitative aspects of mathematical ability. As a result, efforts are being made to expand the ways in which mathematical ability is measured. For example, Vilkomir and O'Donoghue (2009) have explored the development of a low-cost assessment tool that is qualitative in its approach, which is useful when considering mathematical ability from a cognitive perspective. Some other studies have focused more narrowly on the specific mathematical skill being assessed (for example, the development of the concept of number), which is relevant when considering mathematical ability from a performance perspective. Examples of the latter approach to measurement are the use of a worksheet for counting and matching quantities to numbers (Chin & Fu, 2021) and the use of an English version of the originally Finnish early numeracy test, which includes tasks covering numerical relational skills, counting skills, and arithmetical word problems (Aunio et al., 2016; Aunio et al., 2021).

The most frequently used measurements of learners' mathematical ability in South Africa are the three mathematics subtests from the Wechsler Individual Achievement Test, Third Edition (WIAT-III) (Wechsler, 2009). The WIAT-III is, however, standardised against a United Kingdom (UK) population and no local norms are currently available. Such traditional assessment tools do provide relevant information but must be put in context and used alongside other assessment tools. The WIAT-III is discussed in greater detail in Chapter Three. The early detection of low numeracy performance in early education is crucial as it provides the opportunity for early intervention. Research indicates that such early intervention is an effective way to support and remediate learning and possibly prevent later learning difficulties (Heckman, 2012; Wang et al., 2016). Locally there is a need to develop evidence-based, inexpensive and user-friendly assessment tools as well as pedagogical teaching materials for use with learners at risk of mathematics learning difficulties (Aunio et al., 2016, Aunio et al., 2021).

Various labels and key words are used in the literature to describe mathematical problems (Tosto et al., 2015), making it complicated to compare studies, but this also raises awareness of the importance of defining what is meant by mathematical ability or mathematical performance and aligning the measurement accordingly. As demonstrated in a recent study (Orbach et al., 2020), various domains of mathematics require different mathematical skills and have differing cognitive function demands. Orbach et al. (2020) provided evidence that the association between cognitive executive functions and mathematics achievement depends on the specific mathematics skill and test type.

Numeracy as a Foundation to Mathematical Ability

Numeracy is the part of mathematics called arithmetic and provides us with an efficient way of communicating ideas and information (Emerson & Babtie, 2014). A solid foundation of numeracy requires good number sense, which entails understanding what numbers mean, how they relate to each other, and being able to use them to solve problems in the world around us. Numerous studies have found that early numeracy skills are a good indicator of one's performance in mathematics later on (Aunio & Niemivirta, 2010; Aunio et al., 2016; Desoete et al., 2009; Jordan et al., 2009; Mercader et al., 2018; Tobia et al., 2016; Watts et al., 2014), highlighting the importance of developing a solid foundation in numeracy. There is a wealth of literature supporting mathematics requiring 'hierarchical learning', which confirms the cumulative nature of developing these skills. Robert Gagné's (1962) theory of learning proposes a group of hierarchically organised intellectual skills that are inter-related and is a useful reference to consider how numerical ability develops. In this theory, lower-level capabilities form the basis for the learning of higher order capabilities (Scandura & Wells, 1967). In a vertically integrated subject such as mathematics, learning deficits become cumulative and, if left for too many years, can become almost insurmountable to catch up (Spaull & Kotze, 2015).

According to Emerson and Babtie (2014), there are three main aspects of mathematics that may cause difficulty for some pupils. Firstly, mathematics is abstract in that the symbols 0 to 9 are combined in several ways to form many possible numbers. For numeracy to be developed it is crucial to understand that these abstract numbers are derived from and represent concrete objects. Working with concrete equipment to help develop a sense of numbers visually is helpful to make meaning of the abstraction of mathematics. Secondly, mathematics requires logical reasoning and can be thought of as a 'building block' subject that requires hierarchical learning. For mathematics to be developed, learners need to be able to draw on previously learnt facts from their long-term memory and apply them to a new and more involved context. Thirdly, mathematics is complex because a diverse range of information (for example, time, distance, temperature, and quantity) is represented in a few numerical symbols, which can also be represented in many different ways (for example, whole numbers, fractions, and percentages). Further, the mastery of the operations of addition, subtraction, multiplication, and division are all required to manipulate numbers and derive meaning. Emerson and Babtie (2014, p. 4) stated that "pupils who are still struggling to count and compare numbers will not be able to engage with more complex numerical tasks until they have learnt the basics of the number system."

Numeracy in the South African Context

The despairing state of basic numeracy and mathematical ability in South Africa is commonly acknowledged and supported by results from regional, national, and international studies (Reddy et al., 2016). The general agreement across studies is that South African scholars are performing below their peers in mathematics when compared with both developed and developing countries (Reddy et al., 2016; Spaull & Kotz, 2015). According to Modisaotsile (2012), it is recognised that literacy and education equip people to find formal employment for themselves and create work prospects for others. Further, Van der Berg et al. (2011) suggested that without solid foundations in literacy and numeracy South African learners will not obtain the skills needed for development and growth in the country to address poverty and inequality. The Department of Education (2011) recognises the need to address the situation and The Action Plan 2024 acknowledges that reaching basic levels of competencies in reading, writing, and mathematics is an essential prerequisite for future life learning. It is unsurprising that of the first thirteen Action Plan 2024 goals, six are related to numeracy (Appendix A).

A review of large-scale assessments such as the Trends in International Mathematics and Science Study (TIMSS), the National Systemic Evaluation, the National School Effectiveness Study, and the Southern and Eastern African Consortium for Monitoring Educational Quality (SAMEQ) Study was conducted by Spaull and Kotze (2015) and focused on quantifying the lack of learning and remedial opportunities in mathematics. This review study included children attending South African schools in Grade 3 to Grade 9 over the years 2007, 2008, 2009, and 2011. Two main findings supported by numerical data from this review were firstly that only the top 16% of South African Grade 3 learners are performing at an appropriate Grade 3 level, and, secondly, the gap between the poorest 60% of learners and the wealthiest 20% of learners is equivalent to three grade levels by the time of Grade 3, growing to four grade levels by Grade 9. The clear recommendation from this study is that any intervention to improve numeracy levels and mathematics achievement needs to happen as early as possible. This thought is driven not only by the prevalence of underperformance in the early schooling years but also because remediation is considered to be most effective, and with an exponential benefit, the younger the child is (Bai et al., 2020).

A nationally representative survey, TIMSS 2015 (Mullis et al., 2016), showed that 61% of Grade 5 learners in South Africa could not add and subtract whole numbers, had no understanding of multiplication by one-digit numbers, and could not solve simple word problems. The Primary Mathematics Research Project (Schollar, 2008) studied over 7,000 learners from 154 South African schools and found the underlying cause of poor mathematical capability to lie in an inability of learners to extend their skills from basic counting to more complex calculating. Compounding the problem is the reality of many learners being promoted from one grade to the next without the necessary and satisfactory accomplishment of the core competencies of the preceding grade. This results in a ‘multi-grade’ class with wide discrepancy in learner ability and an almost impossible classroom environment in which to teach the required skills and competencies.

Smaller scale research studies with South African children also confirm the poor level of numeracy skills in the early years of education (Aunio et al., 2016; Aunio et al., 2021). In a cross-sectional study of 443 Grade 1 learners from Gauteng province schools (Aunio et al., 2016), early numeracy skills were measured and significant differences in ability were found depending on the context from which the child came. The main contextual factors included whether or not English was a first language and the type of schooling (public versus private). Additional factors including the age at which the child started school, numeracy-related experiences in early childhood, and individual differences in cognitive skills may also partially explain the differences. These findings have implications for teaching basic numeracy skills with a 'one size fits all' national curriculum. A further study by Aunio et al. (2021) investigated whether early numeracy skills of South African Grade 1 learners who were identified as at-risk for mathematical learning difficulties could be improved with an intervention programme. This study was a first to control for confounding variables, which included executive functions, language skills, and previous school attendance. The main finding of this study was the group that benefitted from the intervention improved in their numerical skills more than those in the control group.

The present body of South African research on mathematics achievement highlights the deficiency in gains of basic numeracy skills and the subsequent hurdles to extended learning of mathematics and economic reform. The South African education system is fraught with challenges. One controversial area is psychological assessment and scholastic performance assessments, which are largely compromised due to the lack of relevant norms and/or locally developed assessment tools. The diversity and complexity of South African children (language, race, culture, background, social-economic status and so forth) requires a new approach to better suit the needs at hand and to provide a more relevant and fair approach to assessment and remediation. This new approach should provide insight to the child's propensity to learn regardless of previous experience (Laher & Cockcroft, 2019). The early detection of low numeracy performance in early education is crucial as it provides the opportunity for early intervention. Research indicates that such early intervention is an effective way to support and remediate learning and possibly prevent later learning difficulties (Wang et al., 2016).

Barriers to Success in Mathematics and Confounding Variables

Many different factors may make acquiring numeracy skills and learning mathematics challenging. Butterworth (2008) includes behavioural problems, missing lessons, poor or inappropriate teaching, and mathematics anxiety as causes for low numeracy, while Emerson and Babtie (2014) consider some deficits in cognitive functioning to be some of the key barriers to success in mathematics. For example, long-term memory difficulties can hinder any rote or off by heart learning; short term memory difficulties can hinder any transfer of skill to long-term memory; working memory challenges may make holding the necessary information difficult; and sequencing difficulties can negatively impact learning to count, following a series of instructions, processing and remembering different counting sequences, and managing the successive load of counting to calculate answers to sums (Emerson & Babtie, 2014). There is also growing evidence and support for the impact that a number of neurodevelopmental and specific learning disorders, as classified in the *Diagnostic and Statistical Manual of Mental Disorders, 5th Edition Text Revision* (*DSM-5-TR*), may have on a learner's ability to learn mathematics and develop sound numeracy skills. According to Emerson and Babtie (2014) these include the neurodevelopmental disorders of specific language delay, dyscalculia, dyslexia, dyspraxia, and attention deficit hyperactivity disorder (ADHD), and they also propose that sensory integration disorder and mathematics anxiety will have an impact. In the next section of the literature review some of these potential influencing factors are explored in more detail.

Neurodevelopmental Disorders

Developmental Dyscalculia

Developmental dyscalculia (DD) is classified in the *DSM-5-TR* as a specific learning disorder (F81.2) with impairment in mathematics: number sense, memorisation of arithmetic facts, accurate or fluent calculation, and accurate mathematics reasoning (American Psychiatric Association [APA], 2022). Although mathematical performance deficits such as DD may arise for many reasons, such as environmental (e.g. poor teaching), socio-economic (e.g. low status), psychological (e.g. mathematics anxiety), or behavioural factors (e.g. attention challenges), with the advancement of neuroimaging, more is understood about the neural basis of the disorder (Butterworth & Laurillard 2010; Chinn, 2020; Dowker, 2022; Price & Ansari, 2013; Rapin, 2016; Rubinsten, 2015; Sokolowski et al., 2017). DD can be categorised as primary DD or secondary DD. Primary DD is associated with the impaired development of brain mechanisms responsible for processing numerical information, while secondary DD stems from external factors such as those described above (Price & Ansari, 2013). There is mounting agreement that the underpinning of primary DD is a genetic disorder of 'number sense', the ability to represent and manipulate numerical magnitude non-verbally on an internal number line (Von Aster & Shalev, 2007). The development of this spatially orientated number line occurs during the primary years of school and requires cognitive components such as working memory and number symbolisation (language). As a result, DD is often not isolated and has a high comorbidity (indicated as two-thirds) with developmental dyslexia and ADHD (Berch & Mazzocco, 2007; Luoni et al., 2023; Von Aster & Shalev, 2007).

As the essential deficit in DD appears to be in *understanding* basic number concepts, Butterworth (2018) suggests that the value of interventions to assist dyscalculic learners should be judged not only on a change in performance relative to existing standards, but also in terms of the learner's understanding of number concepts. Butterworth (2018) also suggests that neuroimaging could also be used to evaluate whether interventions create compensatory strategies or if they make the brain operate more normally, as has been done with dyslexia intervention (Eden et al., 2004; Shaywitz et al., 2004). We now understand DD as a neurodevelopmental disorder with a biological origin and specific behavioural signs (Rubinsten, 2015).

Developmental Dyslexia

Developmental dyslexia is classified in the *DSM-5-TR* as a specific learning disorder (F81.0) with impairment in reading: word reading accuracy, reading rate or fluency, and reading comprehension (APA, 2022). Dyslexia is the term used to refer to a pattern of learning difficulties characterised by problems with accurate or fluent word recognition, poor decoding, and poor spelling abilities. Dyslexia can also impact reading comprehension and the acquisition of mathematical ability, learning, and reasoning (Kunwar & Sapkota, 2022). Chin and Ashcroft (2017) state that as high as 60% of dyslexic people have some difficulty with mathematics. Literature suggests that the main areas a dyslexic learner's ability to acquire mathematics skills may be impacted by are reading and comprehension (Almahrag, 2021; Snowling, 2019), working memory and processing speed (Almahrag, 2021; Chinn & Ashcroft, 2017; Roitsch & Watson, 2019), mathematics anxiety and self-esteem (Jordan et al., 2014; Kunwar, 2020), and cognitive competency (Almahrag, 2021; Chin & Ashcroft, 2017). Given these difficulties, a dyslexic learner may struggle to learn basic mathematics vocabulary and symbols; memorise multiplication tables; tell time; interpret specific vocabulary; and carry out arithmetic calculation (Snowling, 2019).

One important domain general cognitive function for mathematical ability is visual spatial processing (Atit et al., 2022). Research into associations between visual spatial abilities and dyslexia has mostly been contradictory (Duranovic et al., 2015). Both compensatory and deficit models have been explored, proposing in some cases that a dyslexic profile may be associated with strong visual spatial skills and, in others to the contrary, a dyslexic profile may be associated with weaker visual spatial skills (Duranovic et al., 2015).

Most often, neurodevelopmental disorders or specific learning disorders such as dyslexia and dyscalculia are investigated in isolation; however, often both disorders co-occur and, given the presence of one, the prevalence of the other is estimated to be approximately 40% (Dirks et al., 2008; Wilson et al., 2015). A study by Peters et al. (2018) compared the neural pathways of children with dyscalculia and/or dyslexia and found that, brain activity during arithmetic tasks may be more aligned than initially thought, despite observed differences at a behavioural level.

Attention Deficit Hyperactivity Disorder

ADHD is a neurodevelopmental disorder classified in the *DSM-5-TR* as a persistent pattern of inattention and/or hyperactivity-impulsivity that interferes with functioning or development, as is characterised by (1) inattention (F90.0) and/or (2) hyperactivity and impulsivity (F90.1) or a combination of both (F90.2) (APA, 2022). It has been found that children with ADHD have greater risks of academic difficulties, greater grade repetitions, challenges with classroom functioning, higher rates of school dropout, and their relationship with teachers and peers may be negatively impacted (Arnold et al., 2020; Evans et al., 2020; Kent et al., 2011; Zoromski et al., 2015). Due to the complex and heterogenous nature of ADHD, further research is required to enrich understanding about the processes underlying educational struggles (Tosto et al., 2015). Considerable literature to date has focused on the relationship between ADHD and dyslexia/reading difficulties (Al Dahhan et al., 2022; Fernández-Andrés et al., 2021; Lonergan et al., 2019); however, literature is growing on the relationship between ADHD and mathematical ability (Orbach et al., 2020; Sella et al., 2019; Tosto et al., 2015). In a systematic review across a total of 30 cross-sectional and four quantitative longitudinal studies of ADHD and mathematical ability (Tosto et al., 2015), substantial evidence suggested a negative relationship between ADHD symptoms and mathematical ability. Interestingly, the association was noticeably more marked for the inattentive presentation of ADHD than for the hyperactive/impulsive ADHD presentation. More specifically, nine out of the 11 studies (Antonini et al., 2013; Bauermeister et al., 2012; Gremillion et al., 2012; Greven et al., 2014; Hart et al., 2010; Massetti et al., 2008; Papaioannou et al., 2014; Thorell, 2007; Todd et al., 2002) looking at predominantly inattentive ADHD found a negative correlation with mathematical performance while only three (Gremillion et al., 2012; Greven et al., 2014; Hart et al., 2010) out of the eight studies looking at predominantly hyperactive-impulsive symptoms found an association with mathematical difficulties, and four out of the six studies that looked at ADHD presenting with combined symptoms (Antonini et al., 2013; Gremillion et al., 2012; Greven et al., 2014; Papaioannou et al., 2016; Todd et al., 2002) reported a significant association. The stronger relationship between attentional factors and mathematics compared to hyperactive-impulsive factors suggests a difference in the relationship of these two ADHD domains with mathematics, further highlighting the heterogeneity with the disorder and the need for further research (Tosto et al., 2015).

In some cases, ADHD is untreated and although there is much debate (Owens & Jackson, 2017), literature does support the benefits that medically treated ADHD can have on academic difficulties (Arnold et al., 2020; Shaw et al., 2012), especially when the symptoms of ADHD are considered to be more severe. The severity of ADHD seems to be an important consideration as it appears that children with more severe ADHD-related behaviours fare worse academically than children with relatively less severe ADHD-related behaviours (Efron et al., 2014; Shaw et al., 2012; Stuart et al., 2009). Owens and Jackson (2017) found that among children with more severe ADHD related behaviours, who were diagnosed with but not medically treated for ADHD, there was an association with lower reading and mathematics achievement. However, an ADHD diagnosis and medication treatment appeared to mediate the impact of more severe ADHD related symptoms to such an extent that their scores on reading and mathematics were not statistically different from undiagnosed, un-medicated peers.

In an extensive systematic review (Arnold et al., 2020), it was found that the majority (75–79%) of both test achievement and academic performance outcomes were reported to be lower for individuals with untreated ADHD than those without ADHD. Keilow et al. (2018), using data from a Danish administrative register, found significant positive effects of consistent treatment, compared to part or full discontinuation of treatment, on both exam and grade point average performances. Similarly, using a register of Swedish learners, Jangmo et al. (2019) also found a positive association between school performance and treated ADHD and specifically found that the greater the length of ADHD treatment medication usage, the more beneficial the impact was. They also identified a more positive outcome for mathematic-related performance outcomes than language-related skills (e.g. reading and writing). The latter is supported by a meta-analysis (Kortekaas-Rijlaarsdam et al., 2019) of the effect of methylphenidate on academic performance, reporting positive effects on mathematics productivity and accuracy, but only on productivity for reading.

Anxiety Disorders

Anxiety disorders are some of the most widespread mental health issues worldwide (Baxter et al., 2013; Remes et al., 2016), exacerbated further by the impact of the Covid-19 pandemic and current war conflicts (Duan et al., 2024; Gondek & Young, 2024; Santomauro et al., 2021). In a literature review of 40 studies across different countries, prevalence rates for anxiety disorders were nearly 17%, taking into consideration major types such as generalised anxiety disorder, panic disorder, phobia, social anxiety as well as post-traumatic stress disorder (PTSD) and obsessive-compulsive disorder (OCD) (Somers et al., 2006). Anxiety disorders are not only restricted to an adult population but are also the most common mental health challenges affecting young people (Bhatia & Goyal, 2018; Creswell et al. 2020; Mohammadi et al., 2020; Rapee et al., 2023; Steinsbekk et al., 2022).

Mathematics Anxiety

In an education setting, learners may suffer from specific test and/or performance anxieties that are associated with a specific subject or knowledge area, the most prominent of which is mathematics anxiety (Barroso et al., 2021; Foley et al., 2017; Luttenberger et al., 2018). Mathematics anxiety has been defined as feelings of apprehension and increased psychological reactivity when an individual deals with mathematics, such as having to manipulate numbers, solve mathematical problems, and when they are exposed to a situation where they have to evaluate in a mathematics context (Carey et al., 2017; Hopko et al., 2003). Mathematics anxiety affects many people, both in school and later in everyday aspects of adulthood (Luttenberger et al., 2018; Sokolowski & Ansari, 2017). It manifests itself on an emotional, cognitive, and physiological level and leads to outcomes such as a decrease in mathematics performance (Luttenberger et al., 2018; Skagerlund et al., 2019).

Devine et al. (2018) investigated the comorbidity of developmental dyscalculia and mathematics anxiety in a large sample of school children. The total sample of 1,757 children comprised 8- to 9-year-old primary and 12- 13-year-old secondary school children. The study found learners with developmental dyscalculia at twice the risk of high mathematics anxiety as learners with typical mathematics performance, and that there was a greater co-morbidity of mathematics anxiety and developmental dyscalculia among girls than boys. Surprisingly the study also found that 77% of children with high mathematics anxiety had typical or high mathematics performance. This finding suggests that cognitive and emotional mathematics problems largely dissociate and challenge the assumption that mathematics anxiety is exclusively linked to poor mathematics performance. Mathematics anxiety can influence many outcomes negatively including performance, working memory, learning behaviours such as procrastination, and academic and vocational choices (Luttenberger et al., 2018). Studies related to mathematics anxiety and performance show a negative relationship. Although there appears to be more studies conducted with samples of secondary and tertiary students (Gabriel et al., 2020; Khasawneh et al., 2021; Zhang et al., 2019), more recently the impact of mathematics anxiety among younger children has been explored with similar findings (Cargnelutti et al., 2017; Namkung et al., 2019; Van Mier et al., 2019).

Young et al. (2012) suggested that when children with high mathematics anxiety solve mathematics problems, the amygdala, a part of the brain important for processing and experiencing emotions (including fear and anxiety), is activated while the areas of the brain that are involved in working memory and mathematical processing (the dorsolateral prefrontal cortex and the intraparietal sulcus) are less activated when compared with the same brain areas in children with low mathematics anxiety. This neurocognitive finding suggests that the emotional responses caused by mathematics anxiety are related to the fear and pain network of the brain (Artemenko et al., 2015).

Research is underway to identify possible interventions to help with mathematics anxiety. Park et al. (2014) explored the role that expressive writing could play in reducing mathematics anxiety and found that when children with mathematics anxiety wrote about their mathematics-related worries, their scores improved. A second study found that doing breathing exercises before a mathematics test helped them to calm down and their test scores improved (Brunyé et al., 2013). A more recent study among a sample of 300 university students explored the impact of four different interventions on the state of mathematics anxiety but with unpromising findings (Ganley et al., 2021).

Obsessive Compulsive Disorder

Obsessive-compulsive disorder (OCD) is characterised by intrusive and distressing thoughts that can be difficult to control (obsessions) and compulsive behaviours or rituals (compulsions) that are engaged in to try and alleviate anxiety related to the obsessions (APA, 2022). One of the key diagnostic criteria for OCD is that the obsessions or compulsions are time-consuming (for example, they take more than one hour per day). Further, a well-documented characteristic of OCD is perfectionism with some individuals reporting a sense of 'incompleteness' or uneasiness until things look, feel, or sound 'just right' (APA, 2022). Leininger et al. (2010) explored considerations for teaching learners with OCD and highlighted that despite having to manage their OCD symptoms continuously, learners struggling with the disorder will often try and hide the symptoms from those around them. A study of 5- to17-year-olds indicated that the two most common problems resulting from OCD in this age group were school-related: (a) concentrating on schoolwork; and (b) completing homework (Piacentini et al., 2003). According to Parker and Stewart (2004), learners with OCD typically perform below their academic potential. They also tend to have more learning disorders, especially nonverbal learning difficulties than those without OCD (Adams, 2004), suggesting they may struggle with tasks that require visual-spatial skills, such as mathematics and handwriting.

A study among 14-year-old Bengali eighth grade learners revealed that learners with subclinical OCD symptoms had poorer cognitive processes, lower achievement, and lower intelligence-achievement correlations than those without symptoms (Malakar & Basu, 2017). Shahrouri (2017) also found that OCD behaviour was associated with poorer academic performance and included symptoms such as too much attention to detail, lack of confidence in executing a task, repeating activities, and failing to complete activities. The results of both of these studies are congruent with earlier findings, such as those by Piacentini et al. (2003) on the impact of OCD on school learners. According to Penn and Leonard (2001), traits such as competitiveness, self-criticism, incessant worry, dissatisfaction over performance, controlling a situation, procrastination, and increased expectations are common among learners and can lead to frustration, depression, and/or demotivation.

Role of the Senses on the Acquisition of Numeracy and Mathematical Ability

From a young age we develop a sense of numbers and subsequent numeracy and mathematical ability by engaging with the environment in a multisensorial way. The mathematical ability of learners who are impaired in any of their senses may be negatively impacted, especially without the implementation of adapted approaches and support to their teaching. For example, impaired vision can have a significant impact on mathematical ability. Mathematics often relies on visual representations, such as graphs, diagrams, and geometric figures; it involves reading and writing, spatial awareness, working with tangible manipulatives and so forth, all of which may be more challenging with impaired vision. It is important to note that individuals with impaired vision can still develop strong mathematical abilities with appropriate accommodations and support. This may involve the use of assistive technology, tactile materials, verbal descriptions, or alternative teaching strategies tailored to their specific needs. Recent studies have explored the benefits of alternative ways to teach visually impaired learners mathematics (Bouck & Weng, 2014; Spinczyk et al., 2019).

Similarly, impaired hearing can also have an impact on mathematical ability (Ariapooran, 2017; Manchishi, 2015; Marcelino et al., 2019). Among others, difficulty in hearing can affect the acquisition and understanding of mathematical vocabulary and concepts, may cause challenges with mathematical instructions and explanations, and can limit the ability to engage in verbal problem-solving activities and collaborative learning. Some mathematical tasks rely on auditory cues and an impairment in hearing may make it difficult to follow and interpret such cues. It is however noteworthy that the extent of the impact of impaired hearing on mathematical ability is likely to be moderated by the severity of the impairment, individual coping strategies, and the availability and implementation of suitable teaching and classroom accommodations and support. Recent studies have explored the benefits and effectiveness of alternative ways to teach mathematics to learners with hearing difficulties (Aftab et al., 2024; Rahmawati & Pamungkas,2023; Tanridiler et al., 2015; Zanin & Rance, 2016).

Theoretical Framework: The Theory of Structural Cognitive Modifiability and Mediated Learning

The Theory of Structural Cognitive Modifiability

The theory of structural cognitive modifiability (SCM) is the umbrella theory of Professor Ruben Feuerstein's belief system and refers to the idea that humans, regardless of their age, limitations, or developmental stage, have the ability for the cognitive pathways of their brains to change and be modified. According to Feuerstein et al. (2006), SCM can be defined as changes of a structural nature in the brain that shape cognitive development. The theory of SCM believes that change is possible and desirable and that new neural pathways are able to be made (Feuerstein, 2000; Feuerstein 2003). Feuerstein's view led to new conceptual formulations of intelligence, such as understanding intelligence to be changeable rather than static or fixed. A number of crucial elements need to work together to achieve such cognitive development, each of which is subsequently reviewed in more detail.

The Zone of Proximal Development and Mediated Learning Experience

The zone of proximal development (ZPD) is a concept developed by Vygotsky (Vygotsky & Cole, 1978) and further expanded upon by Feuerstein (1974). The concept refers to the difference between what a learner can do independently and what they are able to achieve with guidance and support (mediation) from a more knowledgeable individual. According to Feuerstein, the ZPD is not fixed and can be developed through intentional and systematic intervention, which he terms mediated learning experience (MLE). Feuerstein believed that every individual has the potential for cognitive growth and that it is the responsibility of more knowledgeable others, for example teachers and/or parents, to create an environment that fosters growth (Kozulin, 2010). His approach to ZPD focuses on a mediated learning experience that involves a mediator (such as a parent, teacher or even a more skilled peer), actively engaging with the learner to guide and scaffold their learning. In doing so, the mediator helps the learner to bridge the gap between their current learning abilities and their potential abilities.

According to the SCM theory, both direct learning and mediated learning are required for cognitive growth to take place. Direct learning occurs without any intervention whilst mediated learning happens when another human intervenes between the stimulus, the learner, and the environment (Tzuriel, 2021). MLE refers to those “human interactions that generate the capacity of individuals to change, to modify themselves in the direction of greater adaptability and toward the use of higher mental processes” (Feuerstein, 1979, p. 10). Through the sharing of an intentionally selected and meaningful stimulus, the mediator helps the child to develop their thinking and ability in other areas despite possible cognitive, motivational, situational, or cultural hindering factors. Literature demonstrates that children who benefitted from qualitative MLE interventions show higher levels of cognitive modifiability and intellectual functioning than those who have benefitted less from such intervention (Tzuriel, 2021).

Cognitive Functions

Cognitive functions are defined by Feuerstein at al. (1979) as “compounds of native abilities, learning habits, attitudes towards learning, motivational orientations, and cognitive strategies” (as cited in Tzuriel, 2021, p. 27). Feuerstein conceptualised these cognitive functions into three phases of cognitive processing: (1) input (data gathering); (2) elaboration (data processing); and (3) output (data expression). He proposed that an area of deficiency may present itself in one or more of the phases and they are considered key to understanding children’s performance. At an input level cognitive functioning may be impaired by a compromise in the quantity and/or quality of information gathered in relation to a problem, object or experience. Although compromised gathering of data at the input level can also affect one’s ability to function optimally at the elaboration and output levels, it is not always necessarily the case. At an elaboration level, cognitive functions may be impacted by factors that hinder the effective use and elaboration of available data and cues. In some instances although elaboration is original, creative and correct, it may result in incorrect responses if the information gathered at the input level is incorrect. Cognitive functioning at the output level may be weakened when there is an inadequate ability to communicate final responses. It is an important consideration that even data that is adequately perceived at the input level and also elaboration appropriately elaborated can still be expressed incorrectly and incongruently if challenges exist at the output level.

When there is a deficit in cognitive functioning it interferes with the child's ability to benefit fully from the MLE. Feuerstein suggested a list of deficient cognitive functions that are responsible for a variety of thinking skills (Appendix B). It is to be noted that this list is not considered conclusive but rather representative of the major challenges that can affect an individual's cognitive processes. The full elaboration of the list of deficient cognitive skills in each of the phases of cognitive processing are provided in Tzuriel (2021, pp. 28–34). This list of deficient cognitive functions is useful to teachers and parents as it improves understanding of how to help a learner who is experiencing difficulties, enabling the teacher or parent to establish whether the difficulties are due to a lack of knowledge or due to a challenge in cognitive functions. This insight can then inform the appropriate mediation.

Feuerstein Instrumental Enrichment

The Feuerstein instrumental enrichment (FIE) is a critical thinking programme originally developed by Professor Reuven Feuerstein. It is made-up of a series of tasks that are not related to the school curriculum that are designed to strengthen learning skills through a number of different cognitive activities. The FIE programme has two parts: The IE Basic programme for young children and low-functioning individuals, and the IE Standard programme, which is used with children aged nine and older, high school learners, and adults of all ages. Those participating the in the programme are guided through various tasks by a mediator who facilitates the development of strategies for problem solving and analytical thinking. These strategies are applicable not only to the task at hand but to other areas of life. Both programmes are based on structured paper-and-pencil exercises that gradually increase in levels of difficulty and abstraction. The materials presented as workbooks called "instruments" and each instrument focuses on a specific cognitive area. All of the instruments require a mediated learning experience.

The FIE-Basic programme is aimed at enhancing domain-general cognitive functioning in a number of areas (systematic perception, self-regulation abilities, conceptual vocabulary, planning, decoding emotions, and social relations) as well as transferring learnt principles to daily life domains (Kozulin et al., 2010). Like the original FIE programme, the FIE-Basic is designed to provide a healthy environment for the development of cognitive and meta-cognitive structures and each instrument works on both subject content and thinking/cognitive skills. One of the FIE-Basic instruments which is used in this study is the FU2G instrument (Appendix C). FU2G helps children to establish the concept of number and the basic mathematical operations. This is achieved as the instrument helps the learner to discover the way in which objects can be aggregated, segregated, summarised and described. The tasks include counting and grouping simple visual stimuli such as dots, triangles, circles, squares and so on. According to (Kozulin et al., 2010, p. 4) “the instrument promotes systematic exploration of data, systematic following of rules, and consideration of several sources of information, comparison, categorisation, inferential thinking and deductive reasoning” . Acquisition of the concept of number is one of the most important objectives of the instrument, helping the learner to understand both ordinal (sequencing) and cardinal (quantity) qualities of numbers. According to Piaget (1997), one of the greatest challenges of the concept of number is the structure to make it possible that “all 3s are 3”, regardless of what else they are. Three ducks are 3, three sweets are 3, and so on. A group of the same number can therefore be homogenous or heterogenous. A more elaborative overview of this instrument is given in Chapter Three.

Learning from Local and International Studies Related to MLE and FIE

Published literature displays the efficacy of mediation based on Feuerstein’s SCM-MLE theory (Tzuriel, 2021). A study explored the effectiveness of cognitive intervention with the FIE-Basic programme among a sample of children with developmental disabilities (Kozulin et al., 2010). The participants were children with developmental coordination disorder, cerebral palsy, intellectual impairment of genetic origin, autistic spectrum disorder, ADHD or other learning disorders, with a mental age of 5–7 years, from Canada, Chile, Belgium, Italy and Israel. The experiment group of children (*n*=104) received 27 to 90 hours of FIE-Basic programme interventions over a period of 30 to 45 weeks. The comparison group (*n*=72) received general occupational and sensory-motor therapy. All participating children were assessed before and after the intervention using the Revised Wechsler Intelligence Scale (WISC-R). The experiment group demonstrated a significant advantage in three subtests (similarities, picture completion and picture arrangement) as well as the Ravens Coloured Matrices. Results showed a significant advantage of the experimental group over the control group suggesting that it is possible to improve the cognitive functioning of children with developmental disability. Interestingly, there were no differences by aetiology; however, greater gains were made by children who received the intervention in an educational setting where all teachers were committed to and consistent with the principles of mediated learning.

South African studies have explored the impact of MLE among a broad range of learners. In a study among a sample of Grade 5 learners in a remedial school *(n*=20), Seabi and Amod (2009) investigated whether a group of children (*n*=10) receiving a group-mediated intervention programme would perform better on the Ravens Coloured Progressive Matrices than a group of children (*n*=10) receiving an individual mediated learning intervention. The intervention was set variations B-8 to B-12 from Feuerstein's Learning Potential Assessment Device. The results yielded significant differences in only the individual mediation group compared to the control group. Despite this significant improvement within the one group, no significant difference was found between the group mediation and individual mediation groups. The researchers concluded that perhaps the intense and individualised intervention had a crucial impact on the findings within this group. The insignificant change in the pre-test post-test results of the group mediation were surprising and failed to replicate findings from other studies (Seabi & Cockcroft, 2006; Skuy et al., 2002; Tzuriel & Kaufman, 1999). The researchers argue that perhaps the short intervention time influenced the findings.

A further study also explored the impact of a MLE intervention on multi-racial Grade 4 to Grade 7 remedial school learners' cognitive functioning as measured by the Ravens Coloured Progressive Matrices (Seabi, 2012). An experimental group consisted of 42 percent (*n*=28) of the total sample of Grade 4 and Grade 5 learners while the control group comprised 58 percent (*n*=39) of the total sample of learners from Grade 6 and Grade 7. The design of the study was pre-post quasi-experimental with a 30- to 45-minute intervention given to each learner within a week. The results revealed that the experimental group improved significantly from the pre-test to the post-test, suggesting that MLE is relevant and beneficial to learners with special needs. Two limitations of this study include the varied grade composition of the control group as well as the short duration of the intervention. This study does however support the idea that deficiencies that detract from well-functioning execution on cognitive tasks among remedial school learners can benefit from mediation.

A study among 111 South African tertiary engineering students investigated the effects of MLE, tutor support, and peer collaborative learning on academic and intellectual functioning (Seabi & Cockcroft, 2012). Academic results were measured by mid-year and end-of-year marks and intellectual functioning was measured by the Ravens Advanced Progressive Matrices. After a five-week intervention period, results of the mediation group demonstrated significant improvements on both measures, an indication that MLE was a more effective way to enhance students' intellectual functioning and academic performance.

A study among a selected group of Grade R learners was based on the principles of Feuerstein's mediated learning and explored the extent to which a researcher-developed curriculum-based intervention programme could impact children's executive functions (Esterhuizen & Grosser, 2014). The researchers found a striking improvement in the learners' executive functioning related to working memory, cognitive flexibility, and inhibitory control, and is a first step toward new research with diverse groups of participants to claim convincingly that mediated learning improves cognitive development in Grade R learners.

There appears to be no local research available on MLE and mathematics; however, the findings of two additional international studies are informative. Emmanouil and Georgios (2018) studied the effect of a mediated learning experience in a sample of ten children aged ten years/Grade 5 with learning difficulties in terms of a deeper understanding of mathematical concepts. The MLE took place over five one-hour lessons with a focus on fractions. Three data collection points were used: diagnostic essay marks before and after the MLE, interviews, and video recordings. The MLE was not based on a Feuerstein instrument but was MLE in its approach. The results show a marked improvement on the diagnostic essay marks as shown in Appendix D.

A second international study carried out in Egypt explored whether an educational activity programme based on Feuerstein's programme and Gardner's theory increases excellence and creativity in mathematics (Elsayed et al., 2021). An experimental group of 35 8th grade girls and a control group of 26 8th grade girls in the same school made up the sample. Over a period of six weeks with 30 lessons in total, the experimental group was exposed to ten of the FIE instruments. Notwithstanding the limitations acknowledged by the researchers, the experimental group was found to have significantly higher excellence in mathematics and creativity on mathematics scores.

A single case study of how a primary school remedial mathematics teacher incorporated an instructional intervention into her teaching practises in order to teach counting to a learner with mathematical learning difficulties (an at-risk dyscalculic learner) revealed that the mediated intervention (reconnecting learning) improved the counting ability of the learner (Chin & Fu, 2021). This study focused on the abilities of processing and representing numerosity of dyscalculic learners. The study proposed that it may be possible to unlock an individual's potential and assist them to overcome mathematical difficulties by blending Feuerstein's (2015) structural cognitive modifiability theory (discussed previously) with Tall's (2013) theory (which offers an explanation for how children learn counting naturally).

Chin and Fu (2021) explained that the research involved the teacher demonstrating how to count with the learner (intentionality) and the learner providing positive feedback (reciprocity) so that the illustration could continue. It also involved the teacher mediating the meaning of counting to the learner and bridging the idea of counting using language. Notwithstanding the acknowledged limitations of the study, which included the small sample size and narrow focus of the study (Chin & Fu, 2021), two main themes emerged in this research. The first highlights that a reconnected learning intervention requires mediation and active learning and is an instructional-based intervention. The second theme is centred around reconnecting learning, appearing to be a potentially useful intervention for teaching counting to those with a dyscalculic profile. Overall, the findings of this study revealed that the blending of Tall's theory (Tall, 2013) and the theory of structural cognitive modifiability (Feuerstein et al., 2015) was a successful approach to developing an instructional intervention to help at-risk dyscalculic learners to learn the skill of counting. Further, these findings are consistent with the study of Aunio et al. (2021) discussed below.

Aunio et al. (2021) investigated whether early numeracy skills of South African Grade 1 learners who were identified as at-risk for mathematical learning difficulties could be improved with an intervention programme. The study took place over five weeks and included 15 intervention sessions. The teacher manual included 15 lesson plans and the intervention sessions took place three times a week for five weeks. The material was designed to practise essential numerical relational and counting skills (number range 0 to 10). In addition, the participants also practised mathematics-related language such as 'more', 'less', 'many', 'fewer' and so on. Explicit teaching was also part of lesson plans and instructions to teachers and in each lesson numeracy ideas were presented sequentially from concrete to representational to abstract. All manipulatives were made of low-cost, everyday materials readily found in every classroom as well as simple printable material. Based on pre-test early numeracy scores, the 267 participating children were divided into three groups: (1) an intervention group (*n*=40); (2) a low-performing control group (*n*=32), and (3) an average-performing control group (*n*=195). This study was a first to control for confounding variables, which included executive functions, language skills, and previous school attendance. The main finding of this study was that the intervention group improved more in numerical relational skills compared to the control group.

Conclusion

The literature reviewed offers an appreciation of how mathematical ability can be defined and understood as well as the most common measurements of the construct. It also highlights opportunity for considerations when deciding what the most fair and relevant measurement tool may be. Solid numeracy skills are a key foundation to further development and attainment of mathematical ability. South African levels of numeracy are sadly falling well below the expected levels when same-age children are compared in both developed and developing countries. There are however a number of factors that can impact mathematical ability, including, but not limited to, environmental conditions, socio-emotional experiences as well as neurodevelopmental and cognitive functioning. Feuerstein's theory of structural cognitive modifiability and mediated learning offers a hopeful approach to address some of these challenges.

This study proposed a preliminary investigation into the possibility of a mediated learning intervention using the Feuerstein FU2G instrument to impact mathematical ability and cognitive functioning relevant to the acquisition of basic numeracy skills. Although studies among learners in remedial schools appear to be limited, the profile of such learners can be purposefully aligned to those experiencing mathematics difficulties. A remedial environment offers the opportunity for an in-depth study providing the potential for this preliminary investigation to contribute to future research among other South African school populations in need of basic numeracy skills development and/or remediation. While literature and research exists on the challenges, there is limited local research related to the solution. The following chapter will explore the research methodology adopted for this study.

CHAPTER THREE: METHODS

Introduction

This chapter describes the specific methods used to conduct the study, providing a description of the sample, the instruments utilised, and case study research design adopted. The particular procedure, ethical considerations, and data analytic techniques adopted for this study are discussed in detail.

Research Design

As the study is a preliminary investigation with a very small sample size (*n*=3 learners; *n*=2 teachers), a case study research design was utilised. Over recent times, case study research has become more widely accepted as an effective methodology to investigate and understand multi-faceted matters in real-life settings (Harrison et al., 2017). One of the pioneers in case study research, Stake (1978), suggests that a case study approach encourages descriptions of observed data that is holistic, involving the consideration of complex and interwoven variables written in an informal and narrative style. According to Stake (1978), such an approach provides the opportunity for verbatim quotations and illustrations, and it is suggested that although identifying themes and hypotheses are important, it is the understanding of the case itself that is of primary and paramount importance. Harrison et al. (2017) offer an outline of the progression of case study as a methodology and suggest that the definition from Creswell et al. (2007) best captures the concepts and descriptions of 'case study'. This source describes the case study as "a methodology, a type of design in qualitative research, an object of study and a product of the inquiry" (as cited in Harrison et al., 2017, p. 245). They support the following definition as one that captures the essence of the core traits, approaches and features of a case study:

> case study research is a qualitative approach in which the investigator explores a bounded system (a case) or multiple bounded systems (cases) over time through detailed, in-depth data collection involving multiple sources of information (e.g., observations, interviews, audiovisual material, and documents and reports) and reports a case description and case-based themes. (Creswell et al., 2007 as cited in Harrison et al., 2017, p. 245)

Stake (2008) suggests that as a form of research, case studies can be both qualitative and quantitative in their analysis and are defined by the interest in the case(s) themselves and not by the methods of enquiry. This research study was a mixed-methods case study with both quantitative and qualitative elements. The quantitative element of this case study followed a pre-experimental design and was based on assumptions drawn from the post-positivist paradigm, while the qualitative element of this case study followed an interpretive hermeneutic approach and was based on assumptions drawn from the interpretive paradigm. A classic pre-test-post-test single group pre-experimental design is frequently used in educational settings with a "pre-assessment – intervention – post assessment" format but given the small sample size of this preliminary investigation no causal claims can be justifiably made (Marsden & Torgeson, 2012). Findings were augmented by in-depth interviews with teachers as well as other numeric assessments before and after the mediated learning intervention. The case study approach has been selected for use given the preliminary investigative nature of the study on a new topic among a small but complex sample.

Sampling and Sample

A purposive sampling strategy was pursued to identify and recruit three Grade 5 learners and two teachers from a private remedial school in Johannesburg, one of very few schools in South Africa where this instrumental enrichment and mediated learning programme is used. Two teachers were identified as highly suitable for the study due to their specific Feuerstein Instrumental Enrichment-Basic programme training and remedial teaching expertise and were approached to volunteer for the study. All learners and teachers who were approached agreed to participate in the study and there was no need to look for alternative suitable participants. The identified teachers included a specialist teacher trained in the FIE-Basic programme who was skilled to implement the intervention programme and the Head of Remedial Academics who was also responsible for teaching remedial mathematics as part of the curriculum to Grade 5 learners. Specifically, the sampling strategy to recruit the teachers was purposeful criterion sampling (Cresswell & Plano Clark, 2011; Patton, 2014) as they were identified as sources of expert knowledge, experience, and skill. Important considerations including knowledge, experience, a willingness to participate, and an ability to communicate experiences and opinions were made when adopting the purposeful sampling strategy to recruit teachers (Bernard, 2017; Spradley, 2016).

Three Grade 5 learners were identified by the school and invited to participate in the schools' intervention programme based on the difficulties they were experiencing with mathematics. The parents of the learners were approached to provide consent for their children to participate in the study and assent was gained from the learners themselves. Specifically, the sampling strategy to recruit three Grade 5 learners was purposeful extreme sampling (Babbie, 2013; Patton, 2014). According to Piaget (1970), the participating learners (Grade 5) were situated in the concrete-operational stage during two additional logical operations are acquired which enable significant development of mathematical ability. These additional logical operations include seriation, which can be defined as the ability to order objects according to increasing or decreasing values, and classification, which refers to grouping objects by a common characteristic (Ojose, 2008). This was very much aligned to the FU2G instrument that helped the learner to understand both ordinal (sequencing) and cardinal (quantities) qualities of numbers (Kozulin et al., 2010).

The co-education private remedial school who participated in the research accommodates learners across all primary school grades (Grades 0 to 7). The admission protocol accommodates children with learning potential who are currently challenged in a mainstream schooling environment and present with specific or general learning difficulties. Learners attending this school come from diverse cultural backgrounds and tend to come from middle-upper class socio-economic environments. The only language spoken at the school and in which teaching takes place is English.

Data Collection: Instrument and Measurements

Instrument

The Feuerstein FU2G instrumental enrichment was implemented over a 12-week period with three learners by a specialist remedial teacher trained in the FIE-Basic programme. This instrument deals with the prerequisite concepts and functions for mathematics, assisting children to prepare for mathematics. FU2G provides a basis for developing the concept of number which is a complex task involving both ordinality of numbers (a number as part of a sequence, position or rank) and cardinality of numbers (a number as a set or quantity) (Feuerstein, 2009). The instrument aims to achieve this through counting (which leads to the concept of number), through repeated addition (which leads to the concept of multiplication) and through counting on (which leads to the concept of sums and calculations). Given the poor levels of numeracy among South African learners (Aunio et al., 2016; Aunio et al., 2021; Reddy et al., 2016; Spaull & Kotze, 2015) and that the concept of number is the basis for the development of numeracy (Aunio & Niemivirta, 2010; Aunio et al., 2016; Desoete et al., 2009; Jordan et al., 2009; Mercader et al., 2018; Tobia et al., 2016; Watts et al., 2014), the FU2G instrument is a relevant match in exploring what role it may be able to play as a solution to poor foundation skills in numeracy evidenced in South Africa.

The FU2G instrument requires children to manipulate simple geometric shapes and forms to discover the concept of units, groups of units, and units as groups. The FU2G instrument consists of a cover page and 18 working pages that are divided into two sections. Part one of the instrument includes pages 1 through 8 and involve counting and grouping of dots according to number configuration. In these activities the learner must consider group membership irrespective of proximity and the learner must also use multiple sources of information (number of dots in each group and number of groups). Colour is introduced as a variable but does not carry differentiating meaning (Feuerstein, 2009). Part two of the instrument includes pages 9 to 18 and introduces different figural shapes and gradually increases the complexity of the task as additional variables are added. This includes, for example, grouping by colour, grouping by shape, variations in number among groups, and mixing of shapes and numbers among groups. Each frame has a small table on the bottom left that requires the learner to count and sum up the number of units and groups and short sentences of instruction on the bottom right. Each page of the instrument represents a lesson and both repetition and variation are provided from page to page. Selected pages from the FU2G booklet can be viewed in Appendix C. According to Feuerstein (2009), in this instrument addition occurs by combining the groups, subtraction is represented by separating the groups, multiplication by the adding of how many groups in relation to how many units, and division through the separation of the groups by dividing the total amount of objects into groups to determine how many units will be within each group.

Feuerstein (2009) defines six primary goals of the instrument that shape the structure of the lessons using the pages in the FU2G instrument and the mediation offered to the learners. These are:

1. Counting: teaching the child how to count
2. Concept of units as a member of the group
3. Concept of group: as an organising of units into one entity
4. Flexibility of the concept of group: to include heterogenous objects and a group as a unit of larger aggregation
5. Concept of summation: by bringing similar or disparate objects into a unified amount
6. Relationships between groups: to begin to develop the learner’s understanding of moving toward the four mathematical operations of addition, subtraction, multiplication, and division.

Three sub-goals of the instrument are also defined by Feuerstein (2009), which are important dimensions to the learners' learning: classification, planning and to conserve the instruction. It is a prerequisite to using the instrument that some underlying concepts are in place and may need to be taught in advance. The prerequisite underlying concepts include colour (black, green, orange, red, blue); shapes (triangle, line, circle, diamond, half circle, oval, rectangle, hexagon) and number (ranging from 1 through 20).

The goals of the FU2G instrument as outlined above are well-suited to potentially address the gaps faced in early numeracy and foundational mathematics skills in South Africa. From the literature reviewed and limited research studies making use of the FU2G instrument, no data is available regarding its validity and reliability.

Measurements

Three measurement instruments were used to gather data prior to and after the FU2G intervention including the Wechsler Individual Achievement Test, Third Edition (WIAT-III) (Wechsler, 2009), mathematics class assessment marks and semi-structured interviews with the teachers. The WAIT-III scores and mathematics class assessment marks were all provided by the school. The semi-structured interviews were conducted by the researcher.

Mathematics Class Assessments

All Grade 5 learners were assessed with mathematics class assessments each term. The overall marks achieved in Term 1 were compared with those achieved in Term 3 as a further indication of any changes in mathematical ability prior to and after the mediated learning intervention, which took place over a 12-week school term in 2022.

Wechsler Individual Achievement Test, Third Edition. The Wechsler Individual Achievement Test, Third Edition (WIAT-III, UK) examiner's manual describes this test as "an individually administered clinical instrument designed to measure the academic achievement of learners from ages 4 years 0 months to 25 years 11 months through 16 subtests that evaluate listening, reading, writing, speaking, and mathematics skills". The WIAT-III, UK was standardised on a national sample of 744 children and young people, aged 4 years 0 months to 25 years 11 months, and has comprehensive normative information (Weschler, 2009). The WIAT-III UK was also co-normed with the Wechsler Intelligence Scale for Children – Fifth Edition UK (WISC-V UK) (Wechsler, 2016) on a subset of the sample (*n*=387), from ages 4 years 0 months to 16 years 11 months. There is no normative data available for the South African population. Referring to reliability, which relates to the accuracy, consistency, and stability of test scores across situations (Price et al., 2015), it is stated that internal consistency reliability is high for the composite and subtest scores, and that scores are highly consistent over a period of several weeks. The subtests that require judgement in scoring yield similar results when scored by different scorers. As a result, taking this altogether, the evidence provides strong support for reliable interpretation of the WIAT-III scores. Regarding validity, the degree to which evidence support the interpretation of the test scores for their purposes (Price et al., 2015), sufficient validity evidence is provided to support validity of the WIAT-III based on (1) test content, (2) response processes, (3) internal structure, (4) relations to other variables and, (5) testing consequences. The WAIT-III Technical Manual (Wechsler, 2009) describes the reliability and validity of the WIAT-III and can be referred to for more in-depth information.

The WIAT-III yields eight composite scores (including mathematic and maths fluency) with 16 subtests in total (Wechsler, 2009). Changes in mathematical skills prior to and after the mediated learning intervention were assessed through the subtests associated with mathematics and maths fluency. Mathematics is assessed through the maths problem solving subtest and numeracy subtest. The maths problem solving subtest measures untimed maths problem-solving (Appendix E) and the numeracy subset measures untimed, written maths calculation skills (Appendix F). Maths fluency is measured through a subtest of three parts: (1) maths fluency, addition; (2) maths fluency, subtraction; and (3) maths fluency, multiplication. All three fluency tests have a 60-second time limit (Appendix G). As with all assessments, the results obtained from the WIAT-III UK should be, and were, interpreted in an integrated manner with other performance measures and took into account the learner's history, background, culture, personality, current emotional functioning, and attention and motivational levels (Wechsler, 2009).

Semi-Structured In-Depth Interviews. Semi-structured in-depth interviews with open-ended questions were conducted with two teachers after the mediated learning intervention. These interviews assisted the researcher to build a profile of each child in relation to specific diagnoses, behavioural challenges, learning challenges, and mathematical ability as observed in the classroom. They also provided an understanding of the teachers' perceptions of the learners' key deficient cognitive functions related to mathematics as they had been observed through observation in the classroom and over the course of the FU2G intervention programme. The interviews took one to two hours each and took place on the school premises at a convenient time for the interviewees. Responses in the interviews were audio recorded with the consent of the participating teachers.

Semi-structured interviews can provide in-depth information and allow for probing and asking follow-up questions, which were advantageous and well-suited to this preliminary investigation (Brinkmann, 2014). Self-designed interview schedules (Appendix H) were used to obtain data from the teachers on completion of the intervention programme. The structure and content of these interview schedules was based on the aims of the study and the research questions. Prior to data collection, the interview schedule was piloted with a teacher from the school who was not involved in the current research study.

Procedures

Contact was made with the school and permission obtained from the school principal to conduct the study at the school, on condition of ethical clearance being obtained from the Human Research Ethics Committee (HREC Non-Medical) of the University of the Witwatersrand. The school proceeded with their planned intervention during Term 2, 2022 with no input from the researcher. Ethical clearance (H22/06/07) was obtained from the Human Research Ethics Committee (HREC Non-Medical) of the University of the Witwatersrand in August 2022 (Appendix I). Subsequent to approval being received, data was sourced and analysed retrospectively according to three stages: (1) pre-intervention; (2) intervention; and (3) post-intervention. Each stage is elaborated on below.

In the **pre-intervention stage,** all the Grade 5 learners at the participating school were assessed with the Wechsler Individual Achievement Test, Third Edition (WIAT-III) (Wechsler, 2009) in February/March 2022 by the relevant educational professionals at the school. Comparison of the scores obtained on the WIAT-III mathematics subtests were used as the first indicator by the school to identify three learners experiencing the greatest difficulties in mathematics. Term 1 mathematics class assessment marks were reviewed by the school as a second indicator. Once the three learners had been identified, both their parents/guardians and the learners themselves were approached by the school to participate in a mediated learning intervention over the second school term. The researcher engaged with the school, and it was agreed that once approval had been obtained from the Ethics Committee, two identified teachers (following their consent to participate), would be interviewed. The interview schedule can be reviewed in Appendix H.

During the **intervention stage,** the small FIE intervention group *(n*=3) participated in three 30-minute FU2G interventions per week throughout the second term of 2022. The intervention was carried out by a specialist teacher who had been training in FIE and who was familiar with the FU2G instrument. Over the 12-week intervention period the learners, mediated by the mediator, worked their way through the FU2G instrument booklet.

The **post-intervention stage** commenced in the third school term (September to December 2022) following ethical clearance being obtained from the Human Research Ethics Committee (HREC Non-Medical) of the University of the Witwatersrand as well as consent from the learners' parents/guardians and assent from the learners themselves for the researcher to retrospectively explored the impact of the targeted mediated learning intervention of their mathematical ability and deficient cognitive functions. Following consent to participate and for audio recording, semi-structured interviews (see Appendix H) were conducted with two identified teachers. These were transcribed and analysed to build a profile of each learner and report on observed changes in mathematical ability with particular reference to Feuerstein's emerging cognitive functions and the mediated learning intervention. The school provided the researcher with each participating learner's 2022 WIAT-III mathematics subtests scores and their Term 1 and Term 3 mathematics class assessment marks. The learners were reassessed by the Head of Remedial Academics at the school on the WIAT-III mathematics subtests in February 2023 and these scores were also subsequently provided to the researcher.

Data Analysis

Given the small sample size, both the raw scores from the WIAT-III and the termly mathematics class marks were analysed qualitatively. Each learner's observed cognitive processing was qualitatively evaluated prior to and after the mediated learning intervention by the teachers. There were no guidelines for this qualitative evaluation, but the teachers drew on their previous experience and training of working with the FU2G cognitive functions and a mediated learning instrument.

A thematic analysis of the transcription of each of the in-depth interviews with teachers was conducted. A thematic analysis involves the identification of themes or patterns of themes in data. Braun and Clarke's (2006) six phase process for such analysis was followed. The six phases outlined by Braun and Clarke (2006) are: (1) familiarising oneself with the data; (2) generation of initial codes; (3) searching for themes; (4) reviewing themes; (5) defining and naming themes; and (6) producing the report. An audit trail was kept of formally collected reference material and direct quotes were used as a means of cross-verification and checking interpretations with participants wherever possible.

Ethical Considerations

Contact was made with the school and permission obtained from the school principal to conduct the study at the school (Appendix J). Approval to proceed with the study was obtained from the Human Research Ethics Committee (HREC Non-Medical) of the University of the Witwatersrand in July 2022. Written consent was obtained from two teachers who were identified for voluntary participation in the study. This included consent for the recording of the semi-structured interviews (Appendix K). Written consent was also obtained from the parents or legal guardians (Appendix L) of the Grade 5 learners who participated in the school's intervention for retrospective analysis of the impact of the intervention using the pre- and post-measures outlined above. Assent to participate retrospectively in the study was also obtained from the learners themselves (Appendix M).

The purpose, aim, and nature of the study was explained in writing to the school principal (Appendix J). This was also explained to participating teachers via a participant information sheet (Appendix K) and to the parents or legal guardians of the children identified for retrospective participation (Appendix L). The study and what was involved was also explained to these children in language that was easy for them to understand (Appendix M). The participants were informed that non-participation would not disadvantage them in any way. All participants were informed of their right to withdraw at any point in time and that participation in this research study was completely voluntary. Confidentiality was upheld throughout the research process as only the researcher and the researcher's supervisor had access to the data. The data was stored on a password-protected computer to which only the researcher had access. All hard copies of learner-generated classroom material were safely stored in a locked filing cabinet. Only the researcher and supervisor had access to all data collected.

All participant responses were treated confidentially and identities including their names and the name of the school were kept confidential. However, due to the nature of the study with a very small sample size and intimate school setting, confidentiality could not be guaranteed throughout the research process. It was not possible to maintain anonymity throughout the research process as the details of the children who participated in the study were known to the researcher and due to the nature of face-to-face interviews for data gathering. However, anonymity was and will be maintained in any resulting reports and/or publications through the use of pseudonyms. The school was not approached by any parent whose child was not in the study but who was interested in their child participating in the intervention. A summary of the findings will be provided to the school by July 2024. The teachers who participated in the study and the parents of the learners who participated in the study have been asked to contact the researcher for this summary of the results should they wish to. Potential use of the findings may include, but is not exclusive to, conference presentations, training course material, and the publication of findings in the form of a journal article.

Qualitative Rigour and Reflexivity

Reflexivity is an ongoing process of reflection by the researcher on his or her values, and those of the participants, as well as ongoing reflection of their preconceptions, behaviour or presence, which can affect the interpretation of data gathered through the research process (Parahoo, 2006). Throughout the research study, the researcher reflected on possible influence as a researcher on the process and the participants and these are acknowledged in the findings reported. The researcher aimed to disregard any personal preconceived ideas on the topic throughout all the stages of the research and listened actively and objectively to capture the full detail of the participants' views and experiences. The researcher engaged with her supervisor throughout all stages of the research.

Conclusion

In summary, three Grade 5 learners and two teachers participated in this preliminary qualitative research case study. The research procedure included pre- and post-intervention stages. The Feuerstein FU2G mediated learning instrument was implemented over a 12-week period with the three learners by a specialist teacher trained in the FIE programme. In total, three measurement instruments were used to gather data prior to and after the FU2G mediated learning intervention and included semi-structured interviews with the teachers; the Wechsler Individual Achievement Test, Third Edition (WIAT-III) (Wechsler, 2009); and mathematics class assessment marks. Given the small sample size and case study approach, all data was interpreted qualitatively. The researcher aimed to behave in an ethical way throughout the research process and was reflexive regarding any influence she may have had at any stage. In the following chapter the main findings are presented in relation to each participant as a case study and each research question is referred to.

CHAPTER FOUR: RESULTS

Introduction

The case study methodology allowed for the identification of general findings across the sample group as well as for meaningful consideration of these findings in the circumstance of each learner and, aligned with Stake (1978) and supported by Harrison et al. (2017), for descriptions of observed data that is holistic and considerate of complex and interwoven variables. A detailed appreciation of each learner's profile was gained during the semi-structured interviews with teachers and is shared prior to specific findings being presented. Consideration was given to any relevant diagnoses, numeracy skills, and socio-emotional/behavioural challenges. Across the learners, ADHD, dyslexia, OCD, mathematics anxiety, mathematics developmental delays, and hearing impairment were reported.

Findings are presented in relation to each of the research questions: firstly, in relation to the participants' comparative performance before and after the intervention on their mathematics termly class marks and WIAT-III subtests; secondly, in relation to their deficient cognitive functions before and after the intervention; and, finally, in relation to the teachers' perceptions of FIE and MLE before and after the intervention.

Profile of the Learners

The case study methodology and semi-structured interviews with Teacher A and Teacher B allowed for rich insight to be gained in relation to each learner's unique profile.

Participant One was diagnosed with ADHD, dyslexia, and mathematics developmental delays. She was described by Teacher A as easily excitable, dysregulated, and distracted, especially if not on medication. This description was supported by Teacher B who commented on her impulsivity. The interviewed teachers shared that this learner struggled to work with multi-step operations and her impulsivity hindered her ability to look at a problem holistically. There also appeared to be a certain level of anxiety with Participant One and she attended Eagala (horse therapy) to assist with her anxiety. The primary reason Participant One was included in the intervention by the school was due to her mathematics developmental delays, which presented as deficient number concepts and a weak mathematics foundation. She benefitted from both a scribe and a reader for tests.

Participant Two had a hearing impairment and wore a hearing aid in one ear. She had been diagnosed as at-risk for OCD and was described as lacking in self-confidence and self-belief and she often presented with high anxiety. According to one of the teachers interviewed, anxiety appeared to override her cognitive functioning. She did not like to make mistakes and doing so caused anxiety. Both teachers commented on the precision in her work and the slowness of her pace, which is illustrated by the following verbatim quote from Teacher A: "...pace is very, very slow in processing, but it is because she is so thoughtful, she does not want to make mistakes" (personal communication, November 2022). The teachers also described a 'learnt helplessness' despite actually knowing what to do. Further, Participant Two was described as requiring constant mediation and reassurance and it was also she reported that she fatigued easily. The teachers suggested the potential impact of the Covid-19 pandemic on Participant Two's learning was worth consideration given the wearing of masks and her hearing impairment. She too participated in Eagala (horse therapy) to assist with anxiety. The main reason for including Participant Two in the intervention was that her basic numeracy skills were lacking.

Participant Three had a likely but unconfirmed ADHD diagnosis and was unmedicated with the exception of an omega 3 supplement to assist concentration. She appeared to get very easily distracted. Although she had fewer challenges than the other participants, she worked quickly, rushing and not asking questions. As a result, she was described as 'flying under radar', looking like she had got it but she had not. As she did not ask questions it was easy for the teachers to assume that everything was okay until they looked more closely. The main reason for including Participant Three in the intervention was an indication, based on performance in the WIAT-III and class tests, that her basic operations and numeracy skills were underdeveloped and not consolidated. Participant Three was described initially as coming across as coping when she actually was not and that she gave up easily. Findings in relation to each research question are subsequently presented.

Finding One: No Noticeable Impact Evident on Mathematical Ability

The FU2G mediated learning intervention did not appear to have a noticeable impact on the learners' mathematical ability. No definitive trend could be identified by examining the participants' termly mathematics class assessment marks or on their WIAT-III performance. This research finding is in relation to Research Question 1: Is there a change in mathematical ability among a group of Grade 5 learners following a 12-week targeted mediated learning intervention? The research question was assessed on two different measures: firstly, the participants' overall mathematics class assessment marks for the term and, secondly, their performance in the mathematics subtests of the WIAT-III . Given the small sample size, raw scores were compared qualitatively for the overall mathematics class assessment marks and performance ranges were compared qualitatively for the WIAT-III subtests of each learner. Findings for each measure are shared individually for each participant.

Overall Term Mathematics Class Assessment Marks

Overall mathematics class assessment marks for Term 1 and Term 3 were selected as one of the measures to assess the impact of the 12-week FU2G intervention on the participating learners' overall mathematical ability. Although the sample was small it was thought that the intervention would have an impact on overall performance in mathematics. As shown in Table 1, the change was variable with Participant One showing a small marginal gain, Participant Two showing a considerable decline, and Participant Three showing a marginal drop in performance. It is noteworthy that Term 1's overall mark comprises a number of class tests and Term 2's overall mark comprises both a number of class tests and as well as end of year 'exam' assessments. It is also noteworthy that the content of Term 1 and Term 3 class tests and assessments varied significantly bringing into question the like-for-like comparison.

Table 1

Term 1 and Term 3 Overall Mathematics Class Assessment Marks

	Term 1	**Term 3**
Participant One	42.3%	43.8%
Participant Two	62.7%	53.7%
Participant Three	52.9%	51.2%

WIAT-III Assessment Subtest Scores

The WIAT-III is a standardised assessment, the scores of which are comparable for each child's age range from year to year. Table 2 provides an overview of the performance obtained for each learner on all of the WIAT-III subtests administered in 2022 and 2023.

Table 2

WIAT Scores for Mathematics Subtests

Participant One	**February 2022**	**February 2023**
Math Fluency	Low average range	Low average range
Math Numeracy	Very low range	Very low range
Math Problem Solving	Low average range	Low average range
Participant Two	**February 2022**	**February 2023**
Math Fluency	Very low range	Very low range
Math Numeracy	Low average range	Very low range
Math Problem Solving	Average range	Low average range
Participant Three	**February 2022**	**February 2023**
Math Fluency	Average range	Low average range
Math Numeracy	Low average range	Average range
Math Problem Solving	Low average range	Low average range

The maths fluency subtests are timed subtests and were administered in a group class setting while the maths numeracy and maths problem solving subtests are untimed tests and were administered individually.

Participant One maintained the same level of performance on the maths fluency, maths numeracy and maths problem solving subtests that were administered. Participant Two maintained the same level of performance on the maths fluency subtest but had deteriorating changes in performance for the maths numeracy and maths problem solving subtests. A more granular review of the individual subtests revealed that although Participant Two's maths fluency remained in the very low range, there was a deterioration in both the maths fluency Addition and maths fluency subtraction performances from low average range to very low range compensated for by an improvement in the maths fluency multiplication subtest from very low range to low average range.

Participant Three's performance was mixed with a deterioration in maths fluency performance, an improvement in maths numeracy, and a stable performance in the maths problem solving subtests. A more granular review of the individual subtests revealed that although Participant Three's decline in maths fluency performance was driven by a drop in the Math Fluency Addition subtest from average range to low average range, whilst the Subtraction and Multiplication subtests remained stable.

Appendix N can be referred to for an overview of the WIAT-III subtest performance for each learner. Hypotheses for these changes in performance are presented in Chapter Five as a case study of each participant and their unique profile.

Finding Two: Positive Changes were Observed in Deficient Cognitive Functions

Teachers perceived that the FU2G mediated learning intervention resulted in positive changes in deficient cognitive functions for each diverse learner at the input, output and elaboration levels. This research finding is in relation to research questions two and three: Prior to and following the intervention, how do teachers describe each child's observed mathematical ability with particular reference to Feuerstein's Deficient Cognitive Functions? The participating teachers, a teacher trained in the FIE-Basic programme who was responsible for the implementation of the intervention (Teacher A), and a remedial teacher responsible for small remedial mathematics groups with the participants (Teacher B) were each asked to share how they had observed each participant's deficient cognitive functions related to mathematics at the start of the intervention and towards the end of the term following the intervention.

Both teachers shared that all three learners had demonstrated positive shifts in some of the cognitive functions across the input, elaboration and output levels. The teachers' combined qualitative assessment is captured for each learner individually in Appendix O. These tables provide an overview of the qualitative comparison of deficient cognitive functions before and after the mediated learning intervention for each learner, as perceived by the teachers interviewed. Overall, it was felt by both of the teachers that in relation to approaching mathematical tasks, Participant One became less impulsive, more systematic, and more logical in her approach as the intervention progressed. Although Participant Two was very capable, her anxiety overrode her cognitive functioning and this impacted negatively on her work and that Participant Three grew in confidence over the duration of the intervention and as a result became more expressive.

The changes in cognitive functioning that teachers perceived before and after FU2G mediated learning intervention are shared below for each participant. The italics in the following sections refer to the specific cognitive functions from Feuerstein's defined list of cognitive functions that were identified as being most deficient prior to the intervention and to those where teachers observed a change following the intervention.

Participant One: Shifts in Deficient Cognitive Functioning Presented as a Case Study

At an input level, Teacher A described Participant One's most deficient cognitive functions prior to the intervention taking place as having *blurred or sweeping perception*;

unplanned, impulsive and unsystematic exploratory behaviour; *a lack of conservation of constancies* and *a lack of need for precision and accuracy in data gathering*. Teacher B also felt that one of the main barriers in cognitive functioning at the input level was a lack of need for precision and accuracy in data gathering and highlighted a *lack of capacity for considering two or more sources of information at once*. After the intervention, both teachers noted an improvement in Participant One's precision and accuracy in data gathering. They felt she had become more precise. Teacher A also noticed an improvement in the participant's unplanned, impulsive, and unsystematic exploratory behaviour. Overall, she appeared less impulsive.

At an elaboration level, Teacher A described Participant One's most deficient cognitive functions prior to the intervention taking place as *a lack of need for pursuing logical evidence; a lack of inferential, hypothetical thinking; a lack of summative behaviour and a lack of strategies for hypothesis testing.* This teacher shared that Participant One struggled to come to the right conclusion and did not pursue logical evidence. She was observed doing bits in isolation and as a result of not working in a logical order was unable to summarise or conclude what she had done. Her impulsivity appeared to push her to guess. Teacher B identified Participant One's most dominant deficient cognitive function at an elaboration level as *an inability to select relevant vs non-relevant cues in defining a problem.*

Following the intervention, improvements were noticed in the following elaboration cognitive functions for Participant One: *a demonstration of more logical thinking and pursuing logical evidence*; *improved hypothetical thinking*; *improved planning and a little improvement in using strategies for hypothesis testing.* As the intervention progressed, the mediator observed that Participant One had adopted good strategies to help her focus and work in a logical and systematic way.

At an output level, Teacher A described Participant One's most deficient cognitive functions prior to the intervention taking place as *a lack of tools for communicating adequately elaborated responses.* Interestingly, this cognitive function was identified as the most deficient cognitive function for all three learners who participated in the intervention. This was observed in their difficulty to express why something was, suggesting that they had not made meaning of it and could not reason it out. Teacher B identified Participant One's most dominant deficient cognitive function at an output level to be *trial and error responses and impulsive, acting out behaviour.* Following the intervention, it was noted that while Participant One was still a bit hasty there was an improvement in *precision and accuracy in communicating responses*.

Both the teacher who implemented the intervention (Teacher A) and the mathematics remedial teacher (Teacher B) commented on the cognitive function of *spatial orientation* as

Participant One worked from right to left but the instrument is designed to go left to right and downwards. As a result, her shapes were often strange, as indicated by Teacher A:

> She would randomly choose her grouping. So, it was not consistent. It was not ordered. If she was doing it backwards that meant that she did not have a place to make a group of something unless she went around everything.

Appendix P provides illustrative examples from Participant One's FU2G booklet demonstrating the teachers' observations and perceptions as well as verbatim quotes from the teachers.

Participant Two: Shifts in Deficient Cognitive Functioning presented as a Case Study

At an input level, Teacher A (who implemented the intervention) described Participant Two's most deficient cognitive function prior to the intervention taking place as *a lack of, or impaired, spatial orientation.* Both teachers noted the *need for precision and accuracy* as a key strength and this remained throughout the intervention. However, no improvement in spatial orientation was seen by either teacher.

At an elaboration level, the Teacher A described Participant Two's most deficient cognitive function prior to the intervention taking place as *lacking in spontaneous comparative behaviour* as well as having *difficulties with strategies for hypothesis testing*. Teacher B had identified two additional cognitive functions that also appeared to be underdeveloped: an *inadequacy in the perception of the existence and definition of an actual problem* and an *inability to select relevant vs non-relevant cues in defining a problem.* Following the intervention, the teachers interviewed each noticed improvements in different areas of cognitive functioning for Participant Two. Teacher B found that there was improvement in the areas of *pursuing logical evidence, hypothetical thinking and planning,* while Teacher A noticed improvements in *comparative behaviour and a small improvement in making use of strategies for hypothesis testing.*

At an output level, Teacher A described Participant Two's most deficient cognitive function prior to the intervention taking place as *a lack of tools for communicating adequately elaborated responses.* As stated previously, this cognitive function was identified as the most deficient cognitive function for all three learners who participated in the intervention. This was observed in their difficulty to express why something was, suggesting that they had not made meaning of it and could not reason it out. Improvement in two areas of cognitive functioning were observed for Participant Two. Teacher B noticed an improvement in her *trial and error responses* while Teacher A felt that *accuracy in communicating responses* had improved.

Appendix Q provides illustrative examples from Participant Two's FU2G booklet demonstrating the teachers' observations and perceptions as well as verbatim quotes from them.

Participant Three: Shifts in Deficient Cognitive Functioning Presented as a Case Study

At an input level, Teacher A (who implemented the intervention) described Participant Three's most deficient cognitive function prior to the intervention taking place as a *lack of, or impaired, receptive verbal tools which affect discrimination,* while Teacher B (the remedial mathematics teacher) noted challenges with *conservation of constancies* and *difficulty in considering two or more sources of information at once.* Following the intervention, it was felt that Participant Three showed an improvement in *the use of verbal tools which positively affected her ability to discriminate.* This is also reflected in her output cognitive functions linked to an *improved ability to elaborate responses*.

At an elaboration level, Teacher A (who implemented the intervention) described Participant Three's most deficient cognitive function prior to the intervention taking place as *difficulty in using strategies for hypothesis testing.* Following the intervention, improvement was observed by the teachers in the learner's *ability to select relevant vs non-relevant cues in defining a problem; pursuing of logical evidence and elaboration of certain cognitive categories (receptive and/or expressive).*

At an output level, Teacher A (who implemented the intervention) described Participant Three's most deficient cognitive function prior to the intervention taking place as *a lack of tools for communicating adequately elaborated responses.* As stated previously, this cognitive function was identified as the most deficient cognitive function for all three learners who participated in the intervention. This was observed in their difficulty to express why something was, suggesting that they had not made meaning of it and could not reason it out. As shared previously, according to Teacher A (who carried out the intervention), Participant Three became more expressive as the intervention progressed, having a positive impact on her ability to communicate adequately elaborated responses. Overall, it was felt by both of the teachers that Participant Three grew in confidence over the duration of the intervention and as a result she became more expressive.

Appendix R provides illustrative examples from Participant Three's FU2G booklet demonstrating the teachers' observations and perceptions as well as verbatim quotes from them.

Feuerstein (2006) states that the ultimate goal of an MLE is for the mediator to become redundant. It is at this point that the learner is self-mediating and self-correcting, captured well by the following quote from the teacher who carried out the intervention:

> ... and I always feel when you see they have corrected something, that is an “Aha!” moment. Because they are going, “Oh, I made a mistake. Let me correct it.” And that is the time of learning, that’s your zone of proximal development. (Teacher A personal communication, November 2022)

An example of such self-correction can be viewed in Appendix S.

Finding Three: The Intervention Resulted in Positive Teacher Perceptions of MLE

Teachers’ perceptions related to the use and benefits of mediated learning improved positively after their experience of the FU2G intervention. This finding is in relation to the final research question: What are teachers’ perceptions related to the use and benefits of mediated learning prior to and after the intervention taking place? This was explored through semi-structured interviews with teachers following the intervention. The teachers’ overall response to the use and benefits of mediated learning following the intervention was extremely positive; however, their prior perceptions related to the use and benefits of mediated learning differed. These earlier perceptions were influenced by the personal experience and approach to teaching each of them had prior to being exposed to FIE and mediated learning. The teacher who implemented the intervention (Teacher A) with the learners over Term 2 was influenced by her previous teaching of the subject of art, where she explained she had to bring out what the child expressed through constant mediation. She expressed this as follows: “You cannot presume what the outcome is. You have to provide the environment that is an open-ended question” (personal communication, November, 2022). As a result of her experience in teaching art, this teacher had a natural affinity to mediation but admitted that FIE had specific vocabulary that needed to be learnt. She felt training was essential and that the theory of structural cognitive modifiability was critical to understand and to reaffirm the power of being positive with children. She recalled working with children with serious problems who, through mediation and a belief that they could do and learn more, did indeed show improvements. Referring to Professor Feuerstein she stated: “So his belief in optimism, in positivity, is so true” (personal communication, November, 2022).

The second participating teacher was the remedial teacher for a mathematics group (Teacher B), which included the children who participated in FU2G intervention. Prior to any training of FIE, which only happened following the completion of the intervention with the children, she was skeptical of FIE and mediation: “I had seen it and I was like, what is this?” (personal communication, November, 2022). However, after attending the FIE-Basic training she immediately began to experiment with how to mediate and experimented with an individual Grade 7 pupil, also using the FU2G instrument. During the interview she shared she had experienced a noticeable progression over only seven lessons in the Grade 7 learner’s understanding and pace of operations as well as an increase in mathematical terminology. On reflection the teacher shared that she felt the power of FIE lay in rich discussion that led to in-depth understanding, flexible thinking, and bridging to unrelated everyday situations. She shared that it was difficult to mediate but that it got easier with practice. The remedial teacher emphasised the importance of understanding the theoretical principle that modification comes through mediation and that the emphasis is on the deep thinking of the mediatee. Feuerstein’s proposition, “If you love me, do not accept me as I am” (Feuerstein et al., 2013) and the FIE training resulted in a personal reflection by the remedial teacher: “I just think, if I knew this when I started teaching, imagine the children in my class” (personal communication, November, 2022). Despite admitting that when she first discovered FIE it was like a new language and it felt intimidating, the teacher shared how powerful she believes FIE and mediation is and acknowledges the confidence it is able to develop in a learner: “... and I cannot do anything now without thinking about what cognitive function you are actually targeting” (personal communication, November, 2022).

Conclusion

The findings of this preliminary investigation that explored the impact of a targeted mediated learning intervention on the mathematical ability of three Grade 5 learners experiencing mathematical difficulties revealed no definitive trend on either the participants’ termly mathematics class assessment marks or on their performance on the mathematics-related WIAT-III subtests, suggesting that the instrument was unable to impact mathematical ability on the measures on which it was evaluated. However, positive changes in deficit cognitive functions were observed by the teachers following the intervention on all three levels of input, elaboration, and output for each of the participants. Overall, the teachers reported a positive experience of the FU2G instrument and had favourable perceptions regarding FIE and mediated learning. In the next chapter possible reasons for these findings are discussed in the context of each learner’s profile. Implications of the study as well as suggestions for future research are made.

CHAPTER FIVE: DISCUSSION

Introduction

Chapter Five forms the discussion and conclusion of the research report. Initially a summary of the study and findings are presented. The findings are subsequently discussed in the context of each case and links to the literature reviewed are made. Implications of the study are presented and this is followed by some discussion of the limitations encountered throughout this study and suggestions are made for future research.

Summary of the Research Study and the Findings

This case study, a qualitative preliminary investigation, aimed to explore the potential of the FU2G instrument to impact mathematical ability and cognitive functioning related to mathematics among a small group of learners experiencing mathematical difficulties. The study also sought to understand teachers' perceptions related to mediated learning prior to and after the intervention. Data was collected prior to and after the FU2G mediated learning intervention through the WIAT-III (Wechsler, 2009), mathematics class assessment marks, and semi-structured interviews with the teachers. Given the small sample size and case study approach, all data was interpreted qualitatively. Semi-structured interviews provided insight into the unique profile of each participating learner, specifically identifying learning difficulties, neurodevelopmental or other disorders as well as extraneous factors that could have an impact on mathematical ability and cognitive functioning

As presented in Chapter Four, there were three key findings in the research study that are restated and subsequently discussed. Firstly, in relation to the first research question (namely, is there a change in mathematical ability among a group of Grade 5 learners following a 12-week targeted mediated learning intervention?), the FU2G mediated learning intervention did not appear to have had a noticeable impact on the learners' mathematical ability. No definitive 'trend' could be identified on the participants' termly mathematics class assessment marks or on their WIAT-III performance. Secondly, in relation to the second and third research questions (namely, prior to and following the intervention, how do teachers describe each child's observed mathematical ability with particular reference to Feuerstein's deficient cognitive functions?), teachers perceived that the FU2G mediated learning intervention resulted in qualitatively observed positive changes in deficient cognitive functions at the input, output and elaboration levels. Thirdly, in relation to the final research question (namely, what are teachers' perceptions related to the use and benefits of mediated learning prior to and after the intervention taking place?), teachers perceptions related to the use and benefits of mediated learning improved positively after their experience of the FU2G intervention.

The subsequent discussion focuses on a couple of points based on the literature reviewed and the findings of this study. Firstly, the importance selecting the most appropriate tool(s) to measure the impact of the FU2G instrument on mathematical ability is explored and, secondly, indications from the study are that despite the individual impact of each learner's neurodiversity and learning challenges, the FU2G instrument has the potential to positively impact cognitive functions across a broad range of neurodiverse profiles and learning difficulties.

Although the objective of the FU2G mediated learning instrument, to develop the concept of number, is well suited to the address the challenges of poor basic numeracy evident among South African learners (Aniou et al., 2016; Aniou et al., 2021; Schollar, 2008; Spaul & Kotze, 2015), its lack of impact on mathematical ability in the current study was disappointing, especially as other mediated learning intervention studies produced favourable results (Aunio et al., 2021, Chin & Fu, 2021). One reason for this finding in the current study may be that the content of the measurement tool was too removed from the focus of mathematical skill in the instrument. Literature informs that mathematical ability can be defined cognitively and/or pragmatically (Karsenty, 2020). This study examined both perspectives as the FU2G instrument, as is the case of all of Feuerstein's instrumental enrichment tools, works on both process and content (Kozulin et al., 2010). In the current study, the measurements of mathematics class assessments and WIAT-III subtests focused on the pragmatic part of mathematical ability, as they looked to assess learning outcomes such as the ability to perform mathematical tasks and to effectively solve given mathematical problems (Karsenty, 2020). On analysis it became apparent that the content of the class tests and assessments that made up Term 1's mathematics mark differed significantly from the content of those that made up Term 3's overall mathematics mark. Term 1's overall mathematics mark comprised tests and assessments that focussed on place value and addition and subtraction for numbers and operations; patterns, fractions and algebra; time for measurement; 2D shapes for shape and space; and drawing and interpreting a bar graph for data handling. Term 3's overall mathematics mark comprised assessments, tests as well as exam papers that focused on broader and more complex elements of mathematics including fractions; time, length, area and perimeter; angles; and 3D objects. Term 3 also included an exam, which may have been anxiety-provoking for some participants in the current study given their profiles and history of anxiety.

The focus of the FU2G instrument is on helping children to establish the concept of number and the basic mathematical operations by uncovering how objects can be aggregated, segregated, summarised, and described (Kozulin et al., 2010). Given that the acquisition of the concept of number is one of the most important objectives of the instrument, helping the learners to understand both ordinal and cardinal qualities, it is suggested that a measure that more closely resembles the specific numeracy targets of the FU2G instrument would be preferable and provide a greater chance of determining the extent to which the instrument is able to impact the acquisition of these early foundational numeracy skills known to influence future mathematical ability (Aunio & Niemivirta, 2010; Aunio et al., 2016; Desoete et al., 2009; Jordan et al., 2009; Mercader et al., 2018; Tobia et al., 2016; Watts et al., 2014). As reviewed, efforts are being made to better measure both the cognitive (Vilkomir & O'Donoghue, 2009) and pragmatic parts of mathematical ability and studies such as by Aunio et al. (2016), Aunio et al. (2021), Chin and Fu (2021), and Emmanouil and Georgios (2018) are examples of tighter alignment between the mathematics skill targeted by an intervention and the measurement tool. Examples of this approach are the use of a worksheet for counting and matching quantities for numbers (Chin & Fu, 2021) and the use of an English version of the originally Finnish early numeracy tests (Aunio et al., 2016; Aunio et al., 2021).

While the WIAT-III subtests provided a suitable standardised measure and are among the more frequent measures used to measure mathematical ability (Tosto et al., 2015), they may also not be the most suitable measure of mathematical ability in relation to the FU2G instrument in a South African context. As stated previously, there are no South African norms for the WIAT-III and a single psychometric assessment may be highly affected by, among others, the test-tasker's anxiety and concentration levels. Given the profile of learners in this sample, such factors should not be ignored. It is suggested that similar future studies should take careful consideration to ensure like-for-like comparison should class tests and assessments form the measurement tool of the study. Attempts should also be made to align the measurement tool to the specific mathematics skill focused on in the intervention.

Despite the varied and challenged profile of each participating learner in the current case study, positive changes were perceived across the input, output and elaboration stages for each of their deficient cognitive functions. These findings suggest that the FU2G mediated learning intervention has the potential to positively improve deficient cognitive functions across a broad range of neurodiverse profiles and learning difficulties and is aligned to findings by Kozulin et al. (2010) who also found favourable results in a study that explored the effectiveness of a cognitive intervention with the FIE-Basic programme among a sample of children with developmental disabilities. Kozulin et al. (2010) found no difference in results by aetiology, but greater gains were identified for those children who received the intervention in an educational setting, such as the current study.

All three participating learners in this case study presented with mathematics developmental delays, which are reported to present as a deficiency in number concepts. Low numeracy skills can cause learners a lot of distress, low self-esteem, stigma, and disruptive behaviour in class (Bevan & Butterworth, 2007; Butterworth, 2005). As is the case with Participant One, comorbidities are common with neurodevelopmental and learning disorders (Berch & Mazzocco, 2007; Luoni et al., 2023; Von Aster & Shalev, 2007). A growing base of literature supports the negative impact ADHD can have on mathematical performance (Orbach et al., 2020; Sella et al., 2019; Tosto et al., 2015). The stronger relationship between mathematics and attention versus hyperactive-impulsive factors suggests a difference in the relationship between these two ADHD domains and mathematics. This further highlights the heterogeneity with the disorder and the need for further research (Tosto et al., 2015). Given the description of Participant One by the teachers interviewed of being easily excitable, dysregulated, distracted, and impulsive it is felt the combined presentation of ADHD best fits her observed behaviour. Literature reviewed also highlights the possible impact of dyslexia on mathematical ability (Chinn & Ashcroft, 2017; Kunwar & Sapkota, 2022) and given the main areas of impact on a dyslexic learner's ability to acquire mathematics skills (Almahrag, 2021; Chinn & Ashcroft, 2017, Roitsch & Watson, 2019; Snowling, 2019), such learners may struggle to learn basic mathematics vocabulary and symbols, struggle with memorising multiplication tables, battle to tell the time as well as experience difficulties with specific vocabulary and arithmetic calculation (Snowling, 2019). Both general anxiety and mathematics anxiety (Barroso et al., 2021; Foley et al., 2017; Luttenberger et al., 2018) also have a negative impact on mathematical ability due to emotional, cognitive, and physiological symptoms it presents with (Luttenberger et al., 2018). Research highlighted that on a cognitive level, working memory, which is a critical cognitive function for the acquisition and development of mathematical ability (Passolunghi & Costa, 2019), is compromised with both ADHD (Orbach et al., 2020; Sella et al., 2019; Tosto et al., 2015) and mathematics anxiety (Luttenberger et al., 2018).

When referring back to the deficient cognitive functions identified for Participant One prior to the intervention (Appendix O), they are aligned with the impulsivity associated with ADHD and it appeared that the structure and discipline of working through the FU2G instrument helped this participant to slow down and be more logical and systematic in her approach. At the input stage she slowed down to understand and consider the whole picture, setting herself up for a greater chance of success. According to the teachers working with her she became less impulsive and more confident throughout the intervention. As stated previously, both teachers noticed an unusual spatial orientation for Participant One as she worked from right to left but the instrument is designed to go from left to right. Research into associations between visual spatial abilities and dyslexia has mostly been contradictory (Duranovic et al., 2015). Both compensatory and deficit models have been explored, proposing in some cases that a dyslexic profile may be associated with strong visual spatial skills and in others that, to the contrary, a dyslexic profile may be associated with weaker visual spatial skills (Duranovic et al., 2015). In the case of Participant One, it may be hypothesised that her challenged spatial orientation is associated with her dyslexic profile.

As stated in Chapter Four, Participant One maintained performance on all of the WIAT-III subtests administered with the exception of the maths fluency multiplication subtest (Appendix N). This was a surprising subtest for the lower performance to present in given that the FU2G intervention is mostly focused on the concepts of grouping and multiplication. However, given the possible impact of ADHD, dyslexia, and anxiety there could be many extraneous variables behind the performance. A learner with ADHD, dyslexia, and developmental mathematics delays has many learning challenges. It was encouraging to see that participating in the FU2G intervention resulted in a shift in some of her ways of thinking and possibly also played a role in maintaining her WIAT-III subtest scores. Overall, it was felt by both of the teachers that Participant One became less impulsive and more systematic and logical in her approach as the intervention progressed.

As shared in Chapter Four, Participant Two had a hearing impairment and wore a hearing aid in one ear. She had been diagnosed as at-risk for OCD and was described as lacking in self-confidence, self-belief, and often presented with high anxiety. As presented earlier, Piacentini et al. (2003) found that concentrating on schoolwork and completing homework were two of the most common problems among those with OCD, and Adams (2004) suggested that OCD learners may struggle with tasks that require visual spatial skills such as mathematics and handwriting. Further, Shahrouri (2017) also found that OCD behaviour was associated with poorer academic performance and included symptoms such as too much attention to detail, lack of confidence in executing a task, repeating activities, and failing to complete activities. The impact of anxiety and mathematics anxiety as reviewed in literature (Barasso et al., 2021; Foley et al., 2017; Luttenberger et al., 2018) has already been shared for Participant One and is applicable to Participant Two. Further, OCD-related stress and anxiety can make it difficult to think clearly and may lead to errors in problem solving or even complete avoidance of mathematics-related tasks. As reviewed earlier, impaired hearing can also have an impact on mathematical ability (Ariapooran, 2007).

Participant Two's lower performance on all the WIAT-III (Appendix N) subtests following the intervention compared to the performance level before the intervention was a disappointing result. The challenges as supported by the literature reviewed faced by Participant Two due to OCD, impaired hearing, and high levels of anxiety are most likely significant contributing factors to the unexpected results. When referring back to the deficient cognitive functions identified for Participant Two prior to and after the intervention (Appendix O), they can be better understood in the context of the learner's unique profile. The most challenging areas of cognitive function prior to the intervention included spatial orientation, which may be impacted by OCD (Adams, 2004), spontaneous comparison, hypothesis testing, and selecting relevant cues, which may also be impacted by OCD and anxiety, and a lack of tools for communicating adequately elaborated responses, which may be impacted by a hearing impairment. Teacher B had identified two additional cognitive functions that also appeared to be underdeveloped, namely an *inadequacy in the perception of the existence and definition of an actual problem* and, an *inability to select relevant vs non-relevant cues in defining a problem.* It is thought that perhaps the deficiency in these cognitive functions may be linked to a fear of getting it wrong. Both teachers noted the *need for precision and accuracy* as a key strength and this remained throughout the intervention. It is possible that this cognitive function may be linked to the learner's OCD tendency and may at times be problematic. Teacher B found that there was improvement in the areas of *pursuing logical evidence, hypothetical thinking and planning,* while Teacher A noticed improvements in *comparative behaviour and a small improvement in making use of strategies for hypothesis testing.* It is possible that these improvements are driven by an increase in self-confidence and a reduction in anxiety-related OCD.

As shared in Chapter Four, Participant Three had a likely but unconfirmed ADHD diagnosis and was unmedicated with the exception of an omega 3 supplement to assist with concentration. She appeared to get very easily distracted. Although she had fewer challenges than the other participants, she worked quickly, rushing and not asking questions. As a result, she was described as 'flying under radar', looking like she had got it but she had not. As she did not ask questions it was easy for the teachers to assume that everything was okay until they looked more closely. Literature supports the benefits of pharmacological treatment to support ADHD (Arnold et al., 2020; Kortekaas-Rijlaarsdam et al., 2019; Shaw et al., 2012), especially when the ADHD symptoms are considered to be more severe (Efron et al., 2014; Owens & Jackson, 2017; Shaw et al., 2012; Stuart et al., 2009) as appears to be the case based on the teacher's description for Participant Three. Arnold et al. (2020) found that both test achievement and academic performance outcomes were reported to be poorer for individuals with untreated ADHD than non-ADHD controls, a finding also supported by further studies (Jangmo et al., 2019; Keilow et al., 2018).

Although the benefits of the intervention did not reflect on all of the WIAT-III subtests, a positive change was noted in Participant Three's performance on the Math Numeracy subtest (from a low average range to an average range) and it was felt by both teachers that her confidence with mathematics grew significantly. Participant Three's performance on the WIAT-III regressed in her overall maths fluency subtest, driven by the maths fluency addition subtest. These subtests were timed and administered in a group and her performance in such an environment may have been impacted by unmedicated ADHD. The maths numeracy subtest was untimed and administered individually, and her average range performance, according to Teacher B (the remedial mathematics teacher) is more reflective of her mathematical ability. For example, some of Participant Three's most deficient cognitive functions prior to the intervention taking place were perceived to be a *lack of, or impaired, receptive verbal tools which affect discrimination*, *conservation of constancies* and *difficulty in considering two or more sources of information at once.* It is thought that perhaps these were all impacted by her attentional challenges and lack of confidence. As the intervention progressed, progress in her cognitive functioning such an improved *ability to communicate adequately elaborated responses, ability to select relevant vs non-relevant cues in defining a problem and in pursuing logical evidence* may be due to an improved ability to maintain focus and greater confidence to express herself gained through the mediated learning intervention.

Despite the wide variety of learning challenges present within the sample of the current study, there are encouraging signs that the mediated learning intervention had a positive impact on cognitive functioning. This finding is supported by other studies that also found a positive impact on cognitive functioning due to a mediated learning intervention (Elsayed et al., 2021; Emmanouil & Georgis, 2018; Esterhuizen & Grosser, 2014; Seabi, 2012; Seabi & Cockcroft, 2012). One exception to these promising results for mediated learning interventions was reported by Seabi and Amod (2009) whose study resulted in an insignificant change in cognitive functioning following an intervention from Feuerstein's Learning Assessment Potential Device, measured on the Ravens Coloured Progressive Matrices. The researchers argued that perhaps the short intervention time influenced the findings.

Implications of the Study

The present findings have educational implications. This study aimed to evaluate the possibility of a single FIE instrument impacting mathematical ability and/or cognitive functioning among a small sample of Grade 5 private remedial learners with mathematics difficulties. The learners in this study also presented with diverse neurodevelopmental and other learning challenges. Although the study failed to report any noticeable impact on mathematical ability following the intervention, as outlined in the discussion, it is thought that perhaps the measurement tool could be optimised in relation to the goal and focus of the FU2G instrument. Should future research find more favourable results with a better aligned measurement tool, the FU2G instrument may prove to be a well-suited tool to address early numeracy challenges. The tool may be relevant to the foundation phase of mainstream learners as well as to higher grades where mathematics developmental delays present. The cost of the FU2G instrument is however a limitation especially for under-resourced schools, of which there are many in South Africa.

The study showed a positive impact on the deficient cognitive functions of a diverse profile of learners suggesting that such mediated learning through an intentional instrument is beneficial for the development of learners' cognitive functioning, especially when specific learning disorders are present. This implies that FIE and MLE are effective tools among such population groups. This form of intervention is however resource intensive given the cost of the instruments as well as the training, availability, and funding of mediators. This unfortunately suggests that this type of intervention is limited to well-resourced schools, private schools, and schools with a beneficial teacher-to-learner ratio.

Limitations of the Study

The case study approach to research offers many advantages, such as the ability for in-depth exploration of a particular subject and, as in this study, it offers the opportunity for preliminary investigation prior to further studies on a larger scale. It does however have several limitations, some of which were experienced in this study.

One of the primary limitations of small sample size case studies is their limited ability to generalise findings to broader populations and settings (Hackshaw, 2008; Tipton et al., 2017). As the current study focused on only three cases, it is not possible to draw generalised conclusions about similar samples. This is perhaps even more so a limitation in this study as each of the participants presented with different neurodiverse and learning difficulty profiles relative to each other making comparisons even within the study difficult. All of the learners were neurodiverse with well documented literature sharing the impact of such diversity on learning and performing in mathematics. Further, the study was conducted in a private remedial school and the intervention had the benefit of an advantageous teacher-to-learner ratio of 1:3 over its duration. The instrument itself is paper-based and requires original instrument booklets to be purchased due to copyright restrictions. Each FU2G instrumental workbook costs approximately R180 (US$ 9.50). Outside of private schooling it is unlikely that these resources could be delivered, either in terms of instrument booklets or in terms of small teacher-to-learner ratios. Conducting case studies can be time and resource intensive (Hancock et al., 2021). This study required intensive resources in terms of human resource time. A dedicated teacher conducted three 30-minute intervention sessions weekly over a 12-week period. It is possible to assume that most school settings will not have the luxury of teacher resources like this in addition to their core teaching responsibilities. Financial resources were also required to fund the FU2G instrument booklet as previously discussed and in many schools this additional budget may not be available.

Although quantitative data was used in the study with the comparison of mathematics class assessment marks and the comparison of WIAT-III subtest performance scores, given the small sample size the data was limited and interpreted qualitatively. As a result, this study, like most studies adopting an explorative case study methodology, is restricted in its ability to establish causation (Spirtes, 2010).

Due to approval from the ethics committee being received in August 2022, the participating school had already progressed their intervention in Term 2 (May to July 2022). The pre- and post-intervention semi-structured interviews included in the research proposal were subsequently combined into one interview that took place following approval from the ethics committee. As shared previously, the revised interview schedule can be found in Appendix H. While a wealth of insight was gained from this single interview with each teacher after the intervention, it is most likely that a better description of each learner's deficient cognitive functions would have been obtained if the interviews had taken place as originally planned before and after the intervention.

Despite these limitations largely associated with a case study methodology in general, it is felt that the current study was able to offer valuable insight into the use of a mediated learning intervention as a means to improve cognitive functioning related to mathematics as well as overall performance in mathematics abilities. Given its purpose as a preliminary investigation into the topic, a number of implications and suggestions for future research studies of a similar nature have been identified.

Suggestions for Future Research

This research study provides insights into the use of the FU2G Feuerstein instrumental enrichment instrument to impact the mathematical ability and deficient cognitive functioning of learners experiencing mathematical difficulties (mathematics developmental delays related to poor concept of number and weak foundation skills) through mediated learning. The sample of learners in the case study all attended a private remedial school environment and each presented with a unique neurodiverse profile and unique learning challenges. With this context in mind, the following suggestions with regards to future research are made.

The limitations of the present study provide opportunities for further research. Given that the choice of measurement tool of mathematical ability is questioned, it is suggested that future studies take findings from Aunio et al. (2021) and Chin and Fu (2021) and explore the use of a measurement tool that is more aligned to the FU2G instrument. Further qualitative studies with a larger sample size would allow for the exploration of the possible impact of the instrument on mathematical ability among learners with difficulties. As literature highlights, the earlier the intervention into numeracy gaps the better, and it is therefore suggested that future samples include learners in the earlier grades of the foundation phase.

This study made use of the general list of deficient cognitive functions defined by Feuerstein (Feuerstein, 1980). For each instrument within the FIE-Basic, the list of deficient cognitive functions is slightly modified to represent the cognitive functions most relevant to each instrument. The list of deficient cognitive functions for the FU2G instrument can be reviewed in Appendix T. It is recommended that studies of a similar nature that also make single use of the FU2G instrument make use of this expression of the cognitive functions as they are more fine-tuned in alignment to the intervention.

The mediated learning intervention appeared to have a positive impact regardless of aetiology on addressing deficient cognitive functions. This gives promise to a repeat of the study, addressing the concern raised above on the measurement for mathematical ability among a larger heterogenous sample of remedial school children with the inclusion of foundation phase learners. An alternative to such a study may include a comparative study among homogenous samples of the most prevalent learning disorders, for example, ADHD, dyslexia, dyscalculia and a comorbid sample group to establish if the instrument has greater impact on any of the aetiologies. It is possible that operative differences may be found at the input, elaboration, and output phases by aetiology.

It is suggested that future studies give consideration to the neurodiversity and learning difficulties that may exist within a sample. In larger scale studies a control group may be considered to evaluate the extent to which the impact of FIE and MLE interventions differs depending on the extent to which the sample is challenged and/or to compare its efficacy among different neurodiversities.

As the FIE-Basic instruments work as a collective to modify cognitive functions, future studies may want to consider the use of more than one instrument as the intervention. If the emphasis of the study is only on mathematical ability, the single use of the FU2G instrument may remain the most suitable given its focus on developing the concept of number. However, if the emphasis is on more general cognitive functioning the use of more than one FIE instrument may be beneficial.

Practical considerations for future studies of a similar nature were offered by the teacher who implemented the 12-week intervention with the learners in the current study. Working with a small group at a round table seemed ideal. She recommended that, if possible, the group be maintained at three members. She felt she was able to see them think as they were working and processing things through their writing and drawing. She noted the importance of acknowledging with a positive response and rewarding if they did something well. Although coloured pencils were used as a strategy to help the children differentiate the groups, they were drawing in response to the instrument's instructions, gimmicks and distractions should be kept to a minimum. There was one lesson in which one of the children brought brightly coloured pens that also had smells. The pens became the focal point of the lesson and a huge distraction.

The mediator also shared that a lesson was always a combination of working on the FU2G page and bridging or transferring the concept to something else practical. For example, a pack of cards was sorted with the same numbers in a group and also sorted into different shapes. Another example discussed was grouping boys and girls so that groups could be either homogenous or heterogenous but were still groups. The latter helped when the instrument shifted in complexity at page 9 where both different shapes and different colours were introduced. Another bridge asked in each lesson was, "Did you do something where you made groups of things today?"

The mediator initially encouraged the children to self-talk out loud, hearing themselves say the instructions and what was required in terms of groups of units and units in a group. As the intervention progressed, she could see that they were doing it quietly as a strategy to keep themselves systematic. This is a strategy that can be adopted and used across all subjects. Marking each other's work was another key element to the implementation of the FU2G intervention. They enjoyed doing it and loved to sign and give stickers of encouragement to each other.

According to the mediator, a further ingredient for success was having the parents on-board, commenting that "...they all had a wonderful attitude with their children. And that makes a difference. Everyone was on board." They were all supportive and committed throughout the intervention period and one participant's mother commented on the improvement she had seen at home since the start of the intervention. The following feedback was shared in a voice note WhatsApp message with the mediator:

> ... I have found a remarkable difference in her chatting, in her reasoning, in her mindset. I've seen a big improvement. I don't know if it's from the IE or what is it from. But thank you so much. I feel very blessed that she could participate in this. (Personal communication, June, 2022)

Concluding Comments

The fundamental aim of this research study was to explore the potential of a targeted Feuerstein mediated learning intervention, FU2G, to impact mathematical ability and improve deficient cognitive functioning among a small group of learners experiencing mathematical difficulties. Mathematics class assessments and the mathematics-related WIAT-III subtests were used as a measure of mathematical ability before and after the intervention. Semi-structured interviews provided the opportunity for the teachers involved in the study to share their perceptions of any changes in deficient cognitive function before and after the intervention as well as to share their perceptions of the FU2G mediated learning intervention in general. Following the period of intervention, no change in mathematical ability was noted but positive changes in deficient cognitive changes were perceived by the teachers across the input, elaboration, and output levels. Further, the teachers expressed an overall positive impact of their belief in and experience of FIE and mediated learning.

Notwithstanding the limitations of the study, the current case study provides positive insight regarding the impact of the FU2G mediated learning instrument on the deficient cognitive functions across a neurodiverse sample with multiple learning difficulties. Suggestions have been made for consideration of alternative measures of mathematical ability more aligned to the FU2G instrument. The FU2G mediated learning experience had a positive impact on each of the learners, seemingly offering support and new strategies where they were most impacted by their specific individual neurodevelopmental and other learning challenges.

In the foreword to the book *You love me! Don't accept me as I am* (Feuerstein et al., 2006), the "principle of the possible" is referred to. It is this principle that evokes hope through mediated learning that all who benefit from such instruction are likely to shift positively in their level of cognitive function. As experienced in this study, mediated learning has the potential to help learners optimise their way of thinking and achieve more than perhaps they knew they were capable of: "Instead, he or she follows the 'principle of the possible'; that is, whatever the child can be motivated and educated to do successfully just once – not necessarily again and again – becomes the level of reasonable expectation for the future" (Feuerstein et al., 2006, p. XXIX).

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APPENDICES

Appendix A: Action Plan 2024, Goals Related to Mathematics

Goal 1	Increase the number of learners in Grade 3 who, by the end of the year, have mastered the minimum language and numeracy competencies for Grade 3.
Goal 2	Increase the number of learners in Grade 6 who, by the end of the year, have mastered the minimum language and numeracy competencies for Grade 6.
Goal 3	Increase the number of learners in Grade 9 who, by the end of the year, have mastered the minimum language and numeracy competencies for Grade 9.
Goal 5	Increase the number of Grade 12 learners who pass mathematics.
Goal 8	Improve the average performance of Grade 6 learners in mathematics.
Goal 9	Improve the average performance of Grade 9 learners in mathematics.

Appendix B : Feuerstein's Deficit Cognitive Systems

Page 1 of 2

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Deficient Cognitive Functions

Impaired cognitive functions affecting the **Input Level** include those impairments concerning the quantity and quality of data gathered by the individual as he is confronted by a given problem, object, or experience. They include:

1. Blurred and sweeping perception
2. Unplanned, impulsive, and unsystematic exploratory behavior
3. Lack of, or impaired, receptive verbal tools which affect discrimination (e.g. objects, events, relationships, etc. do not have appropriate labels).
4. Lack of, or impaired, spatial orientation; the lack of stable systems of reference impairs the establishment of topological and Euclidean organization of space.
5. Lack of, or impaired, temporal concepts.
6. Lack of, or impaired, conservation of constancies (size, shape, quantity, orientation) across variation in these factors.
7. Lack of, or deficient, need for precision and accuracy in data gathering.
8. Lack of capacity for considering two or more sources of information at once; this is reflected in dealing with data in a piecemeal fashion, rather than as a unit of organized facts.

The severity of impairment at the Input Level may also affect ability to function at levels of Elaboration and Output, but not necessarily so.

Impaired cognitive functions affecting the **Elaboration Level** include those factors which impede the efficient use of available data and existing cues.

1. Inadequacy in the perception of the existence and definition of an actual problem.
2. Inability to select relevant vs. non-relevant cues in defining a problem.
3. Lack of spontaneous comparative behavior or limitation of its application by a restricted need system.
4. Narrowness of the psychic field.
5. Episodic grasp of reality.
6. Lack of, or impaired, need for pursuing logical evidence.
7. Lack of, or impaired, internalization.
8. Lack of, or impaired, inferential-hypothetical thinking.
9. Lack of, or impaired, strategies for hypothesis testing.
10. Lack of, or impaired summative behavior
11. Lack of, or impaired, planning behavior
12. Non-elaboration of certain cognitive categories because the verbal concepts are not a part of the individual's verbal inventory on a receptive level, or they are not mobilized at the expressive level.

"Thinking" usually refers to the elaboration of cues. There may well be highly original, creative, and correct elaboration, which yields wrong responses because it is based on inappropriate or inadequate data on the Input Level.

Page 2 of 2

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Impaired cognitive functions on the **Output Level** include those factors that lead to an inadequate communication of final solutions. It should be noted that even adequately perceived data and appropriate elaboration can be expressed as an incorrect or haphazard solution if difficulties exist at this level.

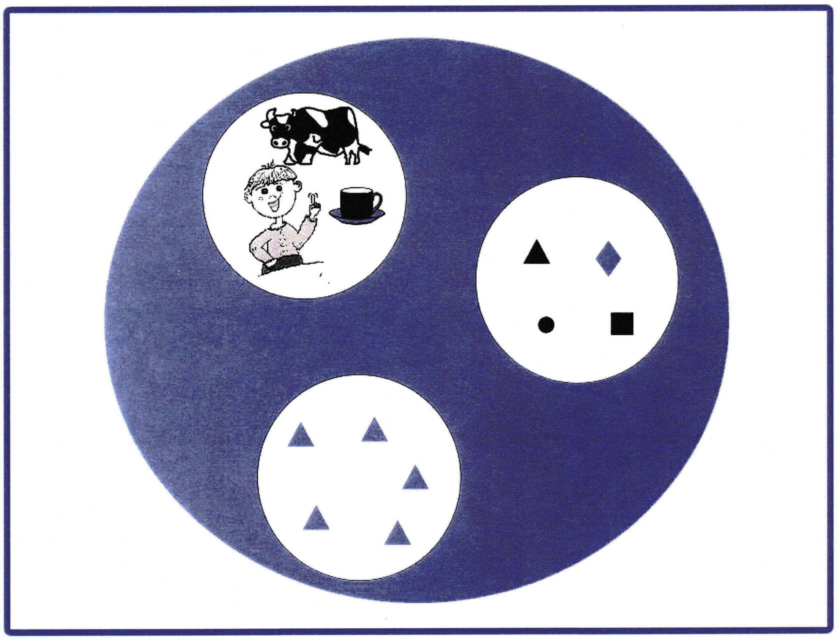
1. Egocentric communicational modalities.
2. Difficulties in projecting virtual relationships.
3. Blocking.
4. Trial and error responses.
5. Lack of, or impaired, tools for communicating adequately elaborated responses.
6. Lack of, or impaired, need for precision and accuracy in communicating one's responses.
7. Deficiency of visual transport.
8. Impulsive, acting-out behavior.

The three disparate levels were conceived so as to bring some order into the array of impaired cognitive functions seen in the culturally deprived. Yet, there is interaction occurring between and among the levels, which is of vital significance in understanding the extent and pervasiveness of cognitive impairment.

Appendix C: Sample Pages of From Unit to Group Instrument

Page 1

FROM UNIT TO GROUP



JUST A MOMENT...
LET ME THINK!

Feuerstein Instrumental Enrichment - BASIC

Page 5


FIE-BASIC
From Unit To Group
5
Name:
Date:
1.
Units
Groups
Total
2 in each group
2.
Units
Groups
Total
2 in a group; 8 in a group
3.
Units
Groups
Total
9 in each group
4.
Units
Groups
Total
2 in a group; 8 in a group
5.
Units
Groups
Total
3 in a group
6.
Units
Groups
Total
2 in each group
Feuerstein Instrumental Enrichment - BASIC
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Jerusalem
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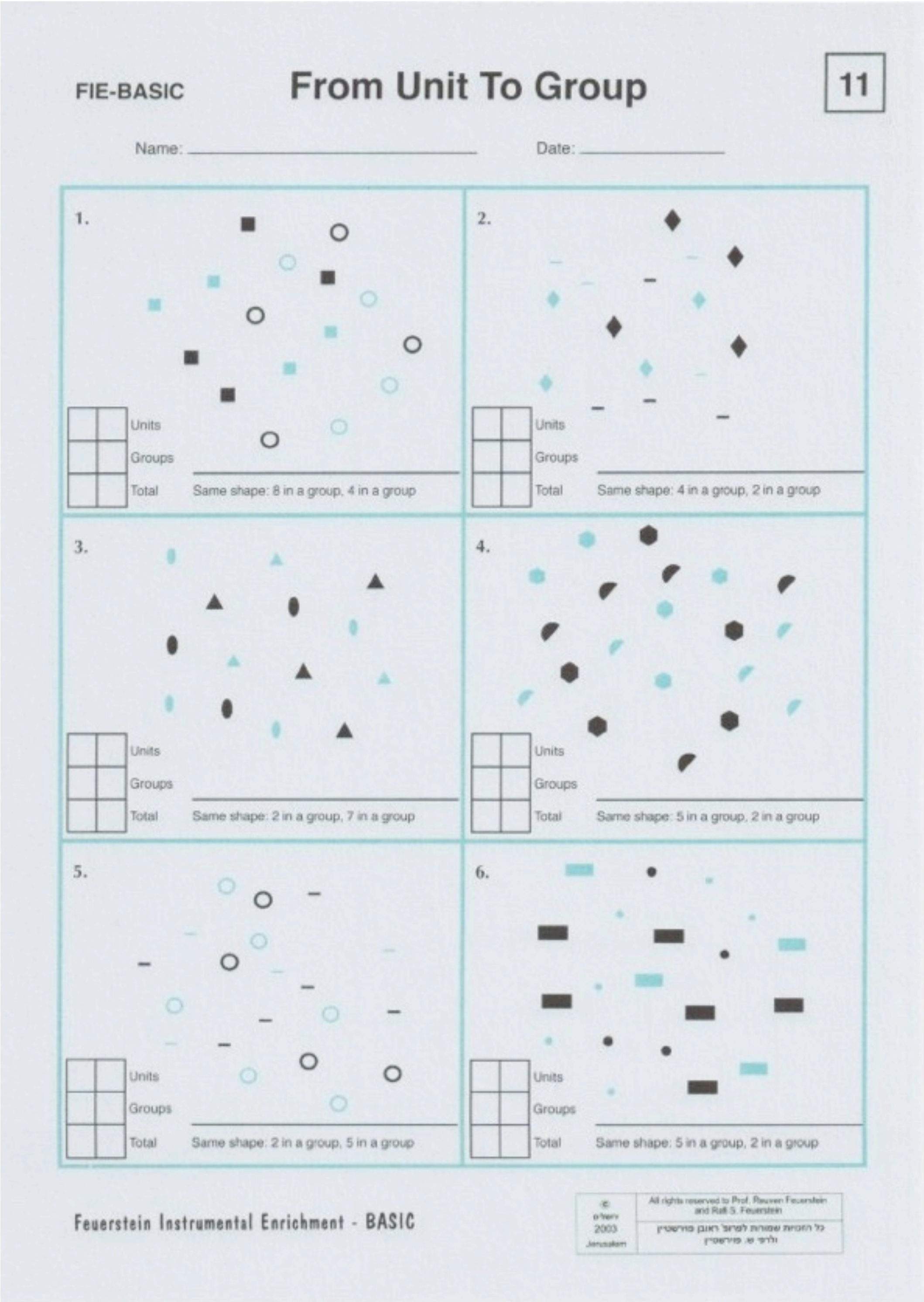
Page 11


FIE-BASIC **From Unit To Group** 11

Name: ______________ Date: __________

1\.
Units
Groups
Total
Same shape: 8 in a group, 4 in a group

2\.
Units
Groups
Total
Same shape: 4 in a group, 2 in a group

3\.
Units
Groups
Total
Same shape: 2 in a group, 7 in a group

4\.
Units
Groups
Total
Same shape: 5 in a group, 2 in a group

5\.
Units
Groups
Total
Same shape: 2 in a group, 5 in a group

6\.
Units
Groups
Total
Same shape: 5 in a group, 2 in a group

Feuerstein Instrumental Enrichment - BASIC

Appendix D: Results in Essays 1 and 2

Results in Essays 1 and 2

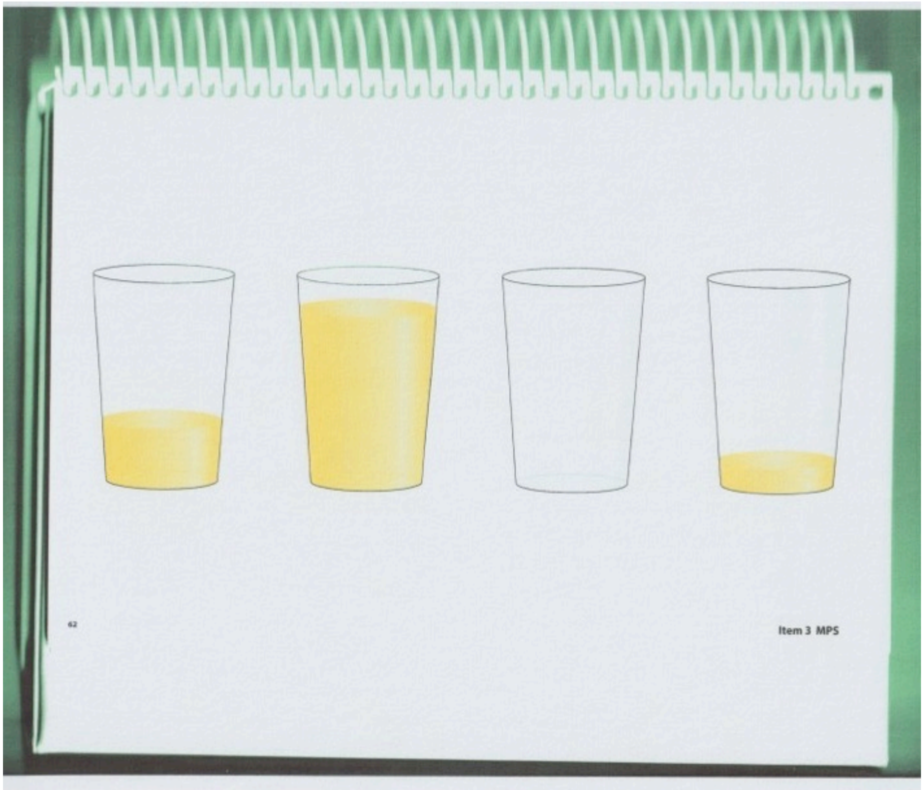
Student	Result Essay 1	Result Essay 2
1	11/28	25/28
2	9/28	26/28
3	17/28	26/28
4	4/28	26/28
5	18/28	26/28
6	16/28	25/28
7	18/28	26/28
8	11/28	24/28
9	11/28	24/28
10	18/28	26/28

Note. Reprinted (summarised) from Emmanouil and Georgios (2018).

Appendix E: WIAT-III Maths Problem Solving Subtest (sample page)

Item 3: MPS

Say: “ Point to the empty glass”.



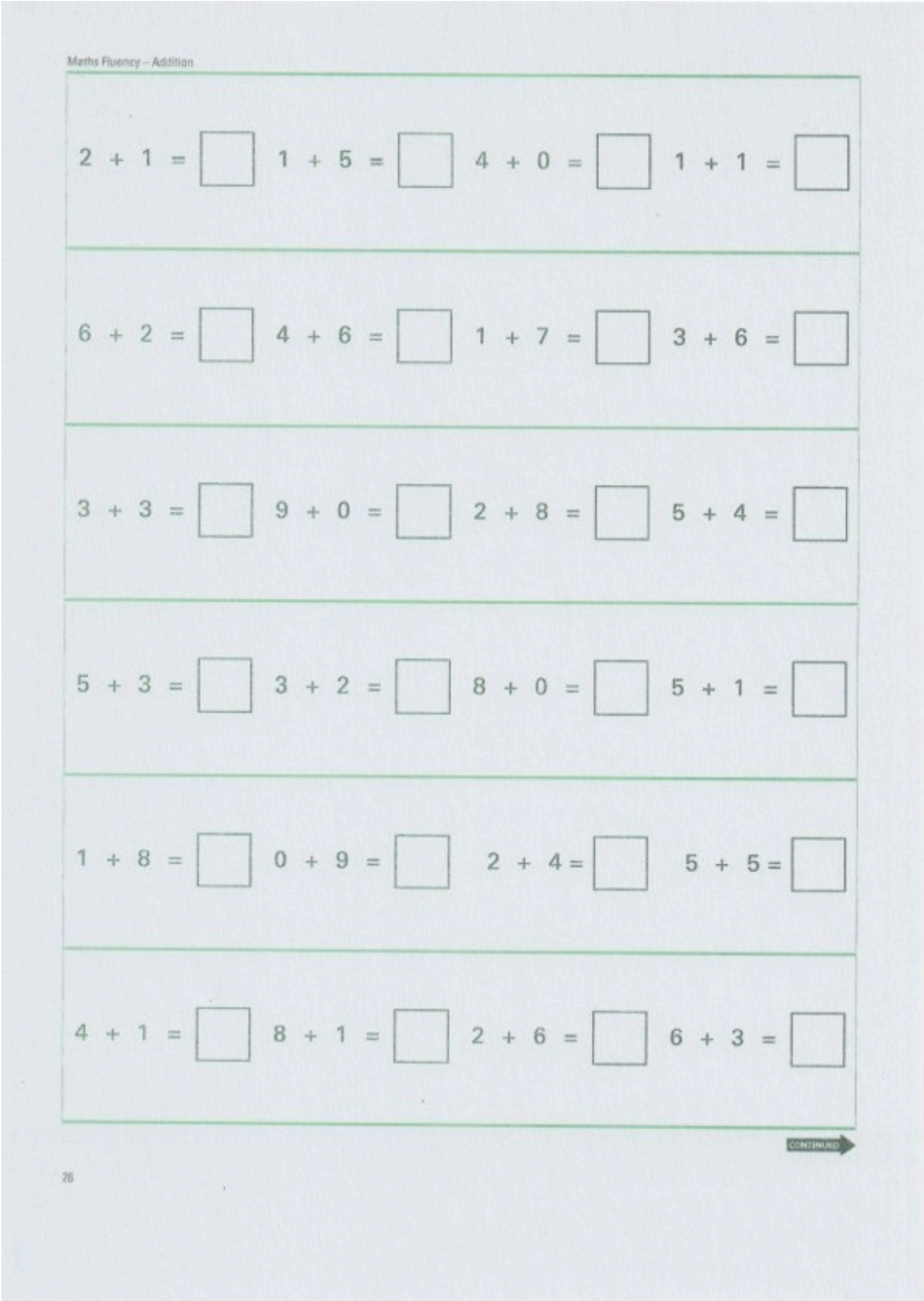
Appendix F: WIAT-III Numeracy Subtest (sample page)

17. $7 + 6 =$ ____	18. $\begin{array}{r} 12 \\ \underline{-\ \ 5} \end{array}$	19. $\begin{array}{r} 63 \\ \underline{+\ 16} \end{array}$
20. $5 \times 5 =$ ____	21. $4 \times 3 =$ ____	22. $6 \times 5 =$ ____
23. $\begin{array}{r} 865 \\ \underline{+\ 236} \end{array}$	24. $\begin{array}{r} 70 \\ \underline{-\ 24} \end{array}$	25. $\begin{array}{r} 140 \\ \underline{-\ \ \ 15} \end{array}$

CONTINUED

Appendix G: WIAT-III Maths Fluency Subtest

Sample Page 1 of 3



Maths Fluency – Addition

2 + 1 =	1 + 5 =	4 + 0 =	1 + 1 =
6 + 2 =	4 + 6 =	1 + 7 =	3 + 6 =
3 + 3 =	9 + 0 =	2 + 8 =	5 + 4 =
5 + 3 =	3 + 2 =	8 + 0 =	5 + 1 =
1 + 8 =	0 + 9 =	2 + 4 =	5 + 5 =
4 + 1 =	8 + 1 =	2 + 6 =	6 + 3 =

CONTINUED

26

Sample Page 2 of 3

$7 - 1 = \square$	$3 - 3 = \square$	$7 - 7 = \square$	$3 - 1 = \square$
$5 - 4 = \square$	$9 - 8 = \square$	$3 - 0 = \square$	$6 - 4 = \square$
$9 - 6 = \square$	$10 - 8 = \square$	$8 - 3 = \square$	$10 - 3 = \square$
$8 - 7 = \square$	$5 - 0 = \square$	$10 - 6 = \square$	$8 - 1 = \square$
$9 - 2 = \square$	$2 - 2 = \square$	$10 - 7 = \square$	$4 - 0 = \square$
$8 - 8 = \square$	$10 - 1 = \square$	$7 - 0 = \square$	$6 - 6 = \square$

CONTINUED

Sample Page 3 of 3

1×7	2×1	4×2	3×5
7×2	4×4	2×7	5×1
2×8	3×0	1×8	6×2
2×9	8×2	7×0	5×4
3×7	4×5	3×4	4×6

CONTINUED

Appendix H: Combined Semi-Structured Interview Schedule with Teachers (After Intervention)

	INTERVIEW SCHEDULE NOVEMBER 2022
Warm-up and Introduction	• Thank you for your participation in the study • Reminder that study is to explore the impact of a targeted mediated learning experience on the mathematical ability of Grade 5 learners who were experiencing mathematical difficulties • Specifically, the research seeks to explore the following research questions: o Is there a change in the mathematical ability among a group of Grade 5 learners following a 12-week targeted mediated learning intervention? o Prior to the mediated learning intervention, how do teachers describe each child's observed mathematical ability with reference to Feuerstein's Cognitive Functions? o Following the intervention, how do teachers describe each child's observed mathematical ability with particular reference to Feuerstein's Cognitive Functions and the mediated learning instrument? o What are teachers' perceptions related to the use and benefits of mediated learning prior to and after the intervention taking place? • In order to answer the research questions, the research study included three phases o Pre o Intervention o Post • As part of the study two semi structured interviews will be conducted with the specialist teacher who conducted the intervention with the children over a 12-week period and with the head of remedial teaching who has been involved in teaching the participants mathematics this year. • These interviews will take an hour to an hour and a half and with consent will be audio recording for the purposes of transcription and interpretation for the research report. Anonymity will be maintained in the final report.

PRE **Case Study/ Profile Building of each Learner**	For each of the learners who participated in the intervention I'd like to ask you some questions that will be helpful to understand the profile of each child related to their general learning and mathematics and in particular. <u>Participant 1:</u> • What grade did the child start remedial school? • Have any learning disorders or other diagnoses been made that may impact on the child's general learning ability or mathematical ability? • What were the main reasons for identifying this child as a suitable participant in the research? • How would describe the child's maths and numeracy abilities as observed in class prior to commencement of the intervention? • If we look at this child's performance in the first terms maths test and her performance on the WIAT subtests how would you describe the difficulties experienced? <u>Participant 2:</u> • What grade did the child start remedial school? • Have any learning disorders or other diagnoses been made that may impact on the child's general learning ability or mathematical ability? • What were the main reasons for identifying this child as a suitable participant in the research? • How would describe the child's maths and numeracy abilities as observed in class prior to commencement of the intervention? • If we look at this child's performance in the first terms maths test and her performance on the WIAT subtests how would you describe the difficulties experienced? <u>Participant 3:</u> • What grade did the child start remedial school? • Have any learning disorders or other diagnoses been made that may impact on the child's general learning ability or mathematical ability? • What were the main reasons for identifying this child as a suitable participant in the research? • How would describe the child's maths and numeracy abilities as observed in class prior to commencement of the intervention? • If we look at this child's performance in the first terms maths test and her performance on the WIAT subtests how would you describe the difficulties experienced?
Feuerstein's Cognitive Functions	<u>PRE</u> • Based on Feuerstein's deficient cognitive functions, and in relation to the learners mathematical and numeracy ability, where do you

	think each participant faced the most challenges prior to or early on in the intervention? • Are you able to give examples to illustrate the difficulties presented? • This can be based on your observation in the classroom or during the beginning intervention sessions. Participant 1: Input / Elaborate / Output (see appendix A) Participant 2: Input / Elaborate / Output (see appendix A) Participant 3: Input / Elaborate / Output (see appendix A) <u>POST</u> • Based on Feuerstein's deficient cognitive functions, and in relation to the learners mathematical and numeracy ability, did you observe any improvement in the previously identified challenging cognitive functions after completion of the intervention? • Are you able to give examples to illustrate such improvement? • This can be based on your observation in the classroom or towards the end of the intervention sessions. Participant 1: Input / Elaborate / Output (see appendix A) Participant 2: Input / Elaborate / Output (see appendix A) Participant 3: Input / Elaborate / Output (see appendix A)
POST Case Study/ Profile Building of each Learner	<u>For each of the participants (1,2, &3)</u> • What was your experience as the mediator working with this learner through-out the intervention? (DB) • Are there any specific examples or experiences from any of the intervention sessions that you would like to highlight or expand on? (DB) • What changes in the learner's ability or way of working, if any, did you notice over the 12-week intervention period? (DB) • Did you receive (or observe) any feedback related to the child's maths and numeracy performance in the classroom during or after the intervention? (DB / MV) • If we look at this child's performance in the third terms maths test (*and her performance on the WIAT subtests - end Jan 2023)* , are there any changes compared to the first term? Please can you expand on these. (DB & MV) • Were there any changes in the child's ability on pages 5 and 11 of the FU2G instrument pre and post the intervention?

PRE-Perceptions about MLE & From Unit to Group (FU2G) instruments	If you think back to the start of the research project, • What was your perception of MLE considering its potential use and benefits? • What was your perception of the FU2G instrument, considering its potential use and benefits? • What did you think the research would show us?
POST Perceptions about MLE & From Unit to Group (FU2G) instruments	On reflection after the 12 -week intervention, has your perception about MLE and / or the potential use and benefit of the FU2G instrument changed in any way? Can you expand on this? • What do you think the research may show us now?
WRAP UP	• Is there anything additional that you would like to share related to the research project in general or the intervention in particular? • Thank you for your time and your participation • Communicate next steps and timing in the study • Is there anything that needs clarification?

INTERVIEW: Appendix A FEUERSTEINS DEFICIENT COGNITIVE FUNCTIONS

Input

1.	Blurred or sweeping perception
2.	Unplanned, impulsive, and unsystematic exploratory behaviour
3.	Lack of, or impaired, receptive verbal tools which affect discrimination
4.	Lack of, or impaired, spatial orientation
5.	Lack of, or impaired, temporal concepts
6.	Lack of, or impaired, conservation of constancies
7.	Lack of, or deficient, need for precision and accuracy in data gathering
8.	Lack of capacity for considering two or more sources of information at once

Elaboration

1	Inadequacy in the perception of the existence and definition of an actual problem
2	Inability to select relevant vs non-relevant cues in defining a problem
3	Lack of spontaneous comparative behaviour or ...
4	Narrowness of the psychic field
5	Episodic grasp of reality
6	Lack of, or impaired, need for pursuing logical evidence
7	Lack of, or impaired, internalization
8	Lack of, or impaired, inferential – hypothetical thinking
9	Lack of, or impaired, strategies for hypothesis testing
10	Lack of, or impaired, summative behaviour
11	Lack of, or impaired, planning behaviour
12	Non-elaboration of certain cognitive categories (receptive and / or expressive)

Output

1.	Egocentric communicational modalities
2.	Difficulties in projecting virtual relationships
3.	Blocking
4.	Trial and error responses
5	Lack of, or impaired, tools for communicating adequately elaborated responses
6	Lack of, or impaired, need for precision and accuracy in communicating one's responses.
7	Deficiency of visual transport
8	Impulsive, acting out behaviour

Appendix I: Ethical Clearance Certificate, University of the Witwatersrand

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Research Office

HUMAN RESEARCH ETHICS COMMITTEE (NON-MEDICAL)
R14/49 Cooke

CLEARANCE CERTIFICATE	**PROTOCOL NUMBER: H22/06/07**
PROJECT TITLE	Exploring the impact of a targeted mediated learning intervention on the mathematical ability of Grade 5 learners experiencing mathematical difficulties
INVESTIGATOR(S)	Mrs B Cooke
SCHOOL/DEPARTMENT	Human and Community Development/
DATE CONSIDERED	24 June 2022
DECISION OF THE COMMITTEE	Approved Risk Level: Low
EXPIRY DATE	23 August 2025

DATE 24 August 2022 **CHAIRPERSON** ____________________
(Professor J Watermeyer)

cc: Supervisor : Professor Z Amod

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10004, 10th Floor, Senate House, University. Unreported changes to the application may invalidate the clearance given by the HREC (Non-Medical)

I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to submit an amendment of the protocol to the Committee. **I agree to completion of a regular progress report. For Minimal and Low studies, this is due annually on 31 December. For Medium and High Risk studies, this is due twice annually on 30 June and 31 December.**

____________________ **______/______/______**
Signature **Date**

PLEASE QUOTE THE PROTOCOL NUMBER ON ALL ENQUIRIES

Appendix J: Principal Information Letter and Consent Form

PRINCIPAL INFORMATION LETTER

30 March, 2022

Dear Principal,

Re: Permission to conduct research at ABC Remedial School

Good Day. My name is Lindy Cooke and I am studying for a Masters' Degree in Educational Psychology at the University of the Witwatersrand. I am seeking permission to conduct research at ABC school following interactions over the last few months with some ABC staff members on the topic.

My research study is a preliminary investigation to explore the potential of a targeted Feuerstein mediated learning intervention to impact mathematical ability among a small group of learners experiencing mathematical difficulties. Furthermore, the study will explore whether such an approach to teaching key mathematics concepts is beneficial to the learners overall cognitive functioning related to mathematics. I understand that as a school ABC is interested in evidence-based practice and is committed to pursue proven cutting-edge intervention strategies, positioning the school as not only relevant within remedial education but as pioneers and influencers on education in its entirety. One area of such progressive thinking is the schools focus on cognitive education and commitment to Feuerstein's Instrumental Enrichment (FIE). Given this approach to education and ABC school's work towards developing and launching the Award in Mathematics and Dyscalculia training program in 2023, it is my hope that this preliminary research study will provide beneficial information to enrich the on-going development of the program as well as provide insight to the teaching and remediation of basic numeracy skills. Given the commonly acknowledged challenges with numeracy levels in South Africa it is further hoped that this preliminary investigation contribute to future research among other South African school populations in need of basic numeracy skill development and / or remediation. While literature and research exists on the challenges there is very limited local research related to the solution.

The research will entail collecting data from two staff members and three to six Grade 5 learners. I request permission to gain access to the learners WIAT-III assessment scores (Feb/Mar 2022 and Oct/Nov 2022); to their Term 1 and Term 3 class mathematic tests and to any relevant material generated through the work with the intervention instrument in the remedial classroom. I also request permission for the two teachers to share background information on each child participating in the study to build a profile of the child in relation to specific diagnoses, behavioral challenges and / or learning challenges.

I will invite two specialist teachers and three to six Grade 5 learners to participate in the study. These teachers have been specifically identified for their expert knowledge and experience – a specialist educator trained in the FIE program and certified to implement the intervention instrument and the Head of Remedial Academics, also responsible for teaching remedial mathematics as part of the curriculum to selected Grade 5 learners. If they agree, the learners will be asked to participate in an intervention program over the course of the second term (specifically to attend three 30-minutes sessions a week prior to the commencement of the regular school day on the school premises). If they consent, the teachers will be asked to participate in two semi-structured interviews of an hour to an hour and a half each. These interviews will take place prior to the intervention commencing and on its completion. These interviews will take place on the school premises at convenient time. The participants' responses in the interviews will be audio recorded should they give consent to do so.

The parents/legal guardians will be asked for consent before the research begins. The children will also be asked for their ascent to participation in the research study. All participant responses will be treated confidentially, and identities including their names and the name of the school, will be anonymous unless otherwise expressly indicated. Individual privacy will be maintained in all published and written data resulting from the study.

The research participants will not be advantaged or disadvantaged in any way. They will be reassured that they can withdraw their permission at any time during this project without any penalty. There are no foreseeable risks in participating in this study. Participants also do not have to answer any questions that they do not feel comfortable with. The participants will not be paid for this study.

All data will be stored on a password protected computer to which only the researcher will have access. All hard copies of learner generated classroom material will be safely stored in a locked filing cabinet which only the researcher has access to. A summary of the results will be provided to the school by March 2023. The results may also be published in a journal article.

I therefore request permission in writing to conduct my research at your school. Should you consent for your school to partake in this study please indicate this in writing by return of the completed attached permission letter which should please be printed be on your school's headed paper, signed and dated, and specifically referring to myself by name and the title of my study.

Please let me know if you require any further information. I look forward to your response as soon as is convenient , preferably by 4th April 2022.

Yours sincerely,
Lindy Cooke

Lindy Cooke
Researcher
MEd Psychology Student
076 400 7001

Professor. Zaytoon Amod
Research Supervisor: Educational & Clinical Psychologist
011 717 8326

PRINCIPAL CONSENT FORM

I, ___________________________________, hereby give consent for Lindy Cooke to conduct her research on the potential of a targeted Feuerstein mediated learning intervention to impact mathematical ability among a small group of learners with mathematical difficulties, at ___________________________ (name of school).

I understand that:

- Participation in this study is completely voluntary and there are no foreseeable risks or benefits for partaking in it.
- The research does not expose any of the participants or the school to any harm.
- All participants and the school have the right to withdraw from the study at any time; without any consequence.
- Participants do not have to answer any questions that they do not feel comfortable with.
- The school's and participants' information will be treated as confidential.
- Anonymity through the use of pseudonyms will be ensured in the final research report or any publications/presentations that might arise from this research.
- The results of the study will be compiled into a report document which will be stored in the University of the Witwatersrand main library, and made available online on the WITS Institutional Repository environment on WIReDSpace, where an electronic copy of all research reports, dissertations and theses are kept.
- Results of the study might also be published in the form of peer reviewed journal articles and/or book chapters. Likewise it might be presented at conferences.
- The school will be provided with an executive summary of the research results.
- Feedback will be offered to Bellavista stakeholders including the teachers participating in the research study at a time that is convenient for them.

____

School Principal's Signature

____

Date

Appendix K: Teacher Information Letter and Consent Forms

TEACHER PARTICIPANT INFORMATION LETTER

Dear Sir/Madam

My name is Lindy Cooke and I am studying for a Master's degree in Educational Psychology at the University of the Witwatersrand. I am conducting research in partial fulfilment for the completion of my degree. The research study is a preliminary investigation to explore the potential of a targeted Feuerstein mediated learning intervention to impact mathematical ability among a small group of learners experiencing mathematical difficulties. Furthermore, the study will explore whether such an approach to teaching key mathematics concepts is beneficial to the learners' overall cognitive functioning related to mathematics.

A small group of Grade 5 learners will participate in an intervention program by attending three 30-minute sessions a week prior to the commencement of the regular school day on the school premises. During this intervention program a Feuerstein mediated learning instrument called "From Unit to Group" (FU2G) will be worked through with a specialist remedial teacher. Based on your experience, knowledge and expertise I would like to invite you to participate in my study. With your consent, I will ask you to participate in two semi-structured interviews of an hour to an hour and a half each. These interviews will take place prior to the intervention commencing and on its completion. These interviews will take place on the school premises at a convenient time. Responses in the interviews will be audio recorded should you provide give consent for me to do so. The data gathered from these interviews will assist me to build a profile of each child in relation to specific diagnoses, behavioral challenges, learning challenges and mathematical ability as observed in the classroom for each child participating in the study.

All participant responses will be treated confidentially and identities including your name and the name of the school will be kept confidential. However, due to the nature of the study with a very small sample size and intimate school setting confidentiality cannot be guaranteed throughout the research process. It is not possible to maintain anonymity throughout the research process due to the data gathering procedure being face-to-face interviews. However, anonymity will be maintained in any resulting reports and/or publications through the use of pseudonym names.

Participation in this study is completely voluntary and it is your choice whether you participate or not. Research participants will not be advantaged or disadvantaged in any way. You have the right to withdraw from the study at any time without any penalty. There are no foreseeable benefits or risks in participating in this study. You will not have to answer any questions that you do not feel comfortable with. Participants will not be paid for this study. The children will also be asked for their assent to participate in the research study.

Should you be approached by parents whose children are not in the study but are interested for their children to participate in the intervention please communicate that this preliminary investigation is the first step to explore the benefits of the FU2G intervention in improving mathematical ability and should the results be positive there will be consideration for wider use and implementation of the tool at which stage the child in case may or may not be considered a suitable beneficiary of the intervention.

All data will be stored on a password protected computer to which only the researcher will have access. All hard copies of learner generated classroom material will be safely stored in a locked filing cabinet which only the researcher and her supervisor would have access to.

The results of the study will be compiled into a research report which would be made available online on the WITS Institutional Repository environment on WIReDSPACE, where an electronic copy of all research reports, dissertations and theses are kept. The results may also be published in a peer reviewed journal article and/or book chapters. Likewise, it might be presented at conferences. A summary of the results will be provided to the school by March 2023 and this summary will also be made available to you upon your request via e:mail to me. Parents can also have access to the summary of the findings by contacting the researcher.

Should you consent to partake in this research, please read and sign the attached consent form. Should you have any questions or concerns with regards to this research study please feel free contact me directly. Any queries regarding ethical issues can also be directed to: The University of the Witwatersrand Human Research Ethics Committee (non-medical): 011-717-1408; hrecnon-medical@wits.ac.za

Yours sincerely,

Lindy Cooke
Researcher
MEd Psychology Student
076 400 7001

Professor Zaytoon Amod
Research Supervisor: Educational & Clinical Psychologist
011 717 8326

TEACHER CONSENT FORM

Exploring the potential of a targeted Feuerstein mediated learning intervention to impact mathematical ability among a small group of learners experiencing mathematical difficulties.

Researcher : Lindy Cooke

I, ___________________________________, hereby give consent for Lindy Cooke to include my participation in her research study.

I agree to the following:
(Please circle the relevant options below)

The research study was explained to me. I understand what this study is about.	YES	NO
The researcher will conduct two semi-structured interviews with me	YES	NO
Participation in this study is completely voluntary	YES	NO
The research does not expose any of the participants or the school to any harm.	YES	NO
I have the right to withdraw from the study at any time; without any consequence.	YES	NO
I do not have to answer any questions that they do not feel comfortable with.	YES	NO
My information will be treated as confidential although confidentiality cannot be guaranteed throughout the research process.	YES	NO
Anonymity cannot be guaranteed throughout the research process however anonymity will be provided in the final research report or any publications/presentations that might arise from this research through the use of pseudonyms.	YES	NO
The researcher may choose to use direct quotation with pseudonym names and all identifying information being sanitized.	YES	NO
The results of the study will be compiled into a research report and will be made available online on the WITS Institutional Repository environment on WIReDSpace, where an electronic copy of all research reports, dissertations and theses are kept.	YES	NO
Results of the study might also be published in the form of peer reviewed journal articles and/or book chapters. Likewise, it might be presented at conferences.	YES	NO
The school will be provided with an executive summary of the research results and I can also have access to the summary of the research findings.	YES	NO

_________________________________ Signature

_________________________________ Name of Participant

________________________________ Date

________________________________ Signature

________________________________ Name of Researcher

________________________________ Date

TEACHER CONSENT FORM, AUDIO RECORDING

Exploring the potential of a targeted Feuerstein mediated learning intervention to impact mathematical ability among a small group of learners experiencing mathematical difficulties.

Researcher : Lindy Cooke

I consent to the interviews being audio-recorded	**YES**	**NO**

_________________________________ Signature

_________________________________ Name of Participant

_________________________________ Date

Appendix L: Parent Information Letter and Consent Form

PARENT / LEGAL GUARDIAN INFORMATION LETTER

Dear Sir/Madam

My name is Lindy Cooke and I am studying for a Master's degree in Educational Psychology at the University of the Witwatersrand. I am conducting research in partial fulfilment for the completion of my degree. The research study is a preliminary investigation to explore the potential of a targeted Feuerstein mediated learning intervention to impact mathematical ability among a small group of learners experiencing mathematical difficulties. Furthermore, the study will explore whether such an approach to teaching key mathematics concepts is beneficial to the learners' overall cognitive functioning related to mathematics.

I would like to invite your child to participate in my research study. Should you grant consent for your child to participate in this study he/she will become part of a mathematics mediated learning intervention group. This small group of learners will participate in an intervention program over the course of a term, attending three 30-minute sessions a week prior to the commencement of the regular school day on the school premises. During this intervention program a Feuerstein mediated learning instrument called "From Unit to Group" will be worked through with a specialist remedial teacher from the school.

This learning instrument that will be used deals with the pre-requisite concepts and functions for mathematics. It assists children to prepare for mathematics through counting which leads to the concept of number, through repeated addition which leads to the concept of multiplication and through counting on which leads to the concept of sums and calculations. The FU2G instrument is the basis for developing the concept of number, a complex task involving both ordinality of numbers (a number as part of a sequence, position or rank) and cardinality of numbers a number as a set or quantity).

Should you grant consent for your child to participate in this study, I will gain access to your child's Wechsler Individual Achievement Test, Third Edition (WAIT-III) assessment results administered by a qualified psychologist in the school in Term 1 and repeated in Term 3, to his/her class mathematics test marks from Term1 and Term 3 and to material generated in the classroom during the intervention sessions. Part of the research study involves semi-structured interviews with two teachers to gain insight to each child participating in the research study and with your consent information gained in these interviews will also inform the research.

All participant responses will be treated confidentially and identities including the name of your child and the name of the school will be kept confidential. However, due to the nature of the study with a very small sample size and intimate school setting confidentiality cannot be guaranteed throughout the research process. It is not possible to maintain anonymity throughout the research process given that the details of the children who participate in the study will be known to the researcher. However, anonymity will be maintained in any resulting reports and/or publications through the use of pseudonym names.

Participation in this study is completely voluntary and it is your choice whether your child will participate or not. Research participants will not be advantaged or disadvantaged in any way. You have the right to withdraw your child from the study at any time without any penalty. There are no foreseeable risks in participating in this study and your child will not have to answer any questions that he/she does do feel comfortable with. Participants will not be paid for this study. Your child will be asked for his or her assent to participate in the research study. All data will be stored on a password protected computer to which only the researcher will have access. All hard copies of learner generated classroom material will be safely stored in a locked filing cabinet which only the researcher and her supervisor would have access to.

The results of the study will be compiled into a research report which would be made available online on the WITS Institutional Repository environment on WIReDSPACE, where an electronic copy of all research reports, dissertations and theses are kept. The results may also be published in a the form of a peer reviewed journal article and/or book chapters. Likewise, it might be presented at conferences A summary of the results will be provided to the school by March 2023 and this summary will also be made available to you upon your request via e:mail to me.

Should you consent for your child to partake in this research, please read and sign the attached consent form. Should you have any questions or concerns with regards to this research study please feel free to contact me. Any queries regarding ethical issues can also be directed to: The

University of the Witwatersrand Human Research Ethics Committee (non-medical): 011-717-1408; hrecnon-medical@wits.ac.za

Yours sincerely,

Lindy Cooke	Professor Zaytoon Amod
Researcher	Research Supervisor: Educational & Clinical Psychologist
MEd Psychology Student	
076 400 7001	011 717 8326

PARENT/LEGAL GUARDIAN CONSENT FORM

Exploring the potential of a targeted Feuerstein mediated learning intervention to impact mathematical ability among a small group of learners experiencing mathematical difficulties.

Researcher : Lindy Cooke

I, ___________________________________, parent/legal guardian of ___________________, currently in Grade ____, hereby give consent for Lindy Cooke to include my child in her research study.

I agree to the following:
(Please circle the relevant options below)

The research study was explained to me. I understand what this study is about.	YES	NO
My child will participate in an intervention program over the duration of a term. This will require my child to attend three 30-minute sessions a week, in the morning prior to the school day commencing.	YES	NO
Participation in this study is completely voluntary	YES	NO
The research does not expose any of the participants or the school to any harm.	YES	NO
All participants and the school have the right to withdraw from the study at any time; without any consequence.	YES	NO
Participants do not have to answer any questions that they do not feel comfortable with.	YES	NO
The school's and participants' information will be treated as confidential although confidentiality cannot be guaranteed throughout the research process.	YES	NO
Anonymity cannot be guaranteed throughout the research process however anonymity will be provided in the final research report or any publications/presentations that might arise from this research through the use of pseudonyms.	YES	NO
The results of the study will be compiled into a research report and will be made available online on the WITS Institutional Repository environment on WIReDSpace, where an electronic copy of all research reports, dissertations and theses are kept.	YES	NO
Results of the study might also be published in the form of peer reviewed journal articles and/or book chapters. Likewise, it might be presented at conferences.	YES	NO
The school will be provided with an executive summary of the research results and I can also have access to the summary of the research findings.	YES	NO

________________________________ Signature

________________________________ Name of Participant

________________________________ Date

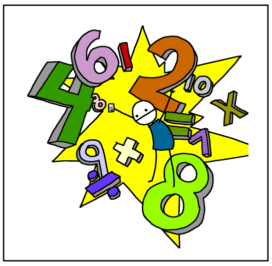
________________________________ Signature

________________________________ Name of Researcher

________________________________ Date

Appendix M: Learner Information Letter and Assent Form

LEARNER INFORMATION LETTER



Hello Grade 5 Learner

- My name is Lindy Cooke and I am a learning just like you are.
- As part of my studies I have to do a research project.
- The project is about a special way of learning to do mathematics.

AN INVITATION TO TAKE PART IN MY PROJECT IF YOU WOULD LIKE TO

- You will become part of a small group with other children in your grade.
- A teacher from your school will do different tasks with you in a fun way.
- Nothing is for marks or for your school report.
- There will always be the opportunity to ask questions and ask for help
- My project is just to see if doing and practicing these different tasks is helpful for your learning in any way.

WHAT WOULD BE NEEDED FROM YOU?

- Come to school a bit early 3 times a week to work in a small group for 30 minutes before school.
- This would only be during the term time and never in the holidays or over the weekend.
- All the activities for this project will happen at school in a classroom you are familiar with.
- This project will not interfere with your school work or other activities
- You can decide whether you want to be a part of my project or not.
- If you no longer want to be part of the project, you can also tell us.
- You can talk about the project as much or as little as you would like to.
- You will never be required to share or talk about anything you don't feel comfortable with.

This research study will be written up as research report and/or publication. The report will be available on the university library website. If you would like to receive a summary of this report, I will be happy to send it to your parents.

If you would like to take part in my study, please complete the Learner Assent Form which will let me know that you have confirmed your willingness to take part in my project. After this a teacher from your school will contact you soon to arrange the first time to get together as a group and begin the project.

If you have any questions during or afterwards about this research study, feel free to contact me or my supervisor on the details listed below. If you have any concerns or complaints about the ethical procedures of this research study, you are welcome to ask your parents to contact the University Human

Research Ethics Committee (Non-Medical), telephone +27(0) 11 717 1408, email hrecnon-medical@wits.ac.za.

Yours sincerely,

Lindy Cooke

Researcher: Lindy Cooke, 2288309@students.wits.ac.za, 076 400 7001

Supervisor: Professor Zaytoon Amod, zaytoon.amod@wits.ac.za, 011 717 8326

LEARNER ASSENT FORM

Exploring the potential of a targeted Feuerstein mediated learning intervention to impact mathematical ability among a small group of learners experiencing mathematical difficulties.

Researcher: Lindy Cooke

If you agree to take part in my research project, please can you fill in your name and sign this letter at the bottom of the page.

Please can you also put a circle around the word YES or NO for each of the statements below:

The research project was explained to me.	YES	NO
I understand what the research study is about.	YES	NO
I understand that it is my free choice to take part in the study.	YES	NO
I understand that I can withdraw from the study at any time, without consequence.	YES	NO
I understand that I do not have to answer any questions that I do not feel comfortable with.	YES	NO
I understand that this research study will be written up as a research report and/or publication. These will be made available on the university library website and my parents can also ask for a copy.	YES	NO

________________________ Your Signature

________________________ Your Name

________________________ The Date

________________________ Signature

________________________ Name of Researcher

________________________ Date

Appendix N: Mathematics Measures Before and After Intervention

Term 1 and Term 3 Overall Mathematics Class Assessment Marks

	Term 1	**Term 3**
Participant One	42.3%	43.8%
Participant Two	62.7%	53.7%
Participant Three	52.9%	51.2%

WIAT scores for Mathematics subtests

Participant One	**February 2022**	**February 2023**
Math's Fluency (MF)	low average range	low average range
MF- Addition	low average range	low average range
MF-Subtraction	low average range	low average range
MF-Multiplication	low average range	very low range
Math's Numeracy	very low range	very low range
Math's Problem Solving	low average range	low average range
Participant Two	**February 2022**	**February 2023**
Math's Fluency (MF)	very low range	very low range
MF- Addition	low average range	very low range
MF – Subtraction	low average range	very low range
MF – Multiplication	very low range	low average range
Math's Numeracy	low average range	very low range
Math's Problem Solving	average range	low average range
Participant Three	**February 2022**	**February 2023**
Math's Fluency (MF)	average range	low average range
MF- Addition	average range	low average range
MF – Subtraction	average range	average range
MF – Multiplication	low average range	low average range
Math's Numeracy	low average range	average range
Math's Problem Solving	low average range	low average range

Appendix O: Qualitative Comparison of Deficient Cognitive Functions Before and After Intervention

Participant One

Most challenging PRE-INTERVENTION	**Improved POST INTERVENTION**
Input	**Input**
blurred or sweeping perception	precision and accuracy in data gathering
unplanned, impulsive and unsystematic exploratory behavior	unplanned, impulsive and unsystematic exploratory behavior
a lack of conservation of constancies a lack of need for precision and accuracy in data gathering.	
a lack of need for precision and accuracy in data gathering.	
lack of capacity for considering two or more sources of information at once.	
Spatial orientation	
Elaboration	**Elaboration**
as a lack of need for pursuing logical evidence;	a demonstration of more logical thinking and pursuing logical evidence;
a lack of inferential, hypothetical thinking	improved hypothetical thinking
a lack of summative behavior	improved planning
a lack of strategies for hypothesis testing	a little improvement in using strategies for hypothesis testing
an inability to select relevant vs non-relevant cues in defining a problem.	
Output	**Output**
a lack of tools for communicating adequately elaborated responses.	precision and accuracy in communicating responses
trial and error responses	
impulsive, acting out behavior	

Participant Two

Most challenging PRE-INTERVENTION	Improved POST INTERVENTION
Input	**Input**
a lack of, or impaired, spatial orientation	need for precision and accuracy
Elaboration	**Elaboration**
lacking in spontaneous comparative behavior	pursuing logical evidence,
difficulties with strategies for hypothesis testing	a small improvement in making use of strategies for hypothesis testing. hypothetical thinking
inadequacy in the perception of the existence and definition of an actual problem	and planning
an inability to select relevant vs non-relevant cues in defining a problem	comparative behavior
Output	**Output**
a lack of tools for communicating adequately elaborated responses.	trial and error responses
	accuracy in communicating responses

Participant Three

Most challenging PRE-INTERVENTION	Improved POST INTERVENTION
Input	**Input**
lack of, or impaired, receptive verbal tools which affect discrimination	the use of verbal tools which positively affected her ability to discriminate.
conservation of constancies	improved ability to elaborate responses
difficulty in considering two or more sources of information at once.	
Elaboration	**Elaboration**
difficulty in using strategies for hypothesis testing	an inability to select relevant vs non-relevant cues in defining a problem;
	pursuing logical evidence
	non-elaboration of certain cognitive categories (receptive and/or expressive).
Output	**Output**
as a lack of tools for communicating adequately elaborated responses.	ability to communicate adequately elaborated responses

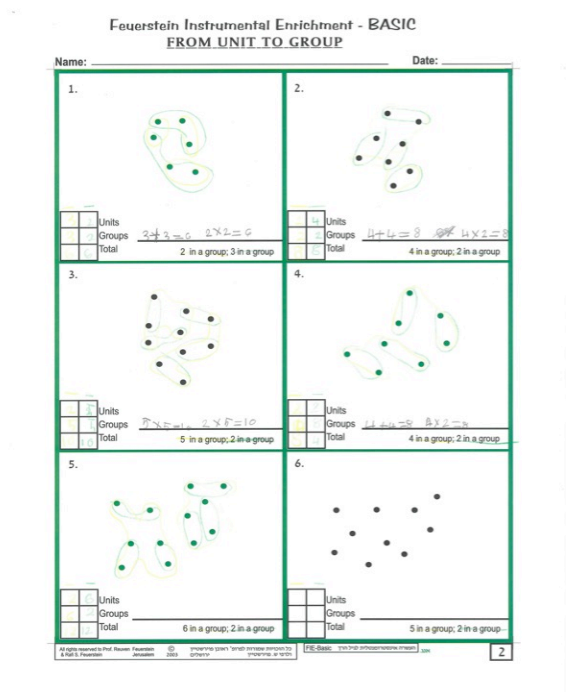
Appendix P: Examples from Participant One's FU2G Booklet

PARTCIPANT ONE

INPUT LEVEL

Figure 1

Participant One, Page Two, FU2G Booklet



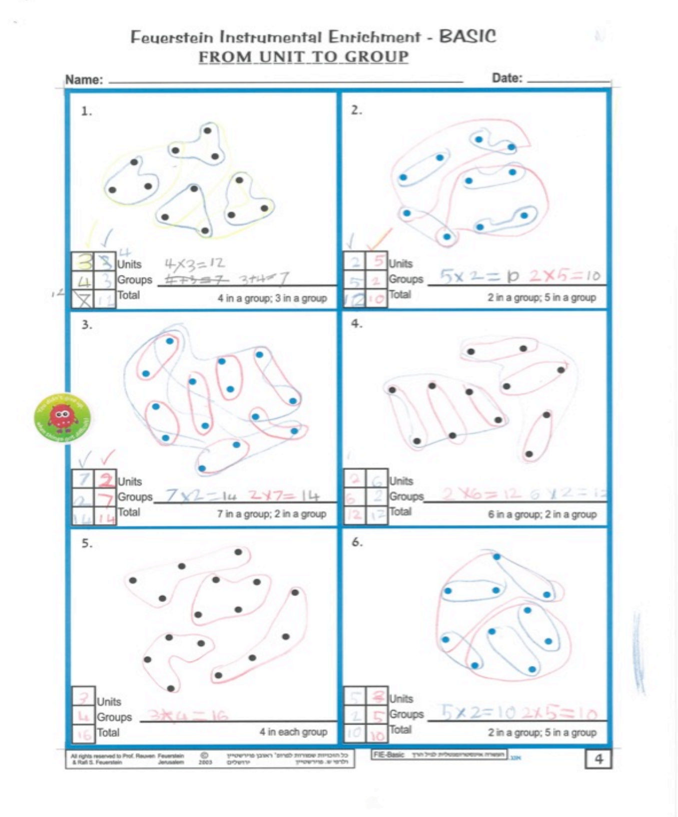
Frame 2 of the FU2G Page 2 showed some signs of impulsivity at the start of the intervention. For example in frame 1, 2 x 2 = 6 was written instead of 3 x 2 and similarly in frame 3, 5X5=10 was written instead of 5x2.

"Always just quickly giving an answer and because of that it was unplanned, impulsive and was un-systematic"
"Oh yes now I get this, I get this. This is what it is." And then it was not ...."
"... because then she would have to go back and say, "Oh no, let me go and count it again."
"She worked quickly so it seemed she had grasped it". As she was quicker than the other group members she had been encouraged to carry out her own examples. It can be seen in Figure 2 that she had not yet fully understood the concepts of groups and units at the end of the second intervention session.

PARTCIPANT ONE ELABORATION LEVEL

Figure 2

Participant One, Page Three, FU2G Booklet

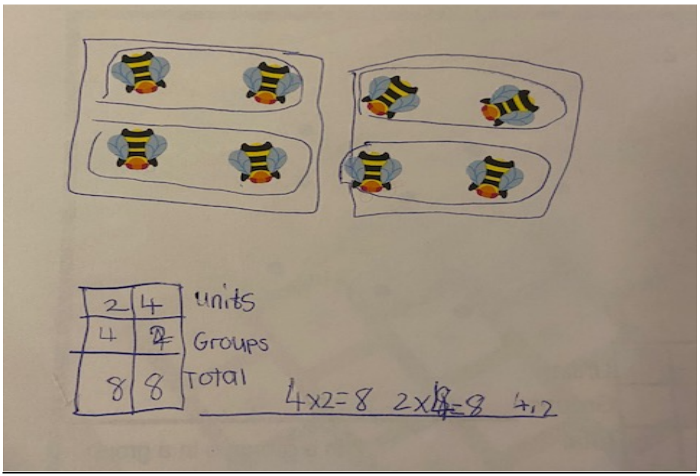


She was observed doing bits in isolation and as a result of not working in a logical order was unable to summarize or conclude what she had done. Her impulsivity appeared to push her to guess: “Oh I feel like this is the right answer”.

As the intervention progressed the mediator observed that Participant One had adopted good strategies to help her focus and work in logical and systematic way. For example, on Page 3 in Figure 3, she highlighted the first column in each frame so that she knew where to start and focus on first. She also adopted the strategy of using two different colour pencils for each combination of groups and units.

Figure 3

Participant One, Page Four Own Workings, FU2G Booklet



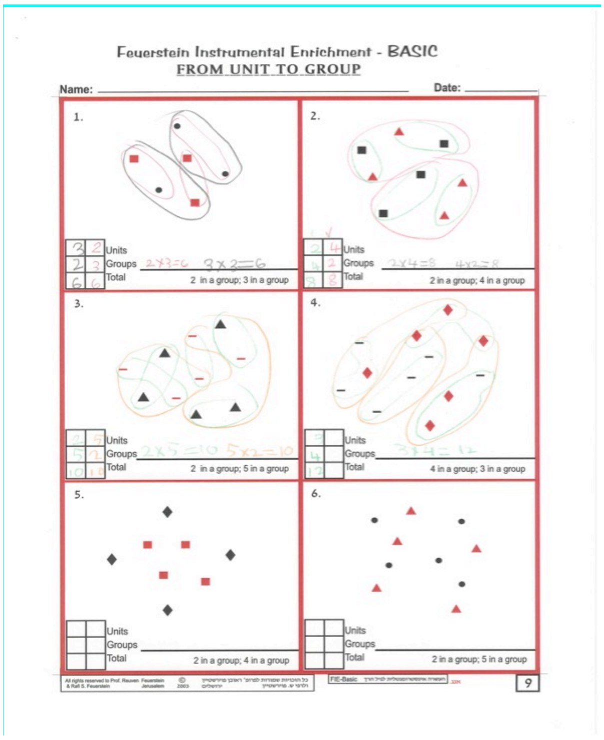
These were drawn after working through page 4 of the instrument, and are an illustration of the participants shift in understanding of the concepts with her own example of units and groups.

PARTCIPANT ONE: OUTPUT LEVEL

On Page 9, shown in Figure 4, the instrument shifted in complexity as different shapes are introduced and more attention needed to be paid to the instruction. It appeared to have taken longer for the participant to work through this page as it was not completed during the lesson.

Figure 4

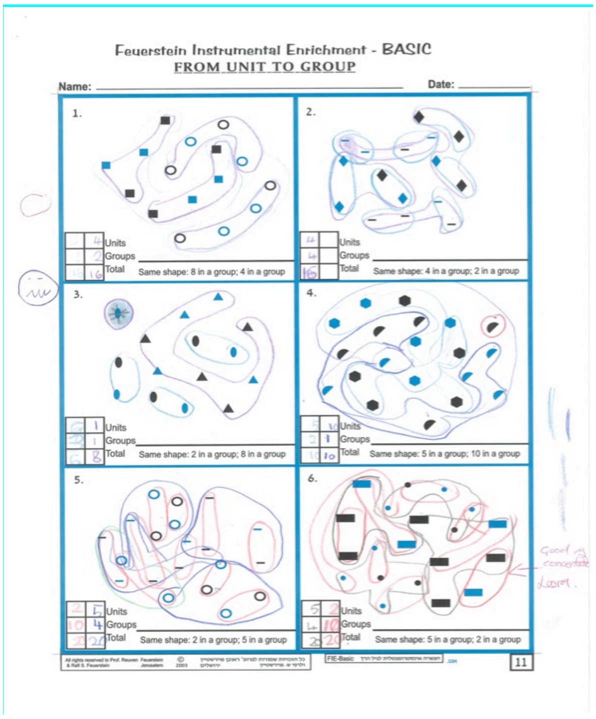
Participant One, FU2G Page 9



However, in Figure 5, the extent of concentration required and applied is demonstrated on page 11, frame 5, indicating Participants One's impulsivity improving and increased systematic planning and is an indication of the progress being made.

Figure 5

Participant One, FU2G Page 11



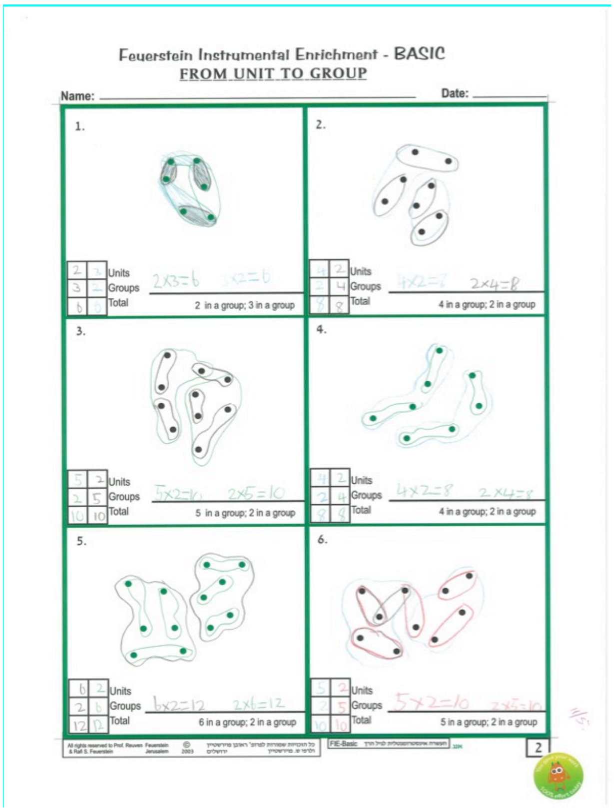
Participant One worked from right to left but the instrument is designed to go left to right and downwards. As a result, her shape was often strange. " ... She would randomly choose her grouping. So, it was not consistent. It was not ordered. If she was doing it backwards that meant that she did not have place to make a group of something else unless she went around everything."

Appendix Q: Examples from Participant Two's FU2G Booklet

PARTICIPANT TWO INPUT LEVEL

Figure 6

Participant Two, FU2G Page 2

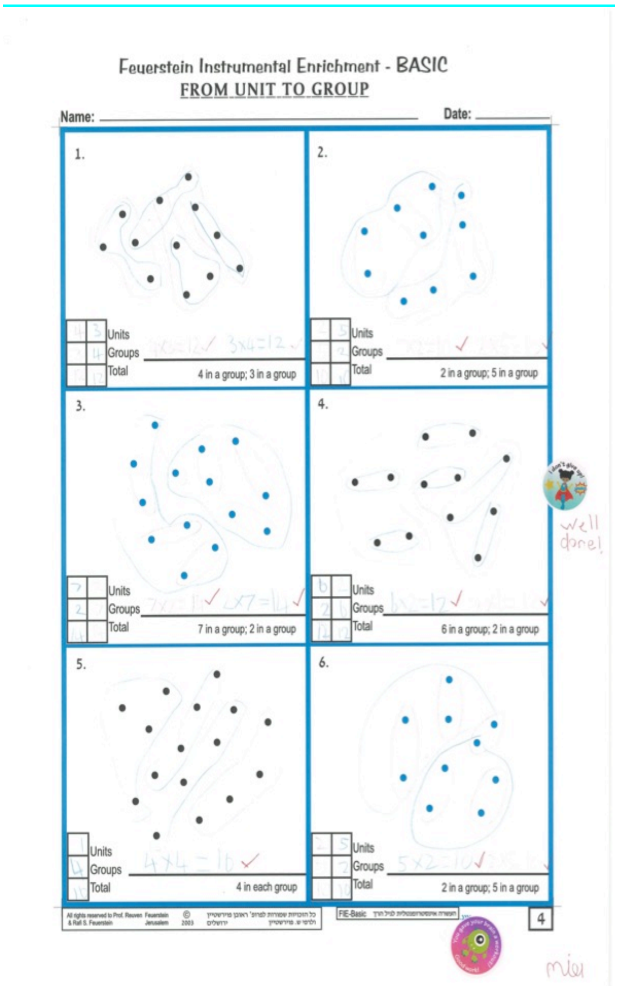


" ... at first she was colouring them in but obviously that was how she made sense of them. So that strategy worked for a bit, but them it was taking too much time. Because that is her perseverance to come back and do it again and again."

PARTICIPANT TWO ELABORATION LEVEL

Figure 7

Participant Two, FU2G Page 4

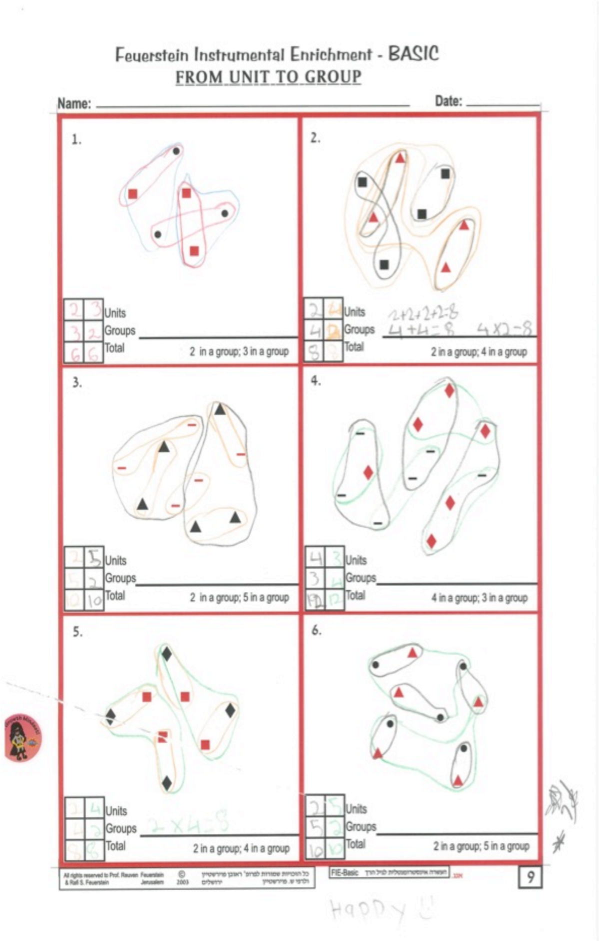


" ... But then as we got going, also by page four for sort it seemed, she also shifted" ; "I think it is because .... you have repeated it" ....

PARTICIPANT TWO OUTPUT LEVEL

Figure 8

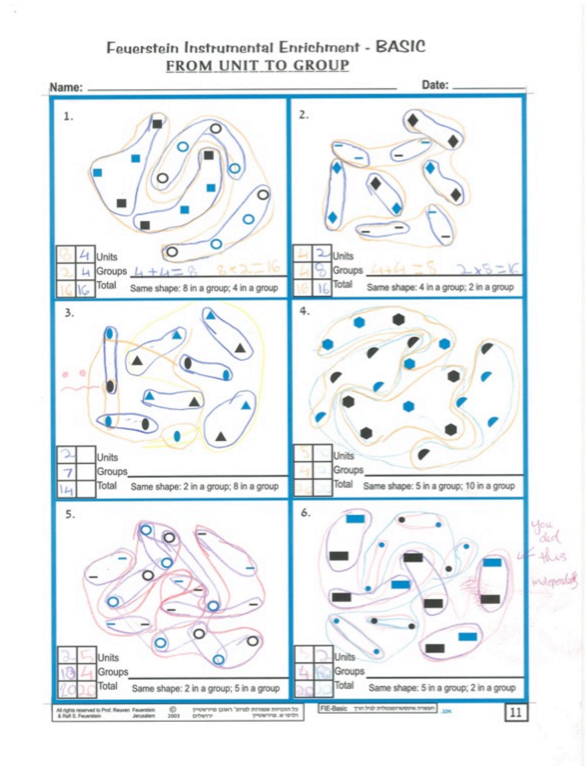
Participant Two, FU2G Page 9



“And this is the complicated one. And then she also did her little exercise. So she obviously finished in time and that is nice when she does things like that. Just generally works consistently. And her confidence really had grown. Although this one was tough. You can see the little face” .... “And she had done that one by herself so she was pleased at the end. She had had to correct it”.

Figure 9

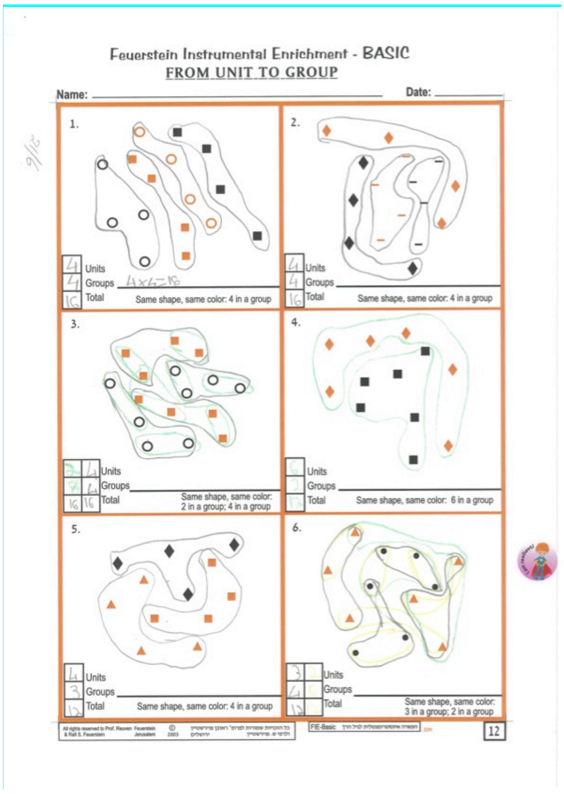
Participant Two, FU2G Page 11



The instructions on this page are complex and the size of numbers are an increase on the previous page. The mediator was encouraged to see that frame 6 had been completed independently and that in frame 3 an error in grouping had been acknowledged independently too.

Figure 10

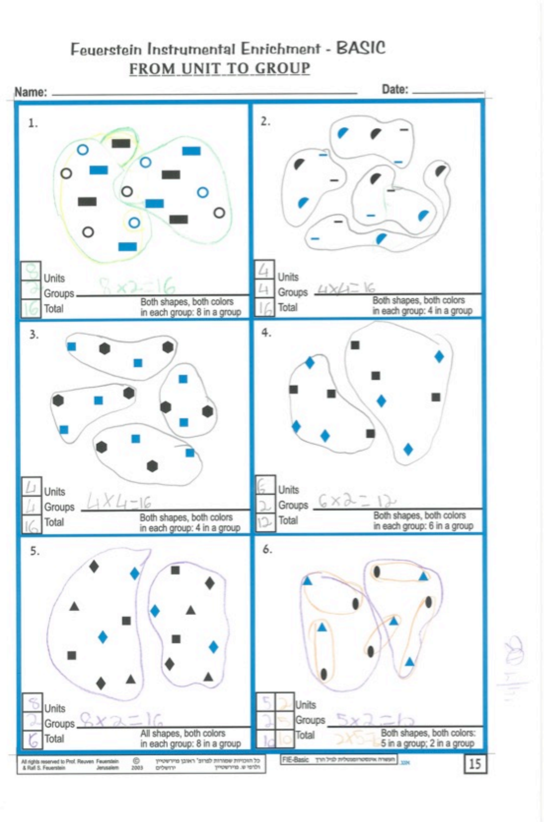
Participant Two, FU2G Page 12



This page was done beautifully and perhaps the same reasoning applies as the repetition leading to page 4. In this case from page 9 to page 12 the same principles has been repeated. By the time page 12 is reached there are strategies in place and a way of thinking has been established.

Figure 11

Participant Two, FU2G Page 15



This page started off as a challenge for the participant as the complexity had increased again and some anxiety apparently set in with that. On this page the groups have to be made up of both colours and shapes and not only one of them. In frame 1 the participant made some errors in thinking straight in but by the end of the page she was working accurately.

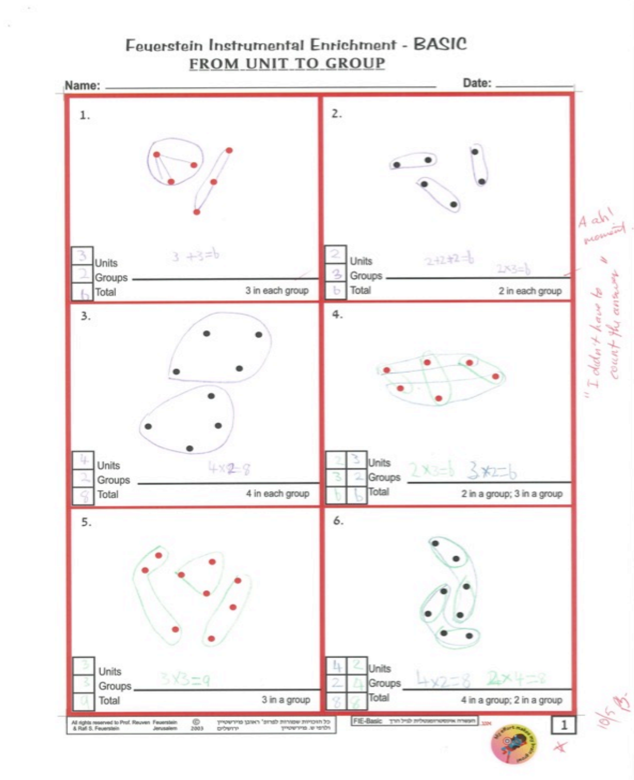
“ ... but then sometimes when we gets worried it slows her down more so, then she perseverates. Then she is her own worst enemy”.

Appendix R: Examples from Participant Three's FU2G Booklet

PARTICIPANT THREE, OUTPUT LEVEL

Figure 12

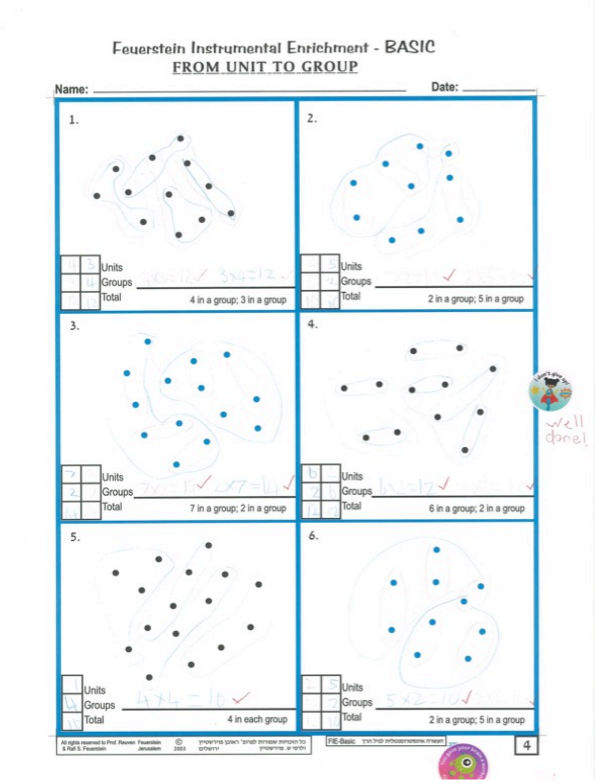
Participant Three, FU2G Page 1



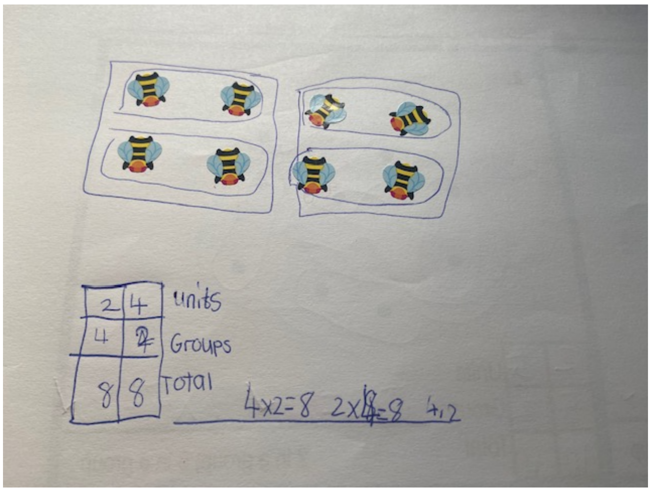
An Aha! Moment: "I didn't have to count the answer", quoted from the participant.

Figure 13a and 13b

13a Participant Three, FU2G Page 4



13b Participant Three, After FU2G Page 4 Own Workings

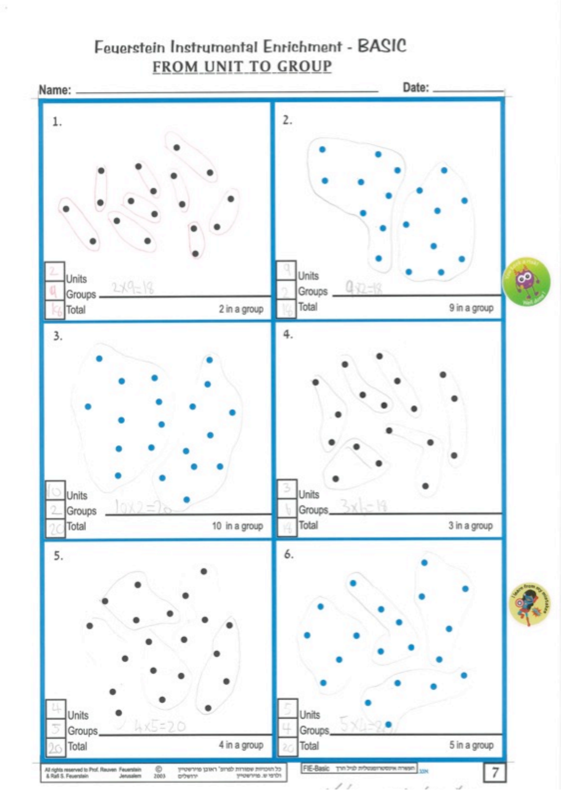


"She really got it"

"And then she made her own. I gave her little dots and then she made her own sum. And she got it. And even when she did it that way ... see here she did not use two colours, she only had one colour."

Figure 14

Participant Three, FU2G Page 7

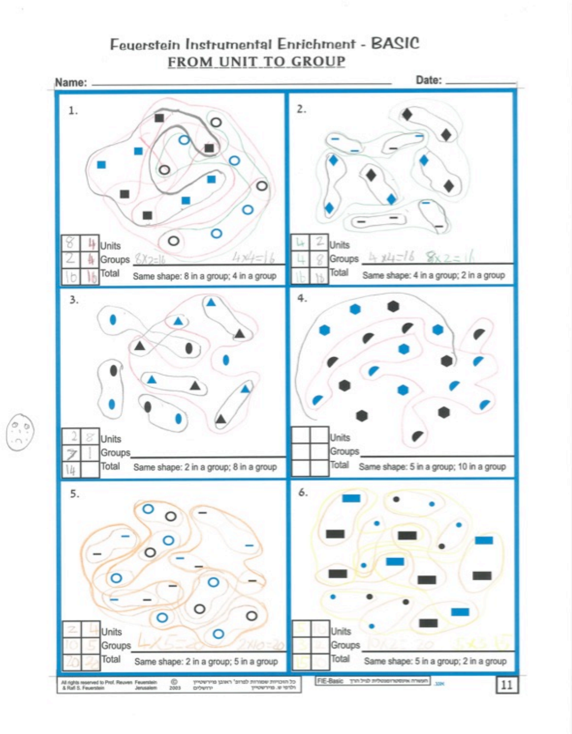


“xx made her brain work faster!”

“She is very consistent, neat and organised”

Figure 15

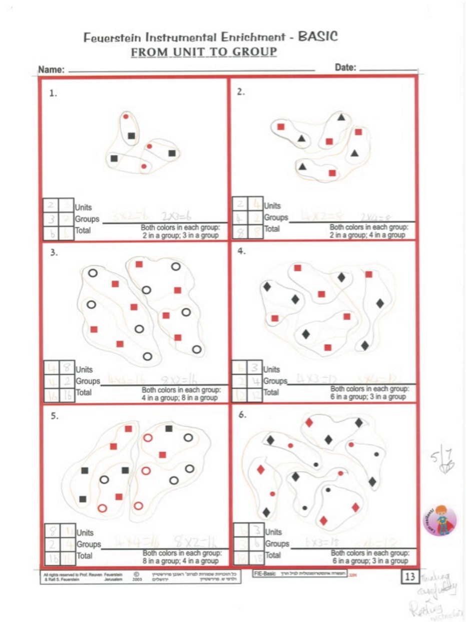
Participant Three, FU2G Page 11



Page 11 is where all three participants seemed to stumble a bit. Despite this she was able to identify her challenges, acknowledge them and work through them independently.

Figure 16

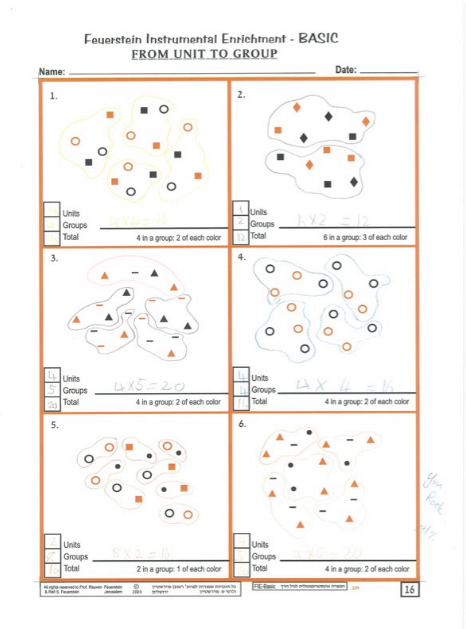
Participant Three, FU2G Page 13



"She was thinking carefully and reading instructions .... And that is the expressive. I did not have to tell her".

Figure 17

Participant Three, FU2G Page 16

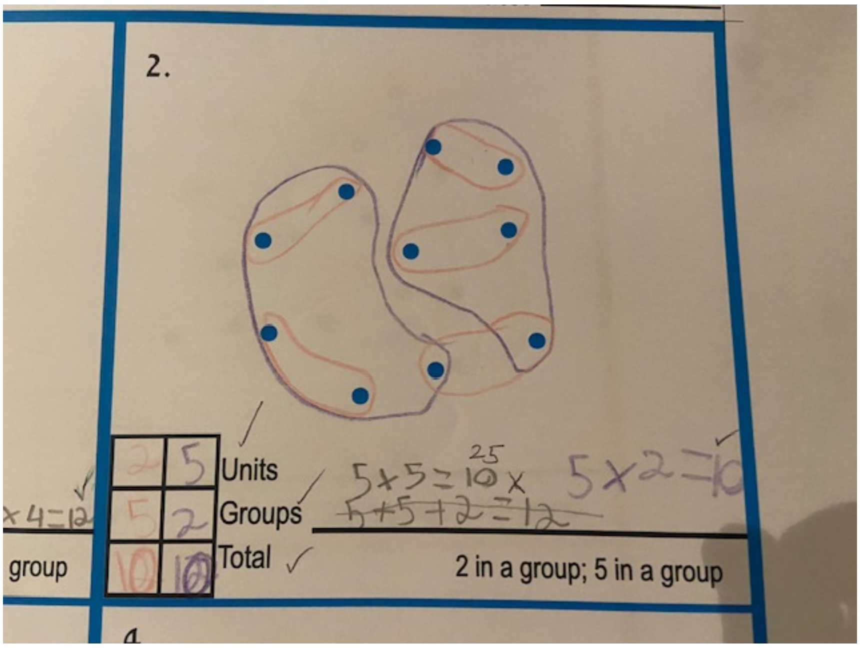


"You Rock!"

Appendix S: Examples of Zone of Proximal Development

Figure 18

Participant One, FU2G Booklet, Page 4



Teacher A, “and I always feel when you can see they have corrected something, that is an ‘aha moment’. Because they are going, “Oh I made a mistake. Let me correct it”.

Teacher A, “and that’s the time of learning, that’s your zone of proximal development”.

Appendix T: Feuerstein's Deficit Cognitive Systems related to FU2G

In the Input Phase

- Clear perception
- Understanding use of concepts
- Systematic search using planned strategies
- Conservation of constancy of rules across variation in the presentation of data.
- Consideration of several sources of information.

In the elaboration phase

- Identification existence of Definition of a problem to be solved
- Using comparative behaviour to systemically organise data according to the critical directions
- Employing a broad mental field to encompass relevant data
- Categorizing according to task demand
- Using logic to explain define, defend Solutions
- Planning behavior to orient and organise responses
- Use of verbal tools to define and elaborate responses
- Summative behavior to check and justify responses

In the output phase

- Scanning data before responding
- considering alternatives when data or tasks demands are ambiguous
- using clear visual transport to translate conceptual understanding into a motor response
- precise and accurate communication of responses at the motor and verbal levels