Helping Children with Dyscalculia:

The Implementation of a Teaching Programme with

Three Primary School Children

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ABSTRACT

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Dyscalculia is a specific learning difficulty which hinders an individual from developing the basic number concepts which are needed for the acquisition of mathematics. The main aim of this study was to explore strategies which would help children with dyscalculia overcome some of their barriers.

After initial assessment of 15 children using the *Dyscalculia Screener* (Butterworth, 2003), three children were identified with dyscalculia. These children, two 10-year-olds and one 7-year-old, were selected as the subject participants for the main part of the study. The parents of the three children were questioned about their children's difficulties to confirm the *Screener*'s assessment. Consequently, the children were formatively assessed using the *Catch Up Numeracy* (2009) assessment tools. Twenty 15-minute sessions were carried out with each child, using the outline provided by the *Catch Up Numeracy* programme as intervention targetting the areas needing development. Post-assessment was carried out to measure the degree of success of the programme for each child. The results demonstrated that if appropriate and specific intervention is provided, children with dyscalculia can succeed at acquiring the basic number concepts needed for mathematics learning. Additionally, the study showed that such intervention would greatly impact the affective domain of children, raising self-esteem and developing a more positive attitude to the learning of mathematics.

DYSCALCULIA DYSCALCULIA SCREENER PRIMARY MATHEMATICS

LEARNING DIFFICULTIES NUMERACY MATHEMATICS EDUCATION

Statement of Authenticity

I, the undersigned, declare that this dissertation is an original piece of work, carried out by myself as a result of my own research.

Esmeralda Zerafa

To all children

struggling with mathematics.

Acknowledgements

I would like to acknowledge in particular my supervisor, Dr Marie Therese Farrugia, for her constant support and encouragement. Her expertise and relentlessly detailed feedback made this research endeavour possible. It is thanks to her guidance and advice that this piece of work was brought to completion.

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Chapter 1

Introduction

1.1 Introduction

I am a Grade 6 (ages 10-11) teacher in a Maltese Catholic Church school for girls. My key area of teaching is mathematics as the school where I teach uses a subject-teaching approach for the teaching of Maltese, English and Mathematics for Grades 5 and 6. Hence I teach mathematics to the three Grade 6 classes, together with Social Studies, Science, Personal Social Development (PSD) and Creative Work to ‘my’ class. In accordance with a Church-State agreement signed in 1989, the children enter the school through a ballot system, and this results in a mix of socio-economic backgrounds within classrooms. Furthermore, the school where I teach embraces a system which allows children to move on to secondary schooling without sitting for selective exams. Moreover, children are not streamed or set in the secondary classes according to achievement. However, the low achievers in mathematics experience a great hurdle when they have to sit for the SEC exams at the end of the secondary school. Not obtaining an Ordinary level certificate in mathematics can be a gate in itself for future prospects.

Since I teach mathematics to mainstream classes, it has always been a challenge for me to address the different abilities of all children entrusted to my care. Whereas the age-appropriate and high-achievers are catered for and perform well, every year there seems to be a number of girls struggling with learning mathematics. Additionally, in each cohort, there are always one or two children who do not grasp the basic numeracy concepts required for further mathematics education.

This situation prompted me to further my studies by taking up a Master degree in ‘Responding to Student Diversity’ to become more knowledgeable on maximising children’s potential according to their unique individuality. I chose to focus on learning difficulties associated with mathematics and how these might be tackled.

1.2 The Aim of the Study

The primary aim of this research project was to explore learning difficulties associated with mathematics, particularly dyscalculia. Dyscalculia is a learning difficulty which affects a child's grasp of basic number concepts and hinders the understanding and application of number facts and procedures. Since international research reports that 5 - 8% of school-age children experience difficulties that interfere with their acquisition of mathematical concepts or procedures*,* (Geary, 2004; Fuchs and Fuchs, 2002) and that an average of 3.6 – 6.5% have severe difficulties with acquiring numeracy and mathematics (Lewis et al., 1994), an increasing interest has been shown towards the subject by international professionals. However, in Malta no research has yet been conducted to establish how many learners may be encountering this difficulty (Said, 2010). Intervention programmes for learners with dyscalculia are still non-existent in local schools and only very few schools are currently using programmes such as 'Numicon' and 'The Stern' with children who are encountering difficulties in mathematics.

Learning difficulties related to mathematics may have greater implications on children's everyday life and on the workplace than literacy difficulties (Brynner and Parsons, 1997). Consequently, it is of utmost importance that not only educators become more informed about specific mathematics learning difficulties such as dyscalculia, but that intervention programmes are developed so that a quality education is provided to *all* pupils, as suggested by the National Minimum Curriculum (NMC) (Ministry for Education, 1999). Keeping this in mind, I sought to explore the following research questions:

i. What interventions can be used to help dyscalculic learners overcome their learning difficulties?
ii. Will children who are assessed with dyscalculia benefit from the programme specifically designed for their needs?

I hoped that deepening my knowledge about dyscalculia would permit me to fulfil my philosophy of inclusion which is to welcome “all children into the local school regardless of ability, disability, background, religion, ethnicity, as a matter of human rights...” and plan teaching around their needs (Powers et al., 1999, p.16).

The objectives set for this study were reached by primarily identifying three children with dyscalculia. This was done by using the *Dyscalculia Screener* (DS[1]) (Butterworth, 2003) with 15 children encountering difficulties in mathematics. The three children which the DS assessed with a profile of dyscalculia were then chosen as the participants of the main study. Findings from this test were compared with an interview with the children’s parents where I asked specific questions to confirm the DS’s assessment. I then used a specific programme, currently being used in the UK, as an intervention strategy with children who were found as having dyscalculia. A formative assessment was carried out, followed by 20 one-on-one sessions with each of the three children. Evaluation of the efficacy of the sessions with the participants was then carried out. The evaluation shed light on what tools were helpful to these learners and gave rise to essential strategies which may allow other dyscalculic learners to overcome some of their barriers to learning mathematics.

1.3 Conclusion

By embarking on this journey I hoped to grow professionally. In the field of education, “the highest stake of all is our ability to help children realise their full potential” (Meisels in Bezzina, 2001, p.14). This goal should be accomplished no matter what the unique characteristics such as interests, abilities and learning needs (United Nations Educational and Scientific Organisation, 1994) of the children entrusted to our care might be. The weight placed on guiding all children

[1] The abbreviation DS will be used throughout the text to refer to the *Dyscalculia Screener* developed by Butterworth (2003).

to succeed highlights the importance of having an appropriate intervention programme within schools and classroom settings. This study may contribute towards helping educators become more knowledgeable about this learning difficulty and develop effective strategies to benefit all learners.

This chapter has introduced the main research questions and set the scene. Chapter 2 outlines the literature currently available about mathematics learning difficulties, with an emphasis on dyscalculia, as well as provides further information about the DS and the intervention programme used. Chapter 3 puts forward the research methods used for the purpose of this research. An analysis of the data follows, in which I discuss the research findings and how these correlate or contrast with the literature previously cited (chapter 4). The conclusion summarises the results and presents suggestions for further research.

Chapter 2

Literature Review

2.1 Defining Mathematics and Mathematics Learning Difficulties

"Mathematics is a symbolic language that enables human beings to think about, record, and communicate ideas about the elements and relationships of quantity" (Lerner and Johns, 2009, p. 478). This universal language which encompasses numbers, form, chance, algorithm and change (Van De Walle, 2004) is meaningful to all people as quantitative information and events are present in all natural environments. Such meaning, however, differs according to culture. "In our kind of numerate society [the child acquiring mathematical skills] encounters a variety of number-specific cultural tools" (Butterworth, 2005a, p. 3). These tools vary from concrete skills such as understanding and using numerical expressions, identifying shapes, counting objects and subitizing (perceiving without counting), to abstract algebraic operations, geometry, data analysis and measurement (National Council of Teachers of Mathematics, NCTM, 2000). Both types of tools are essential in laying the foundations for the learning of mathematics.

Humans are born with the ability to "respond to the numerical properties of their visual world, without benefit of language, abstract reasoning, or much opportunity to manipulate their world" (Butterworth, 2005a, p. 5). Tasks requiring such responses are described by Butterworth as tasks of numerosity. He points out that a child's numerosity is innate. In fact, various research gives evidence of how babies varying from a few weeks to 13-months-old seem to be sensitive to numerosity (Starkey and Cooper, 1980; Starkey et al., 1990; Antell & Keating, 1983; Brannon, 2002). Other research illustrates how at the age of two, children have a knowledge of basic number concepts and have the ability to subitize the numerosity of arrays composed of up to four or five items (Strauss and Curtis, 1981). Numerosity can therefore be defined as "an invariant property of a collection of objects specifying its numerical size" (Van Loosbroek and Smitsman, 1990, p. 1).

Numerosity is the foundation of numeracy and mathematics. Different authors use the latter two terms differently. For example, Sousa (2008) suggests that *mathematics* is the ability to "determine the number of objects in a small collection, to count, and to perform simple addition and subtraction, also without direct instruction" (p. 1). However, this idea is similar to what Dowker (2004) defines as *numeracy*, which she sub-categorises into 10 components, namely:

i. Counting verbally
ii. Counting objects
iii. Reading and writing
iv. Hundreds, tens and units
v. Ordinal numbers
vi. Word problems
vii. Translation (changing objects to numbers, numbers to objects and number words to objects)
viii. Derived facts
ix. Estimation
x. Remembered facts

(Dowker, 2004 in Catch Up, 2009)

She suggests that mathematics is more complex, involving data handling, measurement, geometry and other more abstract tasks as also suggested by the Department for Education and Skills (DfES) (1999). Similarly, Chinn (2004) highlights the essential 12 components of mathematics, as presented by the National Council of Teachers (NCTM) in the USA. These are: problem solving, communicating mathematical ideas, mathematical reasoning, applying mathematics to everyday situations, alertness to the reasonableness of results, estimation, appropriate computational skills, algebraic thinking, measurement, geometry, statistics and probability.

Dowker (2004) suggests that children struggling with numeracy and consequently at a later stage with mathematics, would normally not have grasped one or more components of numeracy at an early stage. Likewise, Chinn (2004) underscores that, “there are many reasons why someone may underachieve in mathematics” (p. 3). However, one of the reasons may be a deficit in all or a few of the skills, concepts and/or areas mentioned by the NCTM in the USA as cited previously. Although “specific disorders of numeracy are neither widely recognised nor well understood” (Butterworth, 2005a, p. 12) the limited research that has carried out investigations within this field highlights areas in numeracy that may be problematic for learners. Although some children may encounter difficulties with all numerical tasks (Landerl et al., 2004), others have shown to have specific difficulties with mathematical facts and/or strategies and procedures (Temple, 1991). As a result, children should not be labelled as ‘good’ or ‘bad’ at mathematics, but their strengths and specific areas of difficulties should be highlighted (Dowker, 2004). Therefore assessing specific areas of numeracy that hinder children’s progress (as listed earlier) is crucial.

My own perspective of the relationship between numerosity, numeracy and mathematics is that numerosity, which is innate, leads to numeracy which in turn allows the development of mathematics. Throughout this write-up, I use the term *numerosity* to refer to the very basic ability to perceive quantity. The term *numeracy* denotes one or more of the 10 components of numeracy mentioned by Dowker (2004). The term *mathematics* is used to refer to a wider definition of numeracy which also includes data handling, geometry and the other topics mentioned by the NCTM (in Chinn, 2004) cited earlier. The methods used in this study focus mainly on numeracy. However, the terms *numerosity* and *mathematics* have also been used as necessary.

2.2 Defining Dyscalculia

In the past twenty years, learning difficulties encountered in mathematics have gained the attention of researchers. With the development of relevant studies, a repertoire of terms has been attributed to developmental mathematics disabilities. These terms are presented in Table 2.1 together with examples of research in which the terms are used:

Developmental Dyscalculia (DD)	Shalev & Gross-Tsur (1993); Temple (1991); Sharma (2003); Butterworth (2003); and Rubinsten & Henik (2009)
Dyscalculia	Chinn (2004); Ernest (2011)
Mathematical Learning Difficulty (MLD)	Hopkins & Egeberg (2009)
Mathematical Disability (MD)	Geary (1993)
Mathematic Disorder	American Psychiatric Association (2000)
Arithmetic Learning Disability (AD, ARITHD or ALD)	Siegel & Ryan (1989); Geary & Hoard (2001); and Koontz & Berch (1996)
Number Fact Disorder (NF)	Temple and Sherwood (2002)
Psychological Difficulties in Mathematics	Allardice & Ginsburg (1983)

Table 2.1: List of terms used to refer to difficulties in mathematics

Geary (1993) and Geary & Hoard (2001) emphasise that in most of the literature and research, all these terms seem to be referring to the same condition - a difficulty to understand number concepts and to acquire the numeracy skills necessary to understand and apply mathematics. For the purpose of my study, the term *dyscalculia* shall be used to refer to all the groups described in Table 2.1. I have multiple reasons for this decision. Primarily, the word dyscalculia itself comes from Greek and Latin and means "*counting badly*" which does describe one characteristic of dyscalculic learners. Second, it is the most prevalent term used in more recent literature. Third, from the literature read, I can deduce that dyscalculia refers to a *specific* difficulty with mathematics as will be delineated below.

Distinct but similar definitions have been provided for dyscalculia. The UK Department for Education and Skills (DfES, 2001) puts forward an explicit definition of dyscalculia. Chinn (2004) builds on the definition and adds his own notes in order to provide a more comprehensive and clear definition of what dyscalculia is. In the following citation, the sections in brackets are Chinn's added notes.

> "Dyscalculia is a perseverant condition that affects the ability to acquire mathematical skills despite appropriate instruction. Dyscalculic learners may have difficulty understanding simple number concepts [such as place value and use of the four operations, + - x and ÷], lack an intuitive grasp of numbers [including the value of numbers and understanding and using the inter-relationship of numbers], and have problems learning, retrieving and using quickly number facts [for example multiplication tables] and procedures [for example long division]. Even if they produce a correct answer or use a correct method, they may do so mechanically and without confidence [and have no way of knowing or checking that the answer is correct]." (p.14)

Chinn's (2004) definition places emphasis on the fact that dyscalculia is a long-lasting condition that affects a learner's ability to tackle numerical and mathematical tasks both during their years at school as well as in their lives as adults. This definition also describes who the 'typical' dyscalculic learner may be. However, there is no formula to help educators identify a child with dyscalculia. The characteristics of children with dyscalculia shall be discussed hereunder with the hope of providing more identification tools for educators and stakeholders.

Since human beings are complex and unique individuals, different learners who might be experiencing dyscalculia will exhibit diverse characteristics related to this difficulty. Bird (2009) highlights that "a dyscalculic learner stands out as having no ‘feel for numbers’ at all, no ability to estimate even small quantities, and no idea whether an answer to an arithmetic[2] problem is reasonable or not” (p. 2). Additionally, Bird (2009) puts forward a list of indicators for dyscalculia which could help educators identify such learners in their classroom. This list includes learners with:

i. An inability to subitise (perceive without counting) even very small quantities;
ii. An inability to estimate whether a numerical answer is reasonable;
iii. Weaknesses in both short-term and long-term memory;
iv. An inability to count backwards reliably;
v. A weakness in visual and spatial orientation;
vi. Directional (left/right) confusion;
vii. Slow processing speeds when engaged in maths activities;
viii. Trouble with sequencing;
ix. A tendency not to notice patterns;
x. A problem with all aspects of money;
xi. A marked delay in learning to read a clock to the time; and
xii. An inability to manage time in their daily lives.

(Bird, 2009, p. 2)

Research findings using different methodologies and criteria seem to agree that learners experiencing dyscalculia fail to recall number facts (Dowker, 2004). Other criteria are mentioned by more than one researcher. Geary (2004) and Bird (2009) both report that slow number processing is a characteristic of dyscalculia. Moreover, the difficulty dyscalculic learners encounter when learning the concept of time is not only evident in the list provided by Bird (2009), but is also stressed by Hannell (2005) who explains that children with dyscalculia encounter problems with numbers associated with the measurement of time (for example: one day is equal to 24 hours). Children with dyscalculia also find difficulties with reading the digital and analogue clock. In relation to this, one

[2] The term *arithmetic* is taken to mean as the term *mathematics.*

may explain how dyscalculic learners tend to confuse the digital time with money – for example 8:30 might be easily mistaken for €8 and 30c. As adults, dyscalculic learners may encounter problems with planning appointments and Poustie (2000) suggests that they tend to write them down wrongly in their diaries.

Bird (2009) suggests that dyscalculic learners experience ‘directional confusion’. Ott (1997) and Chinn and Ashcroft (2007) also report this difficulty and suggest that children with dyscalculia tend to find difficulties with recalling how to write numbers and may thus write them in the wrong direction. Townend and Turner (2000) and Poustie (2000) report difficulties with sequencing and carrying out multiple processes as well as finding difficulties with patterns. Characteristics may vary from one individual to another and whereas one learner might encounter difficulties in one area, another might do so in other areas. Having said this, educators and other stakeholders of children’s education should keep an open eye for these characteristics for early detection and intervention (Doig et al., 2003; Greenes et al., 2004; Griffin, 2004).

There are yet another three key factors which may be highly influential on a dyscalculic learner’s acquisition of numeracy and later mathematics. These are: mathematical language, memory and the affective domain, especially anxiety. Since these three characteristics dominate in most of the literature written about dyscalculia, I shall dedicate the following three sub-sections to them.

2.2.1 Dyscalculia and Mathematical Language

Language is an essential tool for communicating ideas and understanding questions. A delay in the development of this key area will lead to difficulties in relation to dealing with mathematics and its concepts (Grauberg, 1998). In addition, mathematics has its own language. Lee (2006) states that “using mathematical language can be a barrier to pupils' learning because of particular requirements and conventions in expressing mathematical ideas" (p. 2). Similarly Ernest (2011) suggests that the language used for learning mathematics may cause some individuals considerable problems. Mathematics is made up of words and written symbols that are used and must be learnt in a unique way (Butterworth and Yeo, 2004). Halliday (1978) defines these words and symbols as the *'mathematics register'*. From a very young age children are presented with mathematical terms such as 'before', 'after', 'equals', 'more' and 'less'. Moreover, they encounter symbols of which they must learn the meaning. These symbols include, '+', 'x' and '÷'. Without the development of such a repertoire of terms and symbols children will lack important skills needed in the acquisition of mathematics. Pimm (1987) acknowledges that many children find difficulties with acquiring this register and that educators may facilitate the process of acquiring such terms/symbols by providing various situations when children may make use of them. The language of mathematics should be given its due importance as "most of the difficulties seen in mathematics result from the underdevelopment of the language of mathematics" (Henderson et al., 2003, p.20). Therefore children with dyscalculia should be presented with such terms/symbols often. Additionally, situations in which they can be used are to be modelled so that dyscalculics can better interpret such words when found in their particular contexts (Townend & Turner, 2000).

Another key difficulty of language is found when dyscalculic learners are asked to tackle word problems. Since problem solving involves numerous cognitive and linguistic processes, "the ability to solve problems is at the heart of mathematics" (Cockcroft, 1982, p.9). As a result, Rothman and Cohen (1989) indicate that "problem solving for math is the task most often recognised as dependent on both reading and language competence" (p.133). Dyscalculics may not only find difficulties with actually reading and understanding the word problem but may also find it very hard to translate what is being asked and thus to choose an appropriate operation. This difficulty may be aggravated in situations, such as Malta's, when children are asked to tackle word problems which are presented in their second language (Bernardo, 2002). In my own undergraduate study, my research partner and I illustrate that 15 out of 30 pupils scored better in word problems carried out in their first language and another nine gained an equal score on both sets of problems. This shows that children may find it easier to tackle word problems when these are presented in their mother tongue (Baldacchino and Cassar, 2008).

2.2.3 Dyscalculia and Memory

A study with fifty 11- to 12-year-old Spanish monolingual children reveals that the performance of children with Developmental Dyscalculia (DD) and those with Reading Difficulties and Dyscalculia (RDD) in tasks where short-term memory is involved is lower than that of the control group (Roselli et al., 2006). It concludes that this might be linked to a poor working memory and a lack of counting skills. Additionally, this research reveals that it "appears that the ability to retrieve arithmetical facts from long-term memory is defective" (p.813) with children who have DD and RDD. Learners with dyscalculia may encounter difficulties with short-term memory, long-term memory (for mathematical information) and visual memory (Chinn, 2004). With regard to short-term memory, dyscalculic learners may find difficulty with beginning a given task because they cannot remember the instructions or because they cannot remember what they must do to see it through. In fact, Chinn (2004) states that educators should avoid giving a long string of instructions which will make dyscalculic learners struggle to keep up with the pace of the lesson. This should also be taken into consideration when word problems are given as tasks in the classroom (Geary, 1993). If a problem has too many questions, children might become confused as they might forget which question must be answered first. Even though working memory is mostly associated with mental work, it can also affect written work as children with a deficiency in memory would not be able to remember how to write out the numbers. They may also forget the procedure to working out specific mathematical operations.

Long-term memory related to mathematical information also plays a key role in the learning and remembering of important mathematical facts such as simple addition (e.g. 5 + 4) and multiplication facts (e.g. 5 x 4). A study conducted by Chinn (1995) illustrates how a group of children with dyscalculia could not recall simple addition facts in 4 seconds whereas another group of same aged children who did not have such difficulties could. The study also reveals that children with dyscalculia could solve such addition sums in 12 seconds as they found alternative strategies of solving the tasks rather than relying on memory. This again illustrates that lack of working and long-term memory can have a ripple effect on other important skills needed for mathematics such as the speed at which learners carry out their tasks.

Visual memory may also be problematic for dyscalculic learners. Therefore as suggested by Chinn (2004), educators must avoid confusing the child with overcrowded textbooks and worksheets. They should allow enough space between written items (Chinn and Ashcroft, 1998). Attwood (2002) highlights that it is best to use double spacing in exercises and other written tasks. Moreover, Chinn (2004) underscores that print should be very clear, especially when presenting mathematical symbols. The symbols + and x, and the symbols – and ÷ can be indistinguishable if written unclearly. He also states that educators should provide isometric paper when 3-D shape drawing is done as children with dyscalculia may find it difficult to represent 2-D shapes in 3-D form.

2.2.2 The Affective Domain and Long-term Consequences

Faust et al. (1996) outline that mathematical tasks can cause high levels of anxiety particular to mathematics rather than to any other given difficult activity. Furthermore, Burns (1998) states that over two thirds of adults feel anxious when taking up mathematical tasks. The performance of individuals with dyscalculia is highly affected by anxiety especially when this is at high levels. A study carried out by Rubinsten and Tannock (2010) with 23 participants (12 with dyscalulia and 11 control) illustrates that there is a direct link between performance and anxiety. In fact, all the children with dyscalculia showed that their anxiety levels affected their performance whilst this was not the case with the control group. Therefore the level of anxiety "can actually rise to the point where it paralyses their [referring to dyscalculic learners] ability to perform even simple maths operations" (Emerson and Babtie, 2010, p.9). When carrying out mathematical tasks one must concentrate, however, high levels of anxiety interrupts such needed concentration. Therefore, individuals who underachieve in mathematics may be a victim of stress (Henderson et al., 2003).

It is crucial to minimise levels of anxiety as much as possible, as anxiety may be a disability in its own right. Anxiety may fill up the working memory space of the brain without allowing the complete and effective processing of numerical tasks (Ashcraft et al., 1998). This biological process is better explained by Sousa (2008) who suggests Figure 2.1 to show that any form of anxiety releases cortisol in the bloodstream.

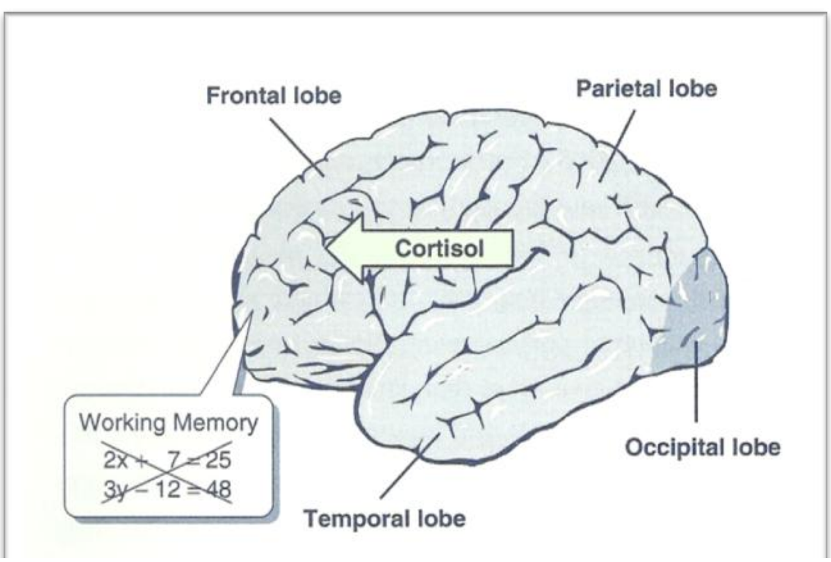


Figure 2.1: The diagram illustrates how cortisol is released in the blood due to anxiety caused by mathematics. Cortisol forces the frontal lobe to deal with this anxiety whilst disrupting any unrelated learning occuring in the working memory (in Sousa, 2008, p.172).

Cortisol is a hormone which refocuses the brain on what is causing the anxiety so that it figures out what action to take next. As a result, the physical well-being of the individual is also affected as the heart rate increases and physical indicators of being worried show up. At this stage, the frontal lobe of the brain which is responsible for processing numerical tasks is no longer in a position to do so as it must first deal with what is appearing to be a threat to the learner's safety.

Dyscalculia may have some serious implications for children if no intervention is provided. Primarily, dyscalculia may impinge on the emotional well-being of learners. Butterworth and Yeo (2004) suggest that even though children with dyscalculia often make a great effort to overcome their difficulties with handling numbers, they are often not successful as they keep forgetting what they would have learnt. Due to this, "most dyscalculic pupils do not enjoy number work at all; most dyscalculic pupils feel discouraged in maths lessons; [and] many dyscalculic pupils develop avoidance strategies in the maths classroom, such as going to the toilet, sharpening pencils, and so on" (p. 9). In a focus group carried out by Bevan and Butterworth (2007) with nine children with dyscalculia, many negative feelings were expressed related to the children's constant failure in mathematics. The children reported that they felt left out, blamed themselves for not knowing how to solve a task, cried, as well as felt 'horrible' and 'stupid'. Additionally, the rest of the students in class, who achieved highly, also noticed the distress which the low achievers experienced. Due to the fact that many of the people around them do not understand what they are feeling, they begin to fear doing mathematics even more, their self-esteem is highly affected and they become anxious about their overall learning ability.

In the long-term, living with dyscalculia can be difficult because dyscalculics often "can exist in a world of total mathematical confusion" (Poustie, 2000, p.147). Anything that deals with numbers is difficult for them to handle. Their difficulties often vary from simply remembering important telephone numbers and dates, to paying the right amount to the cashier when going shopping and checking the change. Other tasks presenting difficulties could be cooking, planning appointments and being able to use the time available in a day appropriately. Adults who have dyscalculia often feel embarassed when they are faced with everyday tasks which they cannot handle. Additionally, Bynner and Parsons (1997) indicate that learners with poor numeracy skills tend to leave full-time education at their first chance. Butterworth and Yeo (2004) state that such persons are more likely to be unemployed, depressed, ill and arrested. All this illustrates that dyscalculia should be handled at a young age before it has irreversable effects on the learner.

2.3 The Roots of Dyscalculia

Limited research is available about the causes of dyscalculia. So far, three factors prevail in most literature about this profile. Dyscalculia seems to develop due to neurobiological causes, genetic reasons as well as environmental factors. In the following sections I outline some of the research carried out in relation to each of these three factors.

2.3.1 A Neurobiological Perspective

Studies indicate that children with dyscalculia find most difficulties with working out approximate calculations. This has been related to the parts of the brain responsible for undertaking estimated calculations. Castelli et al. (2006) and Kucian et al. (2006) note that during tasks involving exact calculations, both children with and without dyscalculia have the same level of brain activation. However, when tasks in which the children have to make approximate calculations are involved, a smaller area of the brain seems to be activated for learners with dyscalculia. This is represented in Figure 2.2.

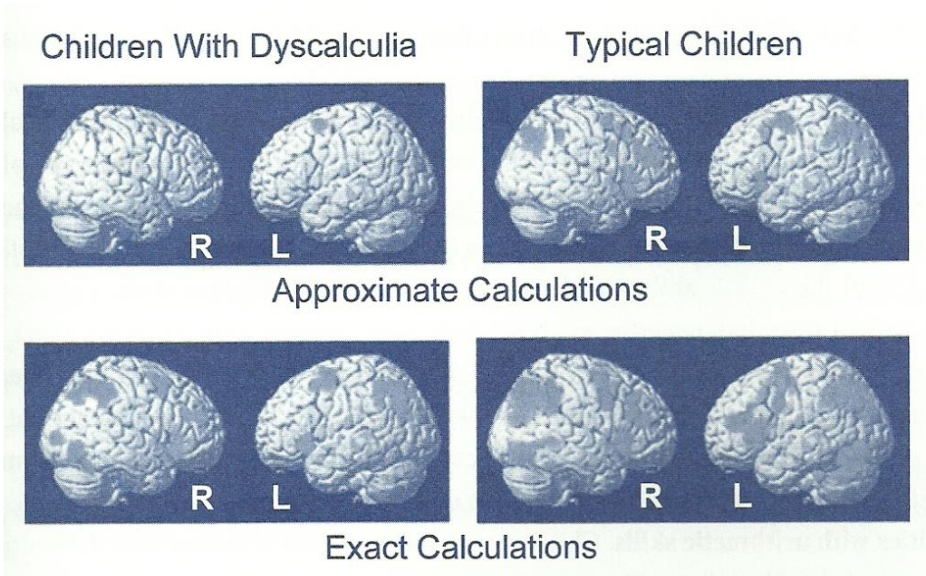


Figure 2.2: Activation of the brain during approximate and exact calculations (Kucian et al., 2006, p. 8)

The parietal lobe of the celebral cortex in the brain (see Figure 2.3) is highly involved with most number operations (Sousa, 2008). Lemer et al. (2003) illustrate how if the parietal lobe is damaged, the individuals encounter problems with understanding and grasping numeracy whilst oral language skills remain untouched. This indicates that children with dyscalculia might have some form of damage within this area.

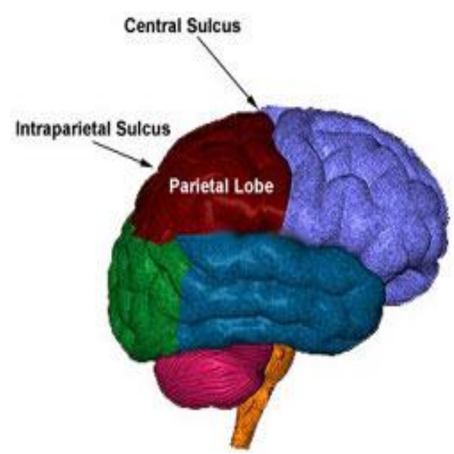


Figure 2.3: An illustration of the Intraparietal Sulcus in the Parietal Lobe (Molko et al., 2003, in Manglani, 2005)

More recent research (Piazza et al., 2010) reveals that the Approximate Number System (ANS) present in the parietal cortex, more specifically within the intraparietal sulcus (IPS) (Figure 2.3), is highly responsible for an individual's number acuity. Additionally, Piazza et al. (2010) conclude that any form of malfunction in this area of the brain may manifest as dyscalculia. The research was conducted with a total of 54 participants, 25 of which were dyscalculic learners and 29 of which were typical developing children. A test made up of 80 numerosity comparison tasks (as illustrated in Figure 2.4) was distributed to the participants.

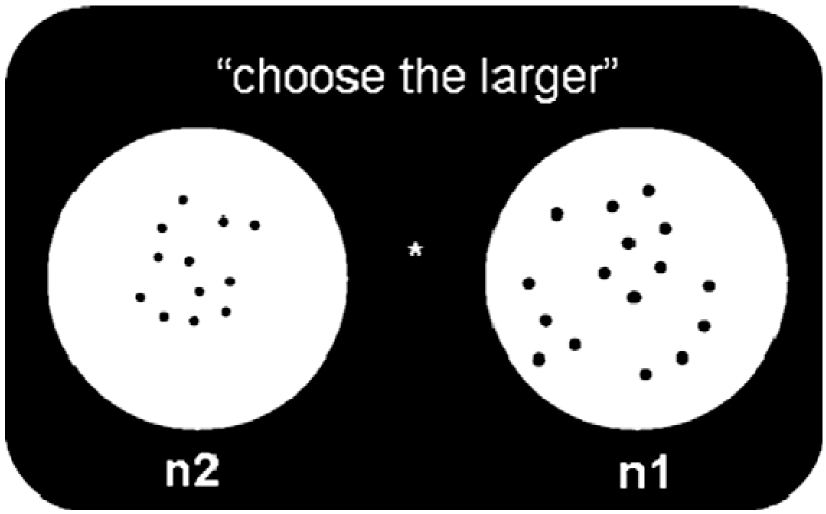


Figure 2.4: Sample numerosity task used by Piazza et al. (2010, p.35)

The nature of the tasks was set in such a way as to elimate any form of verbal or symbolic content to ensure that only the IPS section of the brain was activitated. Children have the ability to discrimate numerosities from as early as three hours after birth (Izard et al., 2009). This ability should be enhanced with age. Piazza et al.'s (2010) research illustrates that in dyscalculics this numerical acuity is severly impaired and develops at a very slow rate. Whereas the typically developing children performed according to their age level on the task given, children with dyscalculia who were 10 years of age, for example, performed as a child aged 5 should have performed. This shows that the IPS which is responsible for the ANS is impaired in children with dyscalculia, hindering them from acquiring other skills and concepts related to numbers and mathematics.

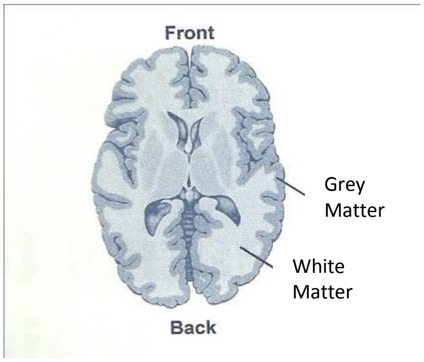


Figure 2.5: Grey matter diagram (Sousa, 2008, p.98)

Another neurobiological cause of dyscalculia may be a reduced amount of grey matter in the brain. Grey matter (Figure 2.5) is the covering of the brain which is about one-tenth of an inch thick and is also known as the *cerebral cortex*. This covering contains cell bodies of neurons and support cells. Isaacs et al. (2001) conclude that there is missing grey matter in prematurely born children with dyscalculia. Butterworth (2005b) however, attributes this to lack of usage. More research is definitely necessary to identify better the neurobiological causes of dyscalculia. However, all the research mentioned above indicates that the brain's structure and functioning may have a great impact on whether an individual experiences dyscalculia or otherwise.

2.3.2 Genetic Causes of Dyscalculia

Genetics also influence the development of mathematical skills (Hallgren, 1950). Kosc (1974) suggests that heredity plays a role in the acquisition of dyscalculia. Alacaron et al. (1997) demonstrate that when one twin had been assessed with dyscalculia, the other twin was likely to be assessed with a profile of dyscalculia too. Alacaron et al. (1997) show that in 58% of the cases with monozygotic co-twins and in 39% of dizygotic co-twins, both twins had been assessed with dyscalculia, illustrating that genetics may play a role in the presence of dyscalculia. Similarly, Shalev and Gross-Tsur (2001) find that nearly half of the siblings of children who are dyscalculic are also dyscalculic themselves. The results demonstrate that the risk of being assessed with dyscalculia is five to 10 times more than for those children whose siblings have never shown traits of being dyscalculic.

2.3.3 Environmental Factors

The home environment also seems to influence acquisition of numeracy and mathematics. Young-Loveridge (1989) show that children whose mothers were not confident with carrying out mathematical tasks themselves, lacked confidence in carrying out such activities. This influence on attitude was also pointed out by Hannell (2005) who illustrates that if learners' home environment promotes a positive attitude towards the learning of mathematics, the necessary skills are developed better. Similarly, Anning and Edwards (1999) show that if children encounter a negative mathematics identity at home, their own identity is influenced by this. Sammons et al. (2002) note that children who come from low socio-economic backgrounds and are socially disadvantaged also encounter challenges with learning mathematics. This research highlights that such children may take longer to develop numeracy skills and therefore also mathematics.

2.4 Dyslexia, Dyscalculia & Co-morbidity

Both dyslexia[3] and dyscalculia are specific learning difficulties (Kirk et al., 2009). However, whereas the former deals with problems in literacy, the latter is concerned with difficulties in numeracy. Studies illustrate that co-morbidity is frequent. Between 20% and 60% of dyscalculic learners also have difficulties with reading and writing (Butterworth and Yeo, 2004). As already pointed out in Section 2.2.1, dyscalculic learners who also have literacy difficulties and who are living in Malta may have a greater hurdle to overcome. In Malta, mathematics is taught and assessed through English so not only do Maltese speaking students have to be proficient in their first language but also in their second to perform well in mathematics. If learners are having difficulties in their first language, then their second language will possibly also suffer, influencing their performance in

[3] Mortimore and Dupree (2008) define dyslexia as "a specific learning difficulty that mainly affects reading and spelling. Dyslexia is characterised by difficulties in processing word-sounds and by weaknesses in short-term verbal memory; its effects may be seen in spoken language as well as written language (p. 14)."

mathematics. Having said this, one must stress that not all dyscalculic learners have difficulties with reading and writing. Chinn (2004) encounters children who have very poor mathematical skills but perform well in languages. Conversely, Attwood (2002) found that 25% of dyslexic learners performed in an above average manner in mathematics. These results imply that even though co-morbidity of dyslexia and dyscalculia is present, they are two separate conditions.

Dyscalculia has also been identified in occurence with other conditions. It has been associated with *attention deficit hyperactivity disorder* (ADHD) (Shalev and Gross-Tsur, 2001), and difficulties with hand-eye coordination (Siegel & Ryan, 1989). There is, however, as yet no definite relationship between dyscalculia and these learning difficulties.

2.5 Assessing for Dyscalculia

Tools for assessing dyscalculia are still very limited. To date there are mainly three tools which can be adopted for assessing dyscalculia (Michaelson, 2007). These are: standardised tests, direct observation and the *Dyscalculia Screener* (DS) (Butterworth, 2003). However, further research is crucial in order to determine the reliability of such identification. Since human beings are "startling contradictions, unsuspected strengths and weaknesses and fascinating complexities" (Ginsburg, 1972 cited in Gifford & Rockliffe, 2008, p.28), diagnosing 'pure' cases of dyscalculia is difficult as there are many aspects of a child's developmental stages that may impinge on their grasp of numeracy. For example, Ginsburg (1997) argues that tests cannot assess the social inequalities which a child may have experienced. In a study carried out in India by Gowramma (2000, in Ramaa and Gowramma, 2002) a total of 1,408 participants from Grades 3 to 4 (ages 7 to 8 and 8 to 9) were chosen from 11 primary schools. Out of these, 328 were found to be experiencing difficulties in mathematics. These participants had to fit various criteria to be identified as having dyscalculia. These criteria included being normal in sensory functioning, visual tracking and eye-hand coordination; having no serious emotional/behavioural problems, as well as not having been absent from school frequently, amongst others. After the elimination of students according to whether they fitted the criteria, 78 were identified as having dyscalculia. This means that only 24% of the students identified as experiencing difficulties with mathematics actually had dyscalculia according to the criteria defined by the researcher.

As indicated by Gowramma (2000 in Ramaa & Gowramma, 2002) influencing factors of mathematics difficulties may include numerous absences from school, poor teaching instructions and family illnesses. These are hard to assess, however, using more than one method for the assessment might actually increase the reliability of the diagnosis. In the following sub-sections I shall delve deeper into the three available methods for diagnosing dyscalculia.

2.5.1 Norm-referenced Testing

General standardised testing is one way dyscalculia may be identified. Shalev & Gross-Tsur (2001) indicate that such tests assess children's mathematical attainment in relation to their age. Standardised testing can be carried out quite easily as such tests may be administered by educators in the classroom. A strong indication of dyscalculia is present if there is a contrasting difference between the overall general performance and performance in mathematics (Geary, 2004). Additionally, dyscalculia could be identified if learners are at least two years behind in their mathematical achievements when compared to their age group (Semrud-Clikeman et al., 1992). Having said this, through such an assessment, one cannot determine to what extent a pupil does have dyscalculia or whether such performance is actually related to other factors. Therefore, further tools for assessment should then be used in addition to standardised tests to determine better whether the child is actually experiencing dyscalculia or otherwise.

2.5.2 Observing the Learner

Another means of identifying dyscalculia is by observing learners over several occasions. From such observations, one should be able to determine whether learners are experiencing any dyscalculic tendencies. Such tendencies have already been highlighted in Sections 2.2, 2.2.1, 2.2.2 and 2.2.3. Checklists have also been produced (e.g. Chinn, 2007 and Henderson et al. 2003). Chinn (2007) presents a checklist for determining anxiety in adults related to mathematical difficulites. Henderson et al. (2003) provide a checklist suitable for educators to be able to identify learners with dyscalculia. The actual checklists are individually presented in Appendix A. According to the number of ticks, observers would be able to determine whether an individual is actually encountering difficulties with numeracy/mathematics due to dyscalculia.

2.5.3 The *Dyscalculia Screener*

The *Dyscalculia Screener* (DS) (Butterworth, 2003) (Figure 2.6) is,

> "a computer based, standardised test designed to diagnose dyscalculia in children aged 6 to 14 years and to distinguish this condition from other issues that can affect performance in mathematics such as difficulties in communication and interaction, behavioural, emotional and social development" (Voutsina and Ismail, 2007, p.85).

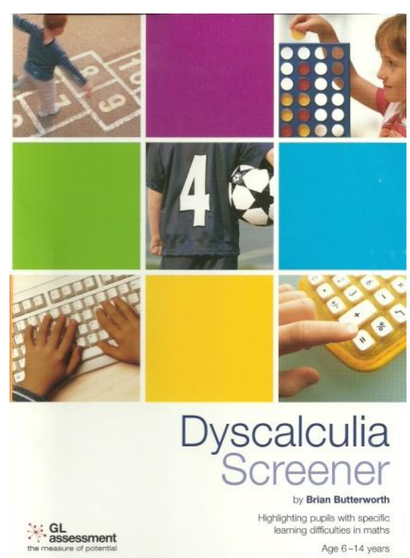


Figure 2.6: Front Cover of *Dyscalculia Screener* (Butterworth, 2003)

A detailed account of how the DS functions is included in Section 3.5.1. I opted to use the DS to identify my main three subject-participants because it has been used in various international research studies. Furthermore, the DS makes it possible to assess learners' potential in numeracy independently of their abilities in other areas such as language or reading. In addition, in order to complete one of the previously mentioned checklists, I would have had to know the subjects well otherwise the outcomes would not have been valid. I had never taught the children so the DS allowed me to screen the subjects without actually knowing them well. Lastly, I chose the DS because since it is computer-based it is most objective and would not allow human errors.

The DS has its own limitations. International research involving the DS has put forward some concerns. Voutsina and Ismail (2007) say the tasks are too lengthy and some children might get bored thus underachieving in a task due to carelessness and disinterest. Another cause for concern they point out is that since there are two options for each task ('yes' or 'no') the children might begin to guess the answers rather than actually work out the tasks. Messenger et al. (2007) identify some children who are in the higher streams for mathematics achieving low 'capacity scores' on the DS, whilst some other children who underachieved were diagnosed as not being dyscalculic. They suggest that this results from the fact that other aspects of the brain come into play when thinking of numbers. These aspects include: language, attention, spatial ordering, sequential ordering and higher-order thinking (Messenger et al., 2007). Therefore caution must be taken when interpreting the results of the DS. In addition, since identifying dyscalculia can be complex and problematic (Gifford, 2006), more than one tool of assessment should be used in order to find out, as truly as possible, whether a child has dyscalculia or not. In the future, with more research being dedicated to this condition, new assessment strategies may be developed to reduce uncertainities.

2.6 Suitable Intervention for Children with Dyscalculia

Research indicates that some dyscalculic learners do make marked improvements when they are taught concepts and skills that they should have learnt long before (Kaufmann et al., 2003). Additionally, they demonstrate that when intervention takes place with children who are in first grade and who display difficulties with calculations, their achievement increases significantly by the end of the scholastic year (Fuchs et al., 2005). These studies show that stakeholders of children's education have to give dyscalculic learners the best chance of success by offering suitable intervention programmes. Henderson et al. (2003) propose a model of how intervention should be provided (Figure 2.7).

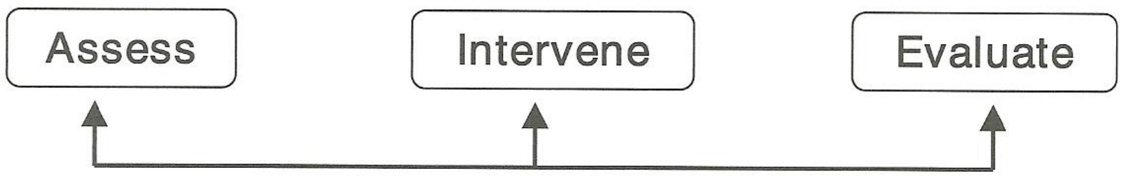


Figure 2.7: The Intervention Cycle presented by Henderson et al. (2003, p. 38)

This cycle shows the three important phases in any intervention programme. Assessment is crucial as it will determine where children stand. Henderson et al. (2003) explain that unlocking "an individual's potential requires an understanding of their learning strengths and a detailed assessment of the barriers to their learning in mathematics" (p.14). The actual intervention can be diverse. Dowker (2004) underscores that this usually entails having one-on-one sessions with the child in order to target their specific difficulties. Chinn (2004) puts forward different suggestions how adaptations should be made to the classroom environment and to the teaching styles and methods. Suggestions vary from using a multisensory approach to the teaching and learning of mathematics, to marking diagnostically in order to show pupils which area they must improve. All such interventions could certainly help children with dyscalculia improve in the subject as well as help them feel happier at school. Constant evaluation of the interventions being put to practice is essential if one is to determine which strategies are working with a child and which are not.

In the UK, a number of intervention programmes for children with difficulties in numeracy have been developed. These include *Springboard*, *Wave 3, Numicon* and *Catch Up Numeracy*. I have chosen to use the latter programme for the purpose of this study because, as I explain in Section 3.2, I had the opportunity to meet the directors of this programme personally and share the success it has had in the UK and other countries such as New Zealand. Additionally, familiarising myself with research on this approach was enriching. This programme is currently being used in many schools in the UK as an intervention programme for children who encounter difficulties with grasping essential numeracy skills. The programme is delivered on a one-on-one basis. This supports Dowker's (2004) suggestion that intervention should be provided on such a basis. The springboard to the intervention strategies is made up of 22 detailed assessments in the ten components of numeracy (Dowker, 2004, referred to in Section 2.1) These assessments conform to Henderson et al.'s (2003) idea that any intervention must start off by assessing competencies. Following this, it is recommended that pupils are provided with two 15-minute intervention sessions weekly. The intervention sessions are very structured. A detailed explanation of how the assessments are conducted and how the sessions are structured will be provided in Chapter 3.

The *Catch Up Numeracy* programme was originally piloted between 2007 and 2008. It was divided into two phases of intervention and consequently two evaluation reports were produced (Evans, 2007, 2008). In the first phase, the intervention was provided to those children identified by teachers as having difficulties with numeracy in 40 schools from six authorities in the UK and in Wales and another four schools in the Oxford area. After the first phase, the evaluation produced (Evans, 2007) reported that the "intervention was a powerful adjunct to pupil learning in numeracy" (p. 8). The teachers who participated in the project reported that:

- The one-on-one structure of the sessions made a big difference to the children's learning;

- The way in which the programme targeted specific components on numeracy made the children more skilful in mathematics;
- *Catch Up Numeracy* introduced new tools and methodology;
- The participants gained confidence in numeracy and engaged better in classroom activities;
- The negative attitudes these students originally had towards mathematics changed to more positive ones; and
- Students were knowledgeable of the progress they were making in the area.

(Evans, 2007)

Standardised tests which had been distributed to the pupils before and after the intervention illustrated that, during this first phase, the cohort of 62 pupils who participated in the intervention gained 7.4 months in their number ages between March and July, while a control group who was given the same test gained only 2.9 months (Evans, 2007). The second phase of the pilot project involved providing the intervention to six pupils in each of three schools in the UK. Out of the six pupils, four fully participated in the *Catch Up Numeracy* programme whilst two were the control group. This phase had similar positive conclusions. In addition, teachers reported that the pupils had managed to grasp better mathematical language and strategies. They also reported that the pupils started to enjoy mathematics more and that the very detailed assessment carried out as part of the intervention "picks out the holes in the pupils' knowledge" (Evans, 2008) and the teacher then knows on what to work. When standardised tests were distributed to the group of 33 pupils who took the intervention programme, they showed that the children gained 11.6 months in number age after approximately 5.75 hours of support, whilst a control group of 16 children gained 6.75 months in number age over the same period of time (Evans, 2008).

2.7 Theoretical Underpinnings

A teacher-researcher, like myself, cannot but develop her study based on the underlying theories of learning. Four main theories underpin the research within an inclusive paradigm (Peterson and Hittie, 2003; Powers et al., 1999; Ministerial Committee for Inclusive Education (MCIE), 2000; Tod et al., 1998; Bartolo et al., 2007). These are: Vygotsky's socio-historical learning theory, Bandura's social learning theory, Johnston's learning patterns and Chinn's attributes to learning.

Vygotsky's 'sociocultural theory' brings to the fore numerous features which I believe should be part of our daily routines as educators. Primarily, I find Vygotsky's 'Zone of Proximal Development' (ZPD) (Vygotsky, 1982 in Hedegaard, 1996) convincing. In his original work, Vygotsky explained that the ZPD is "the distance between the actual development level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (Vygotsky, 1978, p. 86). During my sessions I guided the participants from the level of development they were at to the level of potential development. My role was crucial in providing this guidance. As Vygotsky (1926) himself stated, "the teacher is the director of the environment in the classroom, the governor and guide of the interaction between the educational process and the student" (p. 49). One way in which I did this was through the use of modelling. In Vygostky's definition of 'imitation' and its role within the ZPD, I could view a strong correlation between modelling and 'imitation'. Vygotsky (1978) states that by "using imitation, children are capable of doing much more in collective activity or under the guidance of adults" (p. 88). Consequently, he illustrates how the imitated activity is then internalised and therefore can be repeated independently by the child on other occasions as required. This took place in my study when modelling was used. Bandura's Social Learning Theory (1977, 1986) emphasises that modelling is a fundamental learning process in socialisation. Bandura (1977) suggests that "most human behaviour is learned observationally through modelling: from observing others, one forms an idea of how new behaviours are performed, and on later occasions this coded information serves as a guide for action" (p. 22). During the intervention sessions, I acted as a live model which according to the Social Learning Theory is an actual person demonstrating a particular behaviour. Modelling is crucial for learners with dyscalculia as it allows them to visualise how a task should be carried out and then replicate the actions.

Another way in which guidance was provided in the ZPD was through the use of language. This is known as 'semiotic mediation'. As suggested by Vygotsky, language is primarily used as a means of communication between the child and the adult. However, he highlights that "the most significant moment in the course of intellectual development, which gives birth to the purely human forms of practical and abstract intelligence, occurs when speech and practical activity, two previously completely independent lines of development, converge" (1978, p. 24). During the sessions, I used language to guide the children from what they already knew to what was to be learned.

Through the use of language I enticed the children to metacognitive thought. Metacognition "refers to one's knowledge concerning one's own cognitive process and products, and the cognition of others" (Flavell, 1979, in Silver, 1985). It is essential in engaging pupils in higher order thinking. Thus I asked questions with regard to self-monitoring, regulation and evaluation of the activity undertaken as I have illustrated in Section 4.4.2. I also kept in mind that the children's miscues can provide information about which part of a concept they have mistakenly conceived. Therefore, I made use of metacognitive techniques to guide the children to reflect upon their own miscues so that they understand better what they are misconceiving (Van de Walle et al., 2010). Throughout the sessions, not only did I record the miscues carried out, but I also encouraged the children to reflect about their mistakes. This was crucial in helping the learners with dyscalculia reconstruct their misconceptions in the correct manner.

Apart from language, I used other “tools” including diagrams, manipulatives and various systems for counting (Vygotsky, 1981a, in Wertsch, 1985) which facilitated the children’s development. Such tools facilitated the children’s development of a relational understanding, which entails understanding the process of completing a task and the reason behind it, rather than instrumental understanding of mathematics which involves solving a task without understanding the process. Rational understanding is essential with dyscalculic learners because it facilitates their retrieval of facts at a later stage.

Scaffolding, although not a term used by Vygostky himself, is also an important aspect deriving from his theories. I made certain that sessions were scaffolded and that one session reviewed the previous session through the ‘introduction and review’ phase of each session. Without the scaffolding process, it would not have been possible to guide the children from what they already knew to what they were to learn. The ‘sociocultural theory’ also promotes that instruction should be structured and that this in turn will allow the child to develop further. Children with dyscalculia need specific intervention programmes that target their weakest areas of development. Hence my choice for a structured programme such as *Catch Up Numeracy.*

Johnston’s (1998) theory of learning patterns suggests that learners have a combination of four different patterns through which they perceive learning: confluence, precision, technical and sequential. Teaching should target the learning patterns of the individuals so as to provide tasks in which children may use their dominant learning patterns whilst promoting guided tasks where learners may enhance their other patterns. The learners’ combination of patterns may be identified through a ‘Learning Combination Inventory’ or through observation depending on the individual’s age. I have used the children’s patterns to ensure that activities provided accommodated the specific combination of learning patterns of each child.

Chinn's theory of thinking style was used to identify the children's way of tackling mathematical tasks. Chinn (2009) illustrates that there are two styles of tackling such tasks. These are the 'inchworm' and 'grasshopper' style. The 'inchworm' thinking style is reliant on formulas, procedural, prefers to know and use one method and works in serially ordered steps. The 'grasshopper' has a good understanding of numbers and how to manipulate them, and is intuitive. Chinn (2009) suggests that "ideally a learner needs both styles and the ability to use them at appropriate times" (p. 7). When observing the children I tried to identify their most dominant thinking styles in order to know the learner better and differentiate accordingly.

2.8 Conclusion

This chapter outlined the main issues concerning dyscalculia as well as produced an account of the current literature and research available with regard to this condition. As outlined by Michaelson (2007), "because numeracy is a significant part of daily life, it is vital that dyscalculic students be given special consideration to develop their own capacities of mathematical cognition" (p. 21). Undoubtedly, more research must be carried out in order to establish better what this learning difficulty is and how to help children affected by it. I hope that my research will contribute towards this.

In the following chapter I shall explain how I tackled sensitive issues related to my research such as gaining access to the field and acquiring parents' as well as children's consent to participate in the study. I shall also outline how I used different methods in order to assess, as justly as possible, three children with a profile of dyscalculia. This will be followed by a detailed explanation of how the *Catch Up Numeracy* programme was used with these three children.

Chapter 3

Research Methodology

3.1 Introduction

In this chapter I seek to outline my research questions more specifically and elucidate the choice of such questions. I explain how I chose the most appropriate research methods to carry out my research. Additionally, I highlight the research paradigm which has guided me. I also describe the ways in which I gained access to the field, selected my sample, as well as took into consideration essential sensitivities to protect the privacy and anonymity of the subject-participants. Lastly, I provide a detailed account of how the *Catch Up Numeracy* programme was used to assess the pupils identified with dyscalculia as well as to create a tailor-made programme for each of their needs.

3.2 The Research Questions

After deciding on the general area of interest on which I wished to focus, namely dyscalculia, I brainstormed more specific research questions. As outlined by Robson (2004), it is impossible to plan a research project before its focus is identified. My original plan was to identify three children with dyscalculia using the *Dyscalculia Screener* (DS) (Butterworth, 2003) and carrying out a suitable programme which would suit the children's needs. However, after going through the available literature and research carried out, I became more passionate about the subject and was eager to learn more. This motivated me to search the internet for any international lectures on dyscalculia. I was pleased to learn that the second National Conference about Dyscalculia was being held in the United Kingdom and that key persons in the field were lecturing. I decided to attend the conference which was crucial in helping me to understand my field of interest better as well as making me aware of critical issues which I had not thought about earlier. For example, I realised that I would not be able to create a programme tailor-made for each child unless I assessed the children in detail and took note of their areas of strengths and weaknesses.

At the conference I learned about digital games available to help pupils with dyscalculia overcome their difficulties. I got to know about new publications on the subject. I also learnt about the *Catch Up Numeracy* programme. As one of the directors showed me what the programme offered, I realised it could be a suitable intervention programme for my research. The nature of its detailed formative assessment, could help me identify each child's strengths and weaknesses, a crucial issue which I had to consider. The programme's rich bank of strategies, which had already been used successfully with children encountering difficulties in mathematics, would allow me to identify whether these strategies would be effective with dyscalculic learners. After showing my interest, one of the directors cordially invited me to another related conference, which I attended and which exposed me to the possibility of attending training to carry out the *Catch Up Numeracy* programme as part of my research project. I was provided with this training in September 2010. This training was indispensible for me to learn how to carry out the *Catch Up Numeracy* programme with the children identified with dyscalculia. The training consisted of two full days held at a school in Norfolk, UK. During this time, I was given a brief outline of the causes of difficulties in mathematics and literature about strategies which help children struggling with numeracy. Moreover, the trainers explained how the *Catch Up* assessment was to be carried out and how a typical session would unfold. I had the opportunity to try parts of the assessment phase and a typical session with some children at the school in Norfolk. As a follow up, I was given an assignment which included carrying out parts of the assessment, a session and reflecting upon what happened. I successfully passed this assessment and was awarded a certificate by the Open College University (OCN) for my achievement.

Consequently, I narrowed down my research aim to ascertain the most appropriate strategies to help the research participants overcome at least some of their difficulties. This was to be preceeded by a thorough assessment of the learners. Whilst acknowledging that each child is unique and that the strategies successful with one child may not be so with another, I sought to find some strategies which would be successful across the sample to be able to conjecture which strategies might also be successful with other pupils encountering similar difficulties.

3.3 Choosing a Research Paradigm

As Mertens (1998) highlights,

> "to plan, and conduct your own research, read and critique the research of others, and join in the theoretical and methodological debates in the research community, you need to understand the prevailing theoretical paradigms, with their underlying philosophical assumptions" (p. 45).

A paradigm is a way of conceiving the world. Each research paradigm has its unique way of answering the ontological question which asks about the nature of reality. It has its own epistemological assumptions which explain the nature of knowledge and the relationship between the researcher and the researched. Finally each paradigm has particular research designs associated with it (see Section 3.3.1). After extensive exploration of the different research paradigms and their associated beliefs, I felt that the most relevant was the interpretive/constructivist paradigm. Below I explain the reasons for my choice.

The ontological nature of this paradigm suggests that reality and what is being researched, is socially constructed and that the mind is the main tool which is essential for the construction of knowledge. As reported by Schwandt (1994) "constructivism means that human beings do not find or discover knowledge so much as construct or make it" (p.125). In the literature which has emerged with regard to dyscalculia, the socially constructed nature of knowledge is evident. Primarily, researchers are subjective about their beliefs concerning dyscalculia. In fact the repertoire of words which have been used to describe dyscalculia (Section 2.1) shows that this learning difficulty, like other learning difficulties, is socially constructed and is perceived in different ways depending on the individual exploring it. In my study, I shall invoke the ontological perspective of the interpretive/constructivist research community by putting forward my construction of knowledge with regard to dyscalculia in the following chapter.

The epistemological assumptions associated with the interpretive/constructivist paradigm also match my own beliefs. One of these assumptions suggests that the researcher is in a constant interpersonal relationship with the participant and they influence each other. This is especially true in my study where my sessions influenced the subject-participants through my intervention programme, whilst the participants affected the development of the same programme which was tailor-made for each of their individual needs. Furthermore, due to the nature of the relationship between the researcher and the participants which is typically developed in such a research paradigm, the "interpretive/constructivist therefore opts for a more personal, interactive mode of data collection" (Mertens, 1998, p.13). As a result, my sessions were held on a one-on-one basis to ensure that my data collection was carried out on a more personal level with each participant. Bassey (1995) underscores that "the data collected by interpretive researchers are usually verbal - fieldwork notes, diaries, and transcripts and reports of conversations" (p.13). Due to this, I ensured that throughout the sessions I also took as many notes as possible to be able to analyse the data from different perspectives keeping in mind *hermeneutics*, which is the term used by constructivist researchers to interpret what something means from a particular standpoint. In my case, this means interpreting successful strategies for children with dyscalculia from an educator's point of view. A final epistemological assumption concerning my study was that the interpretive paradigm "is characterized by a concern for the individual" (Cohen et al., 2007, p.21). In fact, my main concern in this research was to find strategies which would benefit the individuals participating in the research project as well as other children experiencing dyscalculia.

3.3.1 Selecting an Appropriate Research Design

After deciding upon the main aims of my research project and the paradigm of this study, the next step was to decide which research design would best allow me to find answers to my questions whilst adhering to my beliefs. Fixed and flexible designs, often referred to as quantitative and qualitative research methods respectively, are the dominant designs used in different fields of research. Since "whereas quantitative researchers strive for breadth, qualitative researchers strive for depth" (Wimmer and Dominick, 1994, p. 140), I felt that the latter form of research would be more suitable to inquire about strategies which could empower pupils with dyscalculia to overcome some of their difficulties. It also fitted best my chosen research paradigm. I wished to emphasise more upon "words rather than quantification in the collection and analysis of data" (Bryman, 2008, p. 264). Having said this, I immediately acknowledged that the first part of the study, which would entail identifying three pupils with dyscalculia using the *Dyscalculia Screener* (DS) (Butterworth, 2003) was going to be of a quantitative nature. Still I did not consider this to be problematic because as Robson (2004) suggests, "while a flexible design cannot be fixed or flexible at the same time, it could have a flexible phase followed by a fixed phase" (p. 87). Therefore although fixed and flexible research designs have been contrasted on numerous occasions, their purpose may still be to complement each other as in the case of this research project.

A schematic diagram (Figure 3.1) represents all the steps undertaken in this study together with a time-line of when they took place.

Figure 3.1: A schematic diagram illustrating the steps carried out

3.3.2 Validity and Reliability

LeCompte and Goetz (1982) argue that any research, even if of a qualitative nature, has to be externally and internally both reliable and valid. Quantitative research gave birth to the terms of *reliability* and *validity*. The appropriateness of these notions is contested by many qualitative researchers (Lincoln and Guba 1985; Winter 2000). Lincoln and Guba (1985) propose that in qualitative research it is more appropriate to examine the *trustworthiness* of a study rather than its *reliability* and *validity*. *Trustworthiness* refers to the quality of a research and comprises the following: '*credibility', 'transferability', 'dependability' and 'confirmability*' (explained in Table 3.1).

Credibility	An evaluation of to what extent the study represents the 'truth'
Transferability	Illustrating that the findings can be replicated in other contexts
Dependability	Determining the quality of the three processes of collecting data, analysing data and generating theories
Confirmability	A measure of how well the findings are supported by the data collected

Table 3.1: An explanation of terms in accordance with Lincoln and Guba (1985)

Other researchers have tackled the terms of *reliability* and *validity* separately. For example, Bogdan and Biklen (1992, p.48) suggest that, "reliability can be regarded as a fit between what researchers record as data and what actually occurs in the natural setting that is being researched" (in Cohen, et al., 2007, p. 149). This explanation is similar to that proposed by Lincoln and Guba (1985) through the notion of 'dependability'. In order to ensure I regarded Lincoln and Guba's (1985) term, I constantly took note of what occured. Additionally, I recorded all the sessions with the subject-participants to be able to go through them at a later stage and comprehend better what took place. Furthermore, I took photos of different activities. I also transcribed parts of the semi-structured interviews to ensure that I provided as holistic a picture as possible of the data collected.

On the other hand, validity is tackled through characteristics such as honesty, objectivity of the researcher, depth and richness (Winter, 2000). I acknowledge that the use of methodological triangulation added to the depth and richness of the study and therefore to its internal validity (*credibility* as per Table 3.1). Due to the fact that some researchers in the field of dyscalculia have found it difficult to identify pure cases of dyscalculia and have also criticised the *Dyscalculia Screener* (DS) (Butterworth, 2003), I felt that making use of this technique was crucial in maintaining the research's *validity* and *confirmability*. Denzin and Lincoln (2000) suggest that, "the use of multiple methods, or triangulation, reflects an attempt to secure an in-depth understanding of the phenomenon in question" (p. 5). Similarly, Flick (1998) states that triangulation is a "strategy that adds rigor, breadth, complexity, richness, and depth to any inquiry" (p. 231). As a result, using semi-structured interviews with the parents of the participants assessed with a profile of dyscalculia permitted me to verify whether the DS was right in its findings. The internal validity of the research was also taken care of through the thorough readings carried out at the beginning of the study to be able to compare findings to theoretical ideas which had been developed by others. On the other hand, the external validity of the project, similar to the term *transferability* (Table 3.1), was going to be quite problematic as also outlined by LeCompte and Goetz (1982). It is difficult to meet this criterion in qualitative research. Since I was going to carry out my study with a small sample and because a social situation cannot be frozen and replicated, it was more difficult for me to ensure my study was externally valid. Having said this, whilst analysing the data collected, I tried to point out key observations which took place with all three participants and which therefore may apply to other children with dyscalculia.

3.3.3 Identifying a Dominant Research Style

I began to search for the research style which best suited the aims of this study and the way in which I wanted it to unfold (see Section 3.3.1). I did not find a specific research style which matched what I had in mind but rather my research seemed to tap on a number of different research styles all within the spectrum of qualititative research. Hence I decided to name the style used in this study a *‘single case teaching experiment’*. This designation derives from a specific style used in psychology called *‘single case experimental design’*. “Single case experiments are scientific investigations in which the effects of a series of experimental manipulations on a single participant are examined” (Wilson, 2000, p. 60). As proposed by Wilson (2000), an example of such a design would be the assessment of the impact of a particular treatment on one individual. My research, like the mentioned research style, was conducted with individuals, similar to case studies, and involved the impact of some kind of ‘treatment’ (in my case the intervention programme). A case study is when a researcher studies a specific individual or phenomenon through observations, planned interviews or natural conversations, document and record analysis and so on (Gillham, 2000a). In my case, I observed and studied individual children with dyscalculia. However, my study also involved the implementation of a teaching programme. This research method is not typically used in relation to case studies.

The ‘experiment’ is the implementation of the intervention programme which is therefore a teaching-related experiment. This implementation stage can also be associated with educational action research since its aims and development are compatible with the ‘teacher-researcher’ model within educational action research (Kelly, 1999). Although I was not reflecting upon my daily praxis but on the execution of the programme, this still suited the definition of educational action research, which is “the systematic study of attempts to improve educational practice by groups or participants by means of their own practical actions and by means of their own reflections upon the effects of those actions” (Burgess, 1985, cited in Kelly, 1999). Additionally, educational action research is about providing a package which is tailored-made for the specific needs of each pupil. It is about providing social change by trying out changes and seeing what happens.

3.4 Gaining Access and Consent

After choosing the research topic and methods to be adopted, “the next stage of field research [was] to select and gain access to an appropriate site” (Frankfort-Nachmias and Nachias, 2003, p. 286). The gatekeepers (Miller and Bell, 2002) play a crucial role in the development of any research project and it is thus the researcher’s responsibility to present themselves as knowledgeable and trustworthy to be able to work within the desired field. Moreover, as Cohen et al. (2007) point out, “researchers will need to ensure that access is not only permitted but also in fact practicable” (p. 109). Since I am an educator, I felt it was more convenient for me to conduct my research at the school where I teach. As I teach at a Church school, I had to obtain permission from the Secretariat for Catholic Education as a sub-division of the Maltese Episcopal Curia. A letter with details about the research project including the questions to be asked at the interviews was sent to the Secretariat, also asking for consent to carry out the project in one of its schools. When written consent was granted, I referred my research project to the Head of School who eagerly allowed me to carry out the study, also giving me her written permission. Gaining access to the research field is mostly about persuading people to let you in their arena (Robson, 2004), therefore it was crucial for the Head of School and myself to discuss my plans. We discussed the ways in which the project could be carried out ensuring that I still honoured all my daily commitments and that the participating children did not lose out on any other lessons. We agreed that the preliminary assessment, the DS, would take place after school hours at the beginning of the scholastic year 2010-2011, whilst once the three participants were chosen, 15-minute sessions would be carried out during my ‘free’ lessons and when the children had long lessons such as a Creative Work which lasts one hour 10 minutes. We considered that taking the child out of class for 15 minutes was not a long period of time and therefore the child could quickly catch up on any work. I agreed that all withdrawals for the sessions would be planned together with the class teacher concerned. In agreement with the Head, I conducted the assessments and sessions of one of the pupils in her home setting since I did not manage to fit all six weekly sessions during school hours.

Following the selection of the participants, as shall be explained in the subsequent section, the next step was to gain written consent from those "who act in guardianship" (British Educational Research Association, BERA, 2004, p.6) of the study-participants. I also gained the children's consent because I believed they were capable of expressing their views. As Gregory (2003) puts it, "every code of ethics designed to guide research involving human subjects gives primacy to the requirement of fully informed voluntary consent on the part of the individuals concerned" (p. 35), in this case the parents and children. A letter with detailed information about the research was sent to the 15 chosen parents (see Section 3.5) both in Maltese and in English (see Appendix B). The information was written in language which the parents could fully comprehend. This was essential because as stated in the Statement brought to the fore by the British Sociological Association (BSA), researchers have the responsibility to "explain as fully as possible, and in terms meaningful to participants, what the research is about" (in Bryman, 2008, p. 481). A separate form, again presented in both languages, asked the parents to give me their consent to conduct the study with their children. I similarly provided the children with a separate 'information' sheet. A separate form was also provided asking for the children's consent to participate in the study and explaining that the children would be able to end their participation at any time without giving any reasons. Again, both sheets (see Appendix C) were provided to the children in Maltese and English ensuring that I was as clear as possible. At all times, I promised the participants full anonimity and consent. Since I acknowledged that it might be relatively easy for an outsider to identify the school in which the study was carried out since it was the school I worked at, I not only used pseudonyms but removed any information that could make the children identifiable. This included removing all the children's personal details from the reports produced by the DS (reproduced in chapter 4). Moreover, I ensured that no child was identifiable in the photos taken. The initial phase of gaining consent was successful as 14 out of 15 parents approached (see Section 3.5) granted their consent. Moreover, all the respective 14 children then granted their own consent.

After identifying the three participants which showed traits of dyscalculia, I asked for their parents' consent to be able to interview them about their children and record the interviews. When the interview terminated, I explained to the parents how and when the programme was going to take place and asked for their written consent to be able to record the sessions to be able to refer to the recordings when needed. I explained that all recordings would be treated with strict confidentiality and that they would only be listened to by myself. Additionally, I answered any queries that the parents had. This helped me build a trusting relationship with them and was crucial to my research as the main part of the research was going to be carried out with their children.

3.5 Choosing the Participants: Criterion Sampling

Since the aim of my research project was to identify three children who according to the DS and other evidence were experiencing dyscalculia, I could not select my sample randomly. Moreover, it was kept in mind that, "researchers working within the interpretive/constructivist paradigm typically select their samples with the goal of identifying information-rich cases that will allow them to study a case in-depth" (Mertens, 1998, p. 261). It had originally been decided that there would be three participants for this study because it is not a large number, therefore leaving space for the in-depth research to be carried out in qualitative research, whilst at the same time a manageable number which would allow me to compare the different ways in which the participants reacted to the intervention programme and to the strategies used.

As I teach at a girls' Church School, the participants' gender was out of my control. At the beginning of the scholastic year (2010/2011) I began selecting my participants by looking at the annual examination results which the cohort I was now teaching had achieved in mathematics during the previous year. I selected the 15 children who had achieved most poorly in the examination and then spoke to their previous mathematics teacher and asked whether she agreed that the children I had selected were the weakest in that cohort. She did generally agree, however, she did make minor changes to my list suggesting that one of the children usually performed well in mathematics but had probably feared the examination, whilst another usually did not do well but had managed to do quite well in the exam.

I carried out the *Dyscalculia Screener* (DS) (Butterworth, 2003) with the selected participants. The results of this phase and how they infleunced further action are reported in Section 4.2. Additionally, an interview was carried out with the parents of the three pupils assessed with a profile of dyscalculia (see Section 3.5.2) by the DS. When the data from the DS and the interviews matched, I decided that the particular children were the best participants for the intervention programme.

3.5.1 The *Dyscalculia Screener* (DS) (Butterworth, 2003)

The DS was the main tool utilised in the selection of an appropriate sample. In this section I explain the main features of the DS and how it concludes whether a pupil has dyscalculia or not. The DS can be used with participants aged 6 to 14. It is user-friendly and uses tasks which can determine a pupil's proficiency in basic numeracy. It is administered on an individual basis and each test takes about 30 minutes per child. The DS's diagnosis of dyscalculia is based on the results of four different tasks, as well as the speed at which the learner completes each of the given activities. The first task is a simple exercise to determine the reaction time of a child. An example of this task is presented in Figure 3.2.

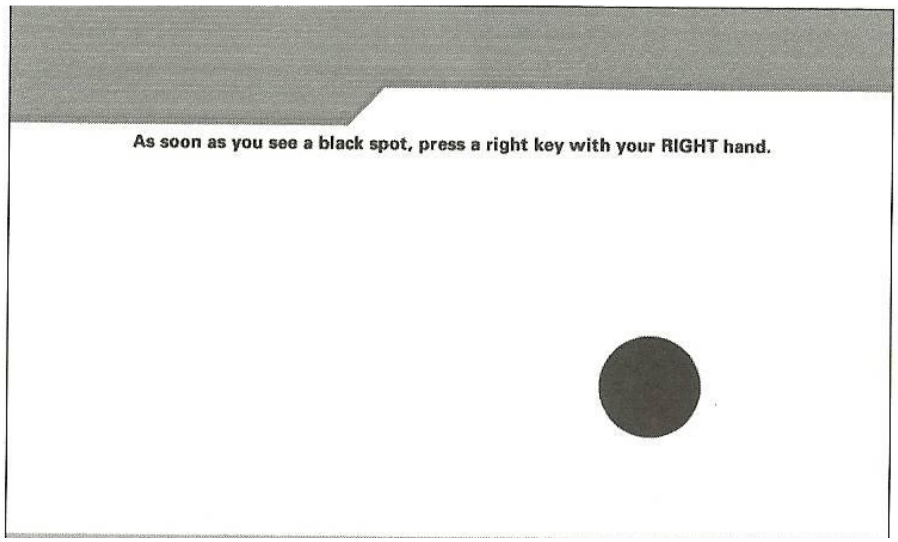


Figure 3.2: Simple Reaction Time is the first task of the DS

The child must press a right key with their right hand as soon as a black dot appears on the screen. The same exercise is then repeated with the left keys and the left hand. The average reaction time spent by the child during this exercise (to spot the dot) is then used in relation to the time spent on the other tasks to determine whether the learner is responding slowly to the questions posed or if s/he is generally a slow responder. The pupil is then given two 'capacity tests'. These tests are referred to by the DS as *Dot Enumeration* and *Number Comparison* (also called *Numerical Stroop*). Screen shots of these two are represented respectively in Figures 3.3 and 3.4. An explanation of the 'capacity' each one assesses will follow.

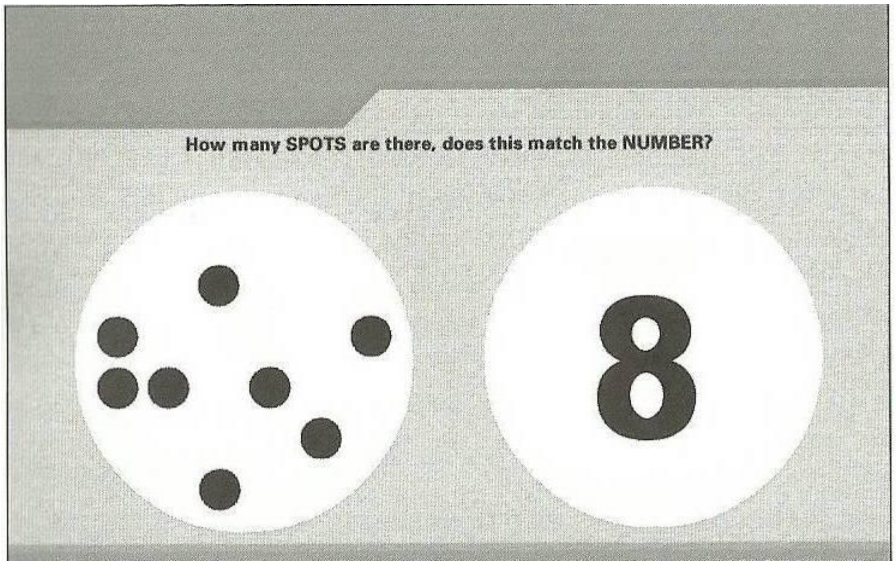


Figure 3.3: *Dot Enumeration*

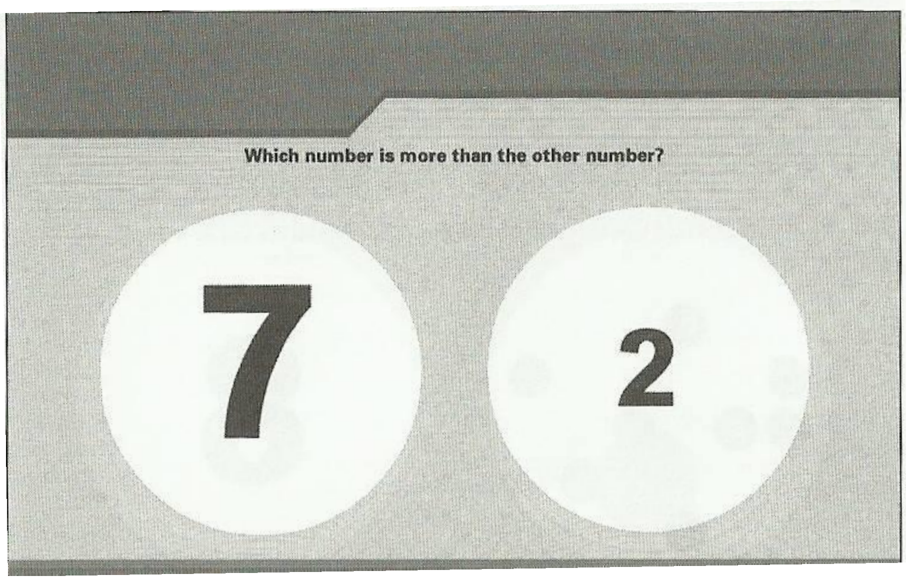


Figure 3.4: *Numerical Stroop*

The *Dot Enumeration* asks that the learner compares a given number with a number of coloured dots. If the number matches the amount of dots given, the child must press ‘yes’ (any right key). If they do not match, the child presses ‘no’ (any left key). The *Numerical Stroop* task asks that the pupil compares two numbers and decides which is largest in value. The number with the larger value is sometimes given in a smaller size in relation to the other number to determine whether this confuses the child or otherwise. Both these tasks are timed because they do not only assess the factor of accuracy as do many standardised tests (Butterworth, *Screener Manual*, 2003). Since these are easy tasks, most pupils are expected to answer all or most questions correctly so achievement on these tasks alone will not help to select dyscalculic learners from other learners. The *Dot Enumeration* uses the recorded time to “separate those pupils who have had problems learning to count because of a deficient capacity for identifying numerosities” (p. 15) from other pupils. Therefore it selects those pupils who have difficulties with numerosity (part of which is subitising). The *Numerical Stroop* records the time taken since extensive research (Butterworth, *Screener Manual*, 2003) has shown that pupils who are slow at this task are likely to be dyscalculic.

The last two tasks are known as ‘achievement tasks’. These tasks are one-digit addition and multiplication sums. For children aged 9 or younger, only addition sums are given. As an example, a screen shot of an addition sum is presented in Figures 3.5.

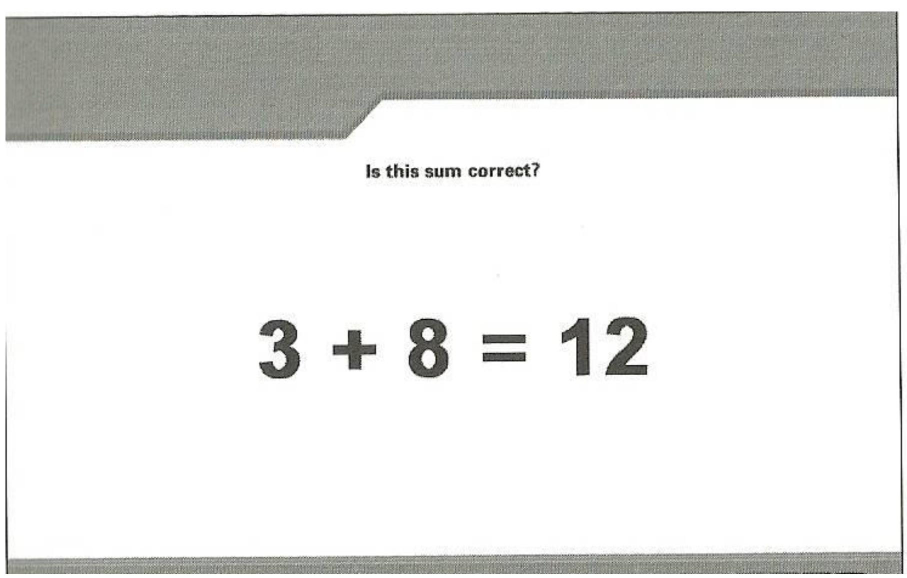


Figure 3.5: Sample numerical task

If the sum given is correct, the child is to press 'yes' whilst if the sum is wrong they are to press 'no'. The score of the sums is taken and the time taken to complete the task/s is recorded. The DS then produces a report (see samples in Section 4.2) to show the child's performance in the tasks in relation to their speed of completing the tasks. A note is inserted in which the administrator is told whether the child is likely to have dyscalculia or otherwise.

The manual of the DS suggests that these four tasks have been selected to conclude whether a child is dyscalculic or not because they are concerned with numerosity (see Section 2.1). Butterworth (2003) illustrates how a child with dyscalculia will mainly have difficulties with numerosity and numeracy, so the tasks are intended to remove other variables and simply test for these two specific categories of mathematics.

3.5.2 Semi-Structured Interviews Carried Out with the Children's Parents

The semi-structured interviews conducted with the parents of the three children assessed with a profile of dyscalculia by the DS were crucial in establishing whether the children really had such a great difficulty with numeracy. I decided to make use of semi-structured interviews to avoid the rigidity of a structured interview whilst ensuring that our conversations brought out answers to the questions I had in mind. As Gillham (2000b) explains, a semi-structured interview "has more structure although being very 'open' in its style" (p. 7). The first step after choosing an interview style was then to plan for the actual interviews. As Gerson and Horowitz (2002) suggest, "an interview study requires substantial fore thought and advance planning" (p. 204). I understood that I had to prepare a "handful of main questions with which to begin and guide the conversation" (Rubin and Rubin, 1995, p. 145) and that through them, as an interpretive researcher, I had to try to elicit the parents' views about the difficulties being encountered by their children as well as become more in touch with their experiences in relation to their children's difficulties with numeracy and mathematics.

I explored some of the major interview questioning techniques (Kvale, 1996; Charmaz, 2002, Stringer, 2004). Following Charmaz (2002), I drew up three types of questions: *open-ended questions, intermediate questions and ending questions* (Appendix D) which would allow me to acquire the needed information whilst maintaining a focus on the key area to be tackled in the interview. The questions were drawn up in both Maltese and English and I posed the questions according to the participants' preferred language.

The interviews were held at the beginning of November 2010 and lasted approximately 20 minutes each. During the interviews, tape recording was used. As highlighted by Bryman (2008), "with approaches that entail detailed attention to language...the recording of conversations and interviews is to all intents and purposes mandatory" (p. 451). Additionally, I took my own jotted notes (Lofland and Lofland, 1995 and Sanjek, 1990) in order to record any valuable body language and gestures which would allow me to analyse my data in a deeper manner at a later stage. Parts of the interviews have been transcribed in chapter 4 to illustrate how they allowed me to conclude whether the children did have dyscalculia or not. The parts in which Maltese was used have been translated to English as faithfully as possible.

3.7 Using a Standardised Test as Pre- and Post- Test

The Catch Up Numeracy Programme suggests that a standardised test is carried out with the participants before and after any form of intervention is done so that the effects of the intervention programme itself may be measured. Standardised tests provide an approximate classification of a child's attainment and reveal both percentiles and quotients achieved by each individual so that the administrator of the test may determine how high or low one's achievement is within the specific area. The recommended standardised test which I have decided to opt for was the 'Basic Number Screening Test' developed by Hodder Education (2001). The test is suitable for children aged 7 to 12 years. The test can be administered either in a group or on an individual basis. I administered the test on an individual basis as I thought that the children would feel more at ease. The test indicates that all the instructions are to be read out to minimise the effects the children's literacy difficulties, if any, may have on the results. This standardised test includes various exercises in which dominant number concepts are assessed namely, addition, subtraction, mutliplication, division and fractions. The tasks used are compatible with the UK National Numeracy Strategy Framework for Teaching Mathematics and National Curriculum (DfES, 2001). The test "was orignally standardised with a total of 3,042 children in age range 7 years 6 months to 11 years 6 months" (Gillham and Hesse, 2001, p.16). Its reliability and validity have been very high. In fact, the Pearson product-moment correlation coefficient was +0.93 signifying high reliability whilst the Spearman's Rho conducted to measure the test's validity indicated an average +0.82 on the test (Gillham and Hesse, 2001). The results of the standardised tests carried out with the children before and after the intervention programme are discussed in the following chapter.

3.8 The Catch Up Numeracy Programme

In this section I explain in detail the *Catch Up Numeracy* programme. However, I must start by stating that even though my training was sponsored, at no point did the sponsor dictate how I should conduct my research, what findings I should have, what should or should not be reported or to 'conceal' who the sponsor was (Cohen et al., 2007). Our agreement involved myself providing the *Catch Up* team with the details of my research results. *Catch Up*'s gain was multifold. Primarily, my research took place with children assessed with a profile of dyscalculia. All of *Catch Up*'s other research has so far been carried out with children encountering any kind of difficulties with mathematics. Secondly, the programme was going to be used outside the UK allowing the organisation to determine its effectiveness in a foreign country. Lastly, it could opt to reveal the results to the public if these helped to advertise its programme. Therefore although I was obliged to provide *Catch Up* with a detailed copy of my results, my research was in no way compromised.

The first fundamental part of the *Catch Up Numeracy* intervention programme was that of performing a thorough formative assessment with each child to assess her strengths and weaknesses in each of the ten components of numeracy (see Section 2.1). I administered the assessments exactly as they are presented in the *Catch Up* resource file. Every assessment lasted between one hour and a half and two hours.

Every assessed numeracy component was divided into sub-components which together provided a detailed snapshot of the learner's achievements in the specific areas. Table 3.2 illustrates how the 10 numeracy components were sub-divided into other components. These have been taken directly from *Catch Up* (2009). However, I have added my own example and/or explanation for each sub-component to illustrate what each on refers to.

Numeracy Main Component	Sub-Components	Example/Explanation
Counting Verbally	Counting Verbally Counting On Counting Back	To count verbally from 0 to a number (5, 8 or 10). To count on from a number to another. To count back from a number to another.
Counting Objects	Counting Objects Order Irrelevance Adding Objects Subtracting Objects	To count a number of objects. To understand the order irrelevant of counting objects. To add given objects. To subtract given objects.
Reading and Writing	Reading Numbers Reading Number Words Writing Numbers	To read numbers e.g. 1, 2, 3, etc. To read number words e.g. one, two three, etc. To write numbers e.g. 1, 2, 3, etc.
Hundreds, Tens and Units	Number Comparison Adding Tens and Units Subtracting Tens and Units	To compare two numbers and say which is greatest. To add tens and units e.g. 10 + 3 = 13. To subtract tens and units e.g. 12 – 4 = 8.
Ordinal Numbers	No Sub-components	To use ordinal numbers e.g. first, second, etc. correctly.
Word Problems	No Sub-components	To solve word problems.
Translation	Objects to Numbers Numbers to Objects Number Words to Objects Number Words to Numbers	To represent objects with number sentences. To represent number sentences with objects. To represent word problems with objects. To represent word problems with numbers.
Derived Facts	Identical Commutative N + N -	e.g. If 4 + 3 = 7, then 4 + 3 = 7. e.g. If 4 + 3 = 7, then 3 + 4 = 7. e.g. If 4 + 3 = 7, then 4 + 4 = 8. e.g. If 4 + 3 = 7, then 4 - 2 = 6.
Estimation	No Sub-components	Estimating the answer to sums.
Remembered Facts	No Sub-components	Recalling number facts without counting.

Table 3.2: A representation of how the main numeracy components are split in sub-components (Adapted from Catch Up, 2009)

For each of the sub-categories, the learner was asked to perform different tasks. For example, for the sub-component of 'counting on', the learner was asked to count on from a given number to another (e.g. count on from 3 to 5). For the 'writing numbers' sub-component, the learner had to write various numbers on a given sheet. Figure 3.6 demonstrates the work done by one of the learners participating in the programme during the assessment of this sub-component.

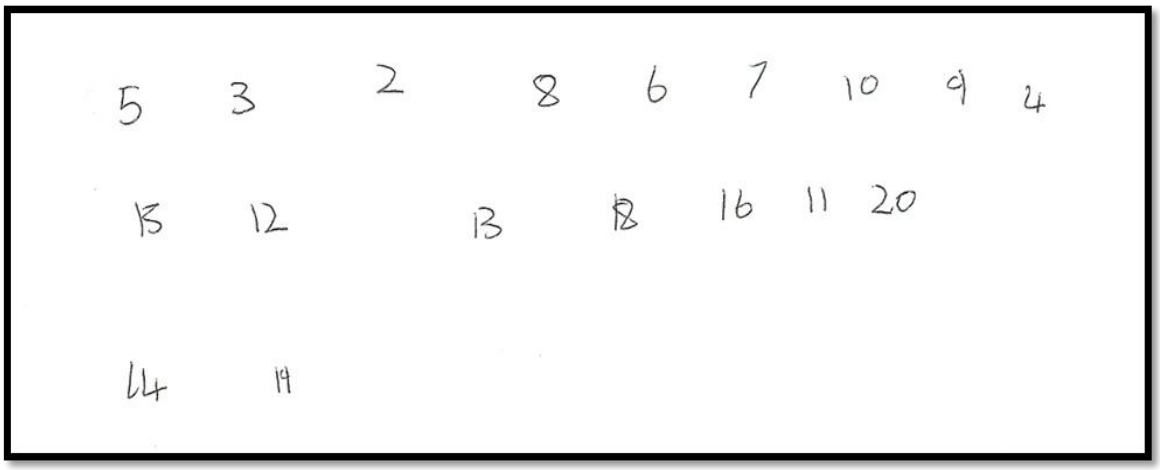


Figure 3.6: Sample work carried out for the sub-component 'writing numbers'.

Assessment began with tasks which utilise the number ranges from 1-5. The exercises then moved on to 0-8, 0-10, 0-15, 0-18 and 0-20 as necessary. As soon as a learner was assessed as not having enough confidence in a particular sub-component within a specific number range, the assessment ceased. When all the assessments for the various components were carried out, a pupil's profile was compiled in order to be able to determine the strengths of the learner and the areas which still needed to be developed. The pupil's profile was also crucial in allowing me to view and prioritise the component/s most lagging behind. Without such an in-depth assessment it would have been impossible to gain a clear view of the child's achievement in the numeracy components. The assessment stage, which took place one week before the actual intervention sessions, was instrumental in ensuring that subsequent intervention was specific and therefore effective.

The intervention sessions were 15 minutes long and were carried out twice a week. The time spent on each session was kept short so that learners did not lose their attention and therefore allowed the sessions to maintain their focus and effectiveness. As stated earlier, the sessions with two of the children assessed with dyscalculia were carried out at school and therefore two 15-minute sessions were conducted twice a week as suggested by the programme. However, due to practical reasons, with the consent of *Catch Up*'s Director and Assistant Director, the two 15-minute sessions carried out with the third child at her home were conducted on the same day. After one session, the learner was given a 30-minute break, and then a second session was conducted. This system seemed to be effective as the learner always gave me her full attention during both sessions.

The participants were exposed to a total of 20 sessions each spread over 10 weeks between the end of November 2010 and the beginning of February 2011. As prescribed by the *Catch Up* intervention programme, the targeted components were individually selected and were those components in which each child was weakest as will be shown in chapter 4. Each 15-minute session was divided into three parts and each section was dedicated a prescribed number of minutes as shown in Figure 3.7.

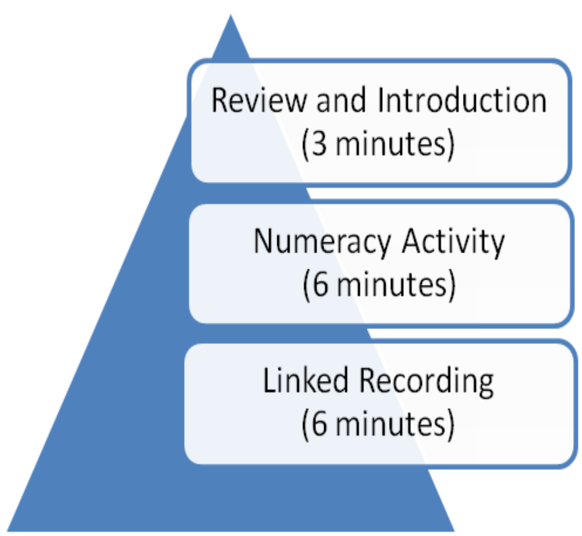


Figure 3.7: The three parts of the Catch Up Numeracy sessions
(adapted from Catch Up 2009)

In the following sub-sections I shall explain in more detail each of the three parts of every session. A list of all the tasks carried out with each child may be found in Appendix D. Prior to the sessions, I planned my own outline of activities for each child. I created my own 'review and introduction' and 'linked recording' activities (sometimes based on the 'numeracy activity' proposed by *Catch Up*), however, I drew on *Catch Up*'s resource file for most of the 'numeracy activities' as the file contains a variety of these. However, I also looked for other activities in *Catch Up*'s on-line resources and also in other sources. I also created many activities myself based on the particular component and on what would suit the particular child. My choice of activity was mostly based on finding the task that I thought would be most successful with each individual child. Moreover, since I knew that the children I was dealing with also had mild to moderate literacy difficulties, I took this into consideration when creating my resources. For example, I used pastel (yellow) coloured paper which is said to reduce the contrast between the print and the colour of the paper, and reduce scotopic sensitivity (Ott, 1997).

For each session, I logged down the following on a specific sheet:

- The component and number range worked upon;
- Any miscues that the child would have done during the particular session and that she still needed to work on;
- Any other components targeted indirectly; example when targeting word problems, the component of writing and reading numbers was also targeted.
- The open-ended questions asked to the pupils about *prediction*, *process* and *reflection* which would metacognitively engage the pupils in their learning process example *'how did you work this out?'*;
- My comments about the learner's performance in that session and some comments from the learner;
- Follow-up tasks to be carried out in further sessions.

3.8.1 The 'Review and Introduction' Phase

The 'review and introduction' phase of each session had twofold objectives. On one hand it aimed at reviewing what the learner would have covered during the previous session. On the other, it allowed me to reveal my objective/s for the session to the learner and determine the numeracy component which will be focused upon and the number range to be used. Additionally it is in this phase that I would decide what related mathematical language would be focused upon and introduced it to the learner. In Table 3.3 I give examples, taken from my notes, of how the 'review and introduction' during one of the sessions.

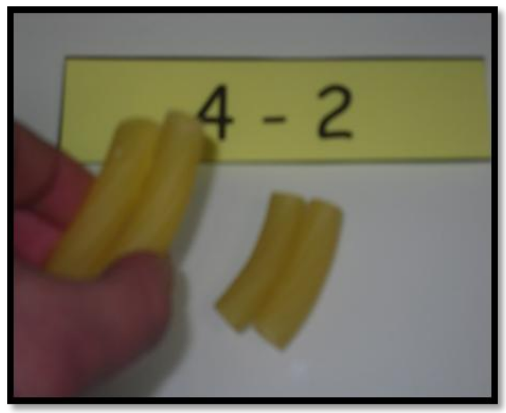
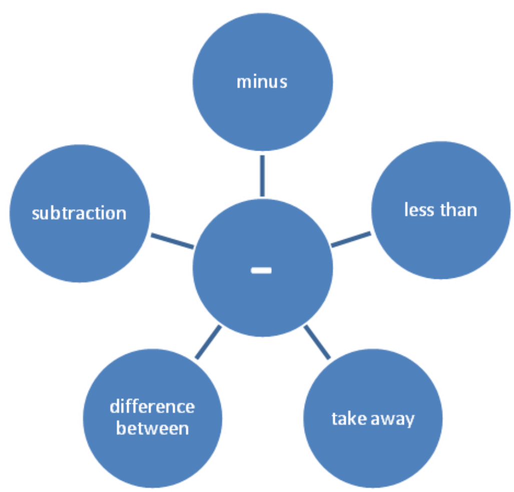
Previous Session	Numeracy Component: Subtracting Objects Number Range: 0 – 8
Actual Session	Numeracy Component: Subtracting Objects Number Range: 0 – 10
Review	The child will be asked to select some subtraction sums (with no answers) from a pile given. She is to represent the sum using some pasta shells (as illustrated by Figure 3.8). By subtracting the objects given, she is to find the answers to the selected sums. Also review the mathematical language introduced (Figure 3.9).  Figure 3.8: Representing the sum 4 – 2 using pasta shells.  Figure 3.9: The mathematical language to be used for subtraction.
Introduction	Introduce the new number range which will be 0 – 10 and explain the objective of today's session which is that of subtracting objects using the numbers between 0 and 10.

Table 3.3: Sample plan for a 'Review and Introduction' section (Subtracting Objects, 0 - 10)

3.8.2 The 'Numeracy Activity'

This phase of the session was that in which an activity was carried out in relation to the objective of the specific session. Its aim was that of allowing the child to practise the skill being introduced or focused upon.

According to the *Catch Up* programme, during this phase of the session, the educator is expected to guide the child in engaging in a metacognitive process. This is done by asking questions about prediction, process and reflection. An example of a question related to prediction is *'what do you think the answer will be?'* In addition, sample questions about each of the process and reflection respectively are '*how did you work this out?*' and *'was your answer accurate?*'. Metacognitive thought allows the child to think about the way s/he is processing the information being learnt. In addition, it allows the educator to provide guidance within the child's Zone of Proximal Development (ZPD) (see Section 2.6). Therefore in the following example of the 'numeracy activity' (Table 3.4) carried out during the sessions I shall also mention which metacognitive questions were planned to be asked.

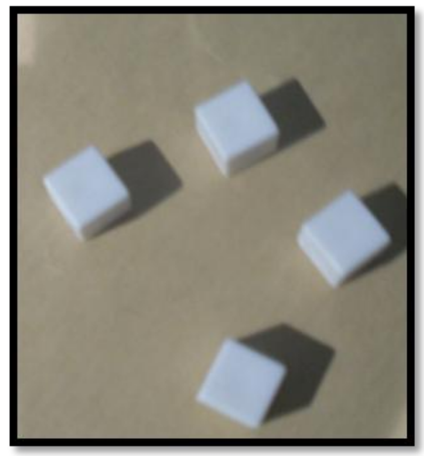
Numeracy Component	Subtracting Objects
Number Range	0 – 10
Activity	The child is to pretend that she is shopping at a stationery shop. A number of objects and their prices are set out on the table. Explain that instead of money she will be using cubes (cuisinaire one value rods, shown in figure 3.10) where 1 cube will represent €1. Pretend to be the cashier. Ask her to buy different things, one thing at a time.  Figure 3.10: Four one-value cuisenaire rods Each time ask the child to subtract the cubes she 'spent' from the cubes she had left from previous buyings. Ask her to predict the answer and then ask her to actually subtract the objects (cubes) to see if she was right. When her cubes are almost finished, tell her that it is the weekend and that she gets some more cubes as pocket money. Carry out the role-play until you are sure that the child has grasped the skills necessary to subtract objects. *(Activity created by myself.)*
Metacognitive Questions to be Asked	• How many cubes do you think you will have left if you buy this item? • Was your answer accurate? • If your friend did not know how to subtract objects, how would you explain they should do this?

Table 3.4: A sample 'numeracy activity' (Subtracting Objects, 0 - 10)

3.8.3 The Final Phase: 'Linked Recording'

The 'linked recording' phase is completed at the end of every session. In this part of the session, the child is asked to complete a task or written exercise related to the numeracy activity conducted during that particular session. The task or exercise is recorded on the sheet used to log down the details for every session. The 'linked recording' section not only allows the learner to put into practice the skills learnt but since it is recorded it is proof of the child's progress and can be referred to any time such reference is needed. Figure 3.11 below provides a sample of the work completed for subtracting objects (0 – 10) as part of the 'linked recording' section.

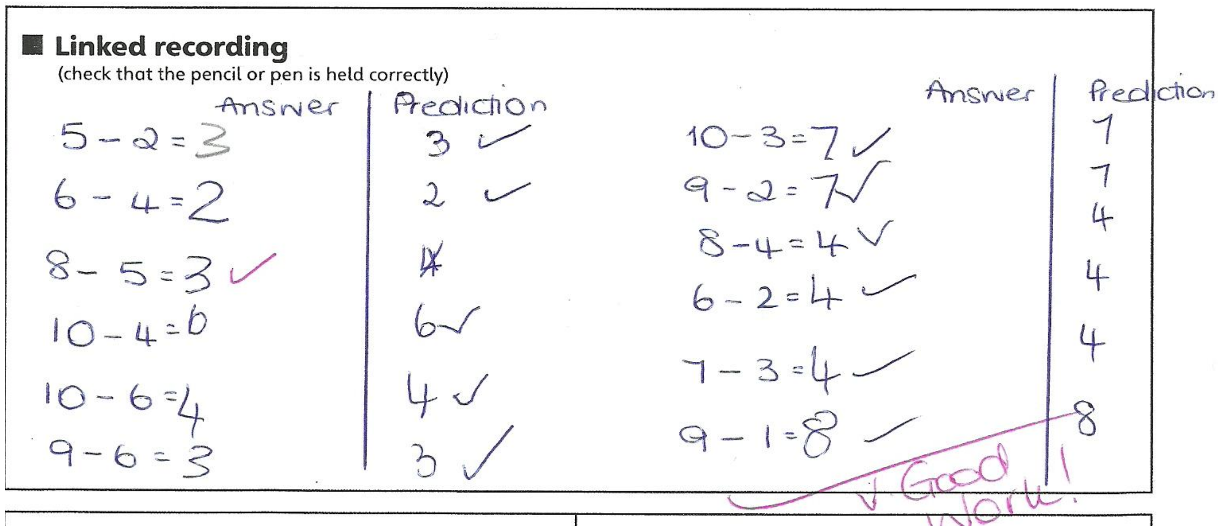


Figure 3.11: Sample 'linked recording' (Subtracting Objects, 0 -10)

3.9 Conclusion

In this chapter, I have identified the objectives of the study and my underlying research paradigm. Furthermore, I have explained the research design adopted and the investigative tools used. Ethical considerations were also discussed. In the next chapter I analyse the data collected to shed light on strategies which educators may use to help pupils with dyscalculia reach their full potential.

Chapter 4

A Journey of Observation and Reflection

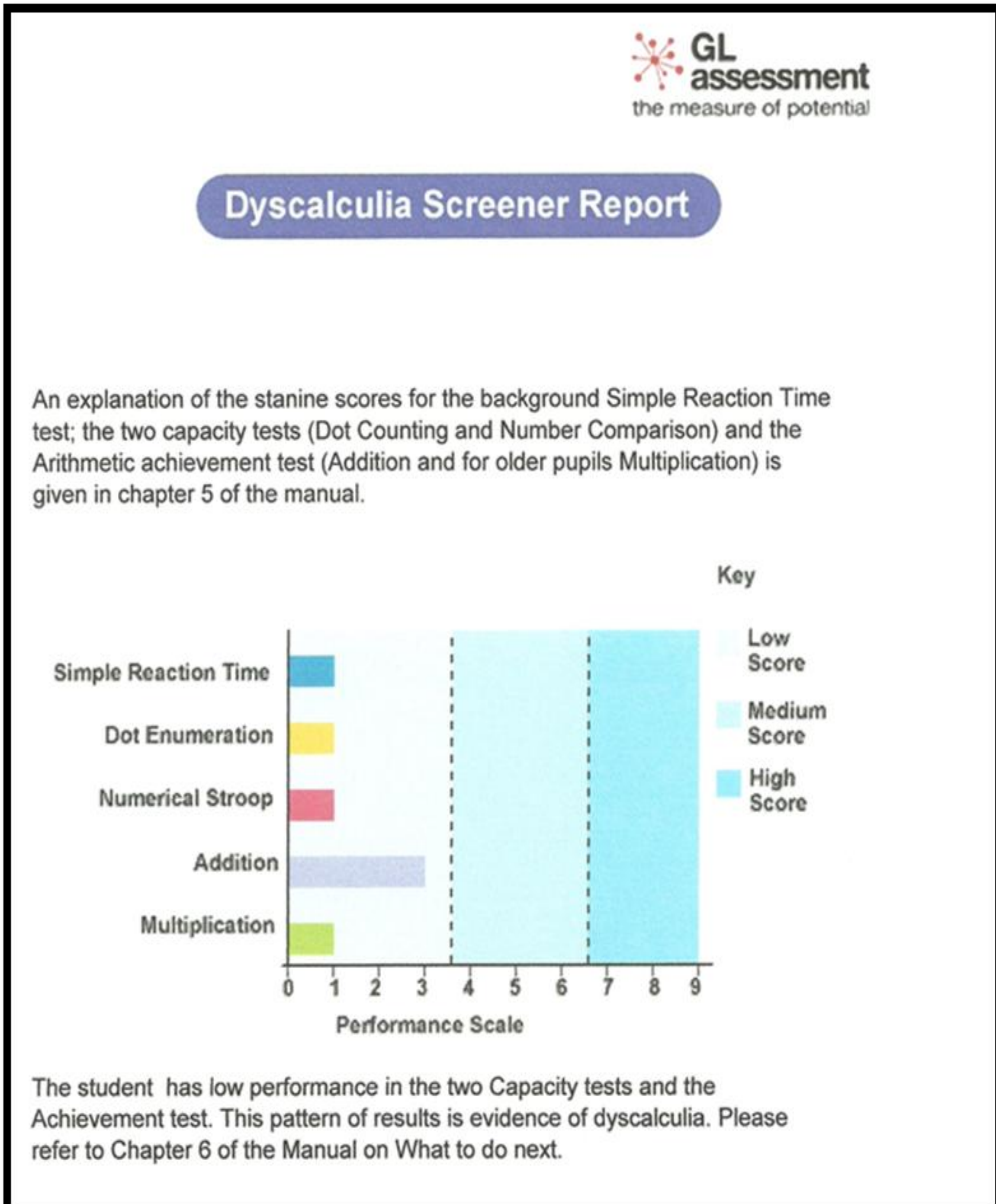
4.1 Introduction

Throughout this chapter, I shall embark on a journey of reflection which will reveal my observations, thoughts and perspectives about all the data collected through the administration of the *Dyscalculia Screener* (DS) (Butterworth, 2003), the interviews with the parents, the standardised test carried out, Catch Up's formative assessment, the actual intervention programme as well as the final assessments and results. I shall attempt to view the data through different outlooks, to continue fulfilling my role as an interpretivist/constructivist researcher. As the chapter unfolds, I will provide the reader with a clear profile of each of the three learners who participated in the intervention programmes. I shall also discuss emerging key points which have cropped up throughout the intervention providing some room for generizability to take place. Finally, I shall summarise the main conclusions and give suggestions regarding assistance that might be offered to pupils with similar difficulties to overcome their barriers to learning mathematics.

4.2 The Initial Stages

The practical part of my research project began when I started looking for children experiencing dyscalculia. I must admit that this venture was harder than I had imagined it would be. As there is as yet little research with regard to the way children are assessed for dyscalculia, within the cohort of Grade 6 pupils (10-11 year olds) I had during the scholastic year 2010 – 2011, there were no children assessed with dyscalculia by an educational psychologist or any other professional so I had to decide to whom to administer the DS by viewing the children's performance in their previous annual exam in mathematics.

I administered the DS to 14 children who had scored between 30 and 50 in their mathematics examination. I thought that it was obvious that if they had performed so poorly in their mathematics exam, at least some of them would be encountering difficulties with regard to dyscalculia. However, to my great surprise, when I carried out the DS with these children, only one child was clearly assessed with a profile of dyscalculia. This child will be referred to as Martina. The report produced by the DS is shown in Figure 4.1[4].


GL assessment
the measure of potential

Dyscalculia Screener Report

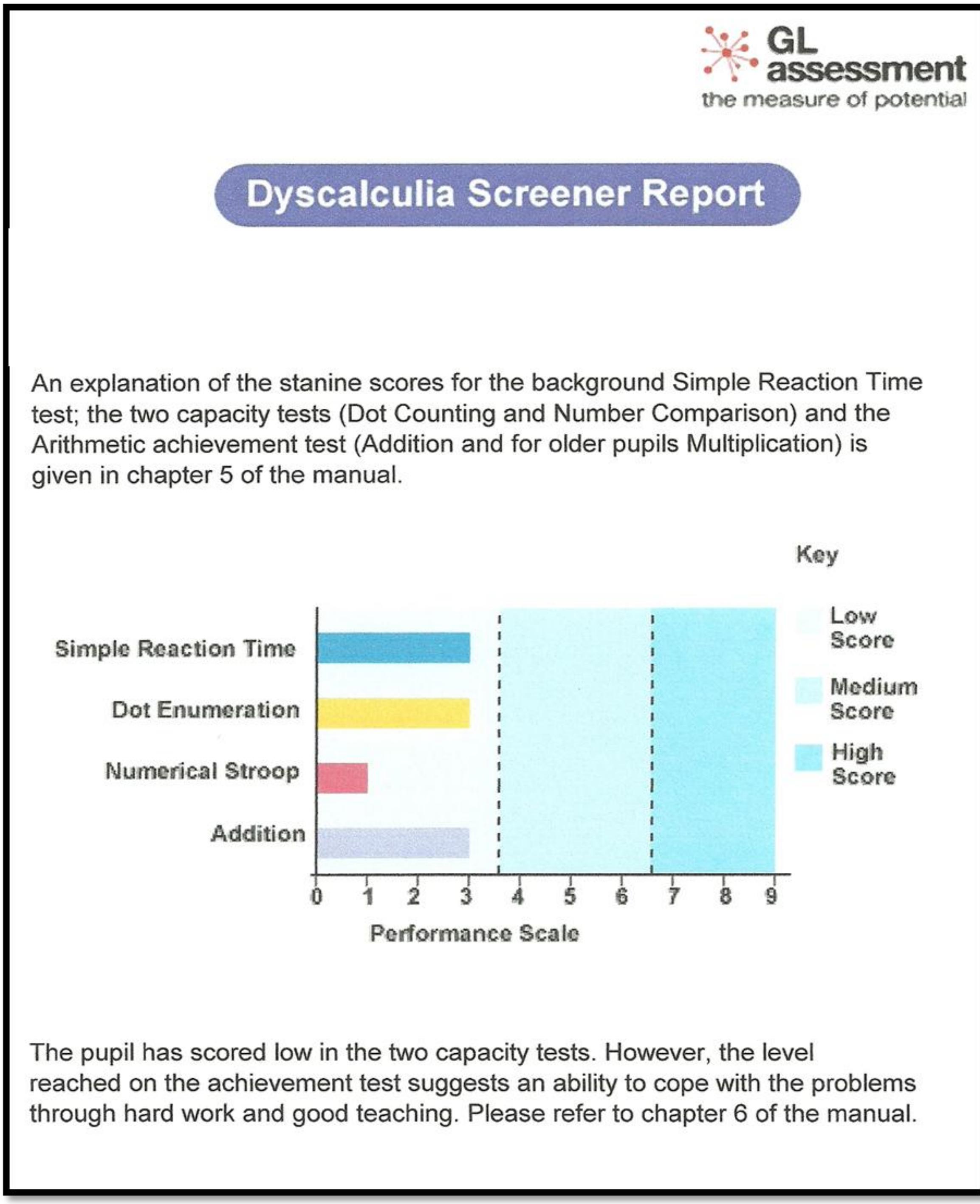
An explanation of the stanine scores for the background Simple Reaction Time test; the two capacity tests (Dot Counting and Number Comparison) and the Arithmetic achievement test (Addition and for older pupils Multiplication) is given in chapter 5 of the manual.

The student has low performance in the two Capacity tests and the Achievement test. This pattern of results is evidence of dyscalculia. Please refer to Chapter 6 of the Manual on What to do next.

Figure 4.1: Martina's report

[4] All the details which could reveal the child's identity have been removed from every report.

Another child, who will be referred to as Charmaine, was assessed with the profile provided in Figure 4.2.


GL assessment
the measure of potential

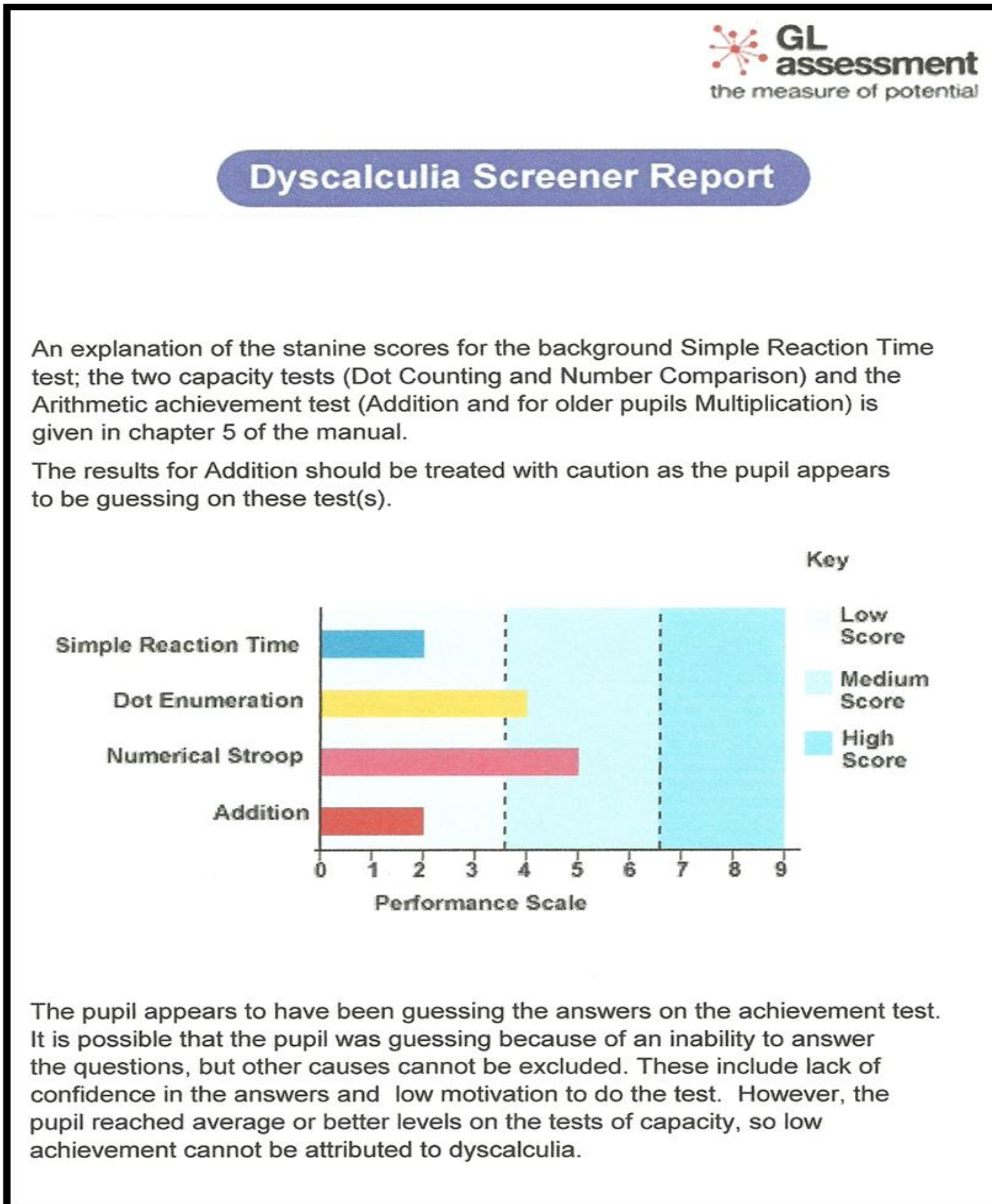
Dyscalculia Screener Report

An explanation of the stanine scores for the background Simple Reaction Time test; the two capacity tests (Dot Counting and Number Comparison) and the Arithmetic achievement test (Addition and for older pupils Multiplication) is given in chapter 5 of the manual.

The pupil has scored low in the two capacity tests. However, the level reached on the achievement test suggests an ability to cope with the problems through hard work and good teaching. Please refer to chapter 6 of the manual.

Figure 4.2: Charmaine’s first report

This profile made me question whether the child was dyscalculic or not. As advocated by the DS's manual I re-administered the DS and the results in Figure 4.3 emerged. In the latter, it seemed that the DS diagnosed the child as


GL assessment
the measure of potential

Dyscalculia Screener Report

An explanation of the stanine scores for the background Simple Reaction Time test; the two capacity tests (Dot Counting and Number Comparison) and the Arithmetic achievement test (Addition and for older pupils Multiplication) is given in chapter 5 of the manual.

The results for Addition should be treated with caution as the pupil appears to be guessing on these test(s).

The pupil appears to have been guessing the answers on the achievement test. It is possible that the pupil was guessing because of an inability to answer the questions, but other causes cannot be excluded. These include lack of confidence in the answers and low motivation to do the test. However, the pupil reached average or better levels on the tests of capacity, so low achievement cannot be attributed to dyscalculia.

Figure 4.3: Charmaine's second report

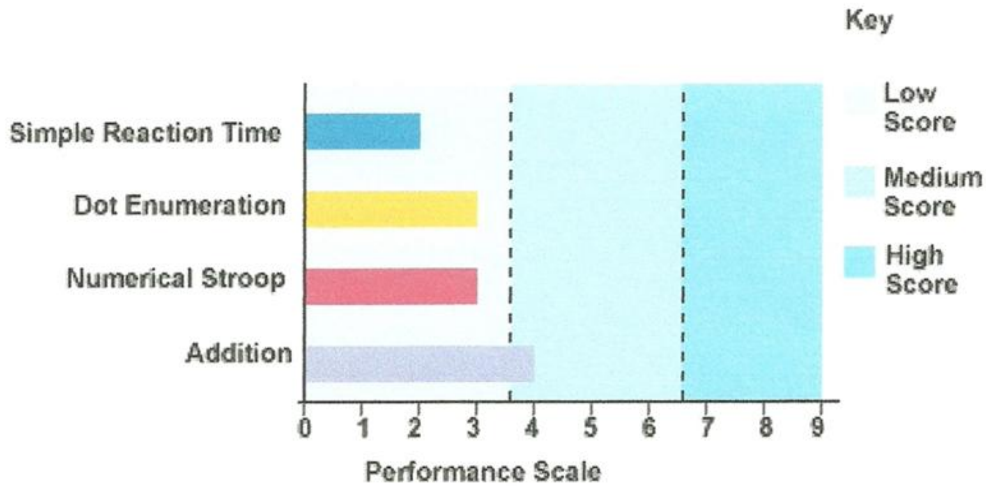
not having dyscalculia solely because she had reached average or better in the capacity tests. However, the previous report suggested that she had achieved a 'low' level in these tasks. As a result, I chose to go for a more formative assessment of my own design and assessed the basic components of numeracy including simple addition and subtraction. Charmaine first stared at me when I asked her to add 2 and 4. She had no idea what she had to do. This contradicted the first profile (Figure 4.2) created by the DS in which it was evident that all of Charmaine's scores were low and that the DS had concluded that she was not dyscalculic because she could add. However, given my formative assessment, I could conjecture that she had guessed the answers to the addition sums given just as the second report (Figure 4.3) had concluded. Additionally, I suspected that in the second test, her scores turned out higher because of the confidence she had gained from repeating the tasks. I took note of all my observations and tried to judge the situation as professionally as possible. After discussing the matter with other professionals, including the Learning Support Assistant (LSA) in Charmaine's class, the Inclusion Co-ordinator and her previous mathematics teacher, as well as my supervisor and adviser, I finally decided that Charmaine was certainly experiencing great difficulties related to numeracy and that therefore she was probably dyscalculic. It was also obvious that she did need my help in this area. Charmaine was thus selected to be the second participant of this research project.

The rest of the children to whom the DS was administered were assessed as performing age-appropriately. A sample report provided for one of the other children can be viewed in Figure 4.4.

GL assessment
the measure of potential

Dyscalculia Screener Report

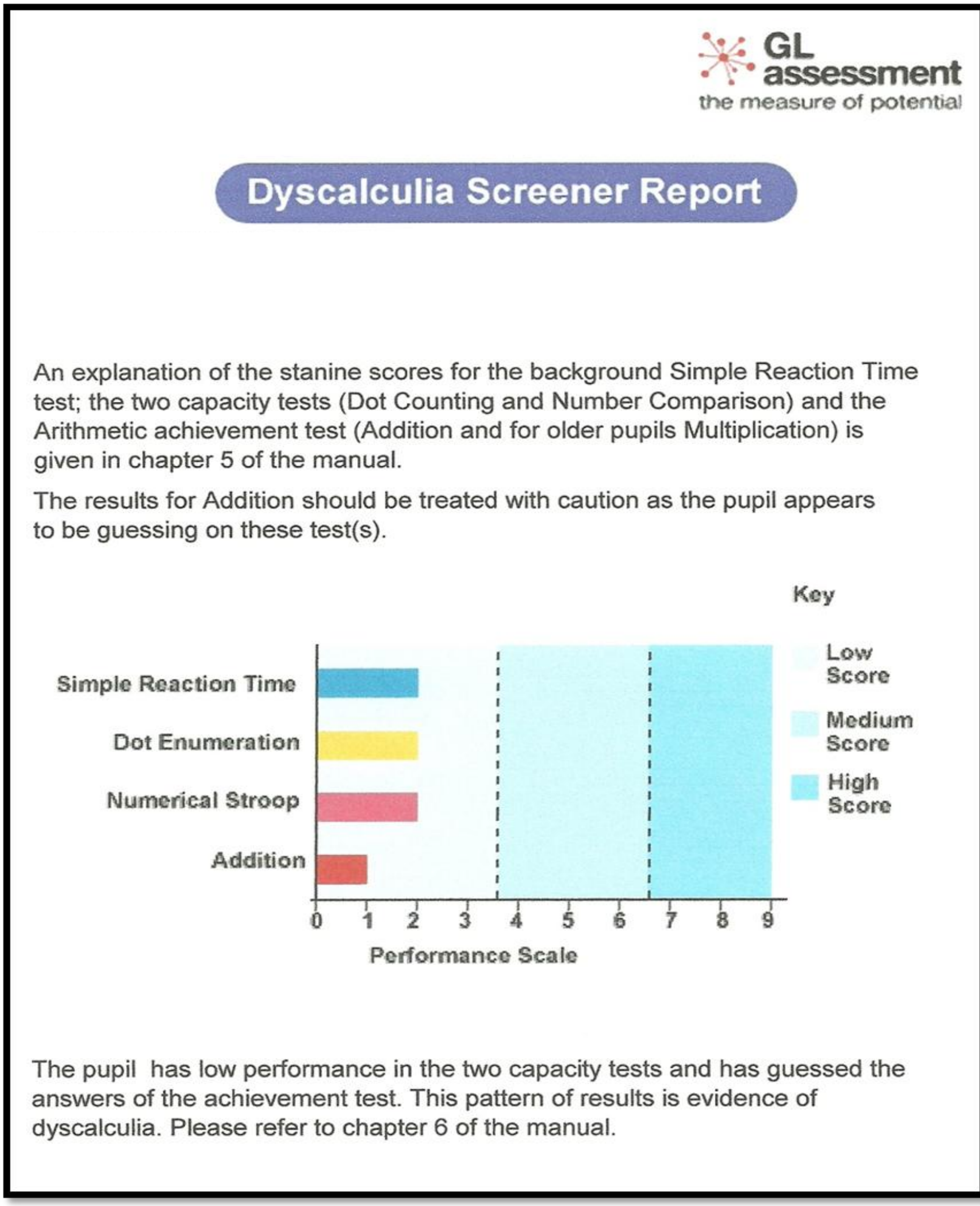
An explanation of the stanine scores for the background Simple Reaction Time test; the two capacity tests (Dot Counting and Number Comparison) and the Arithmetic achievement test (Addition and for older pupils Multiplication) is given in chapter 5 of the manual.



The pupil performs appropriately for their age-group in the capacity and achievement tests and is therefore unlikely to have dyscalculia.

Figure 4.4: Sample report of one of the other learners assessed

Due to the complexity of assessing dyscalculia, I could not find another pupil who had been assessed with a profile of dyscalculia and who was 10 to 11 years old. I phoned a number of educational psychologists and professionals but none referred me to any child assessed with dyscalculia. I strongly suspected that there are children who have dyscalculia, however, it may be that lack of knowledge of this difficulty and objective tools for its assessment are not allowing it to receive the importance it deserves. Since I wished to have a third participant, I asked my Inclusion Co-ordinator for any pupils experiencing great difficulties in mathematics. She mentioned a child in Grade 3, aged 7 and a half, who was encountering great difficulties with numeracy. With the parents' consent, I carried out the DS with the child who shall be referred to as Victoria. The DS assessed the child with a profile of dyscalculia. Figure 4.5 shows the child's report. Hence I decided that she could be the third participant for my project.


GL assessment
the measure of potential

Dyscalculia Screener Report

An explanation of the stanine scores for the background Simple Reaction Time test; the two capacity tests (Dot Counting and Number Comparison) and the Arithmetic achievement test (Addition and for older pupils Multiplication) is given in chapter 5 of the manual.

The results for Addition should be treated with caution as the pupil appears to be guessing on these test(s).

The pupil has low performance in the two capacity tests and has guessed the answers of the achievement test. This pattern of results is evidence of dyscalculia. Please refer to chapter 6 of the manual.

Figure 4.5: Victoria's report

After experiencing Charmaine's case and the fact that none of the other children (even though they were performing much below the average) were assessed with dyscalculia, I started to question how effective the DS was in identifying children with dyscalculia when it is used as an only form of assessment. This thought reflected that experienced by other researchers after they made use of the same tool to identify children with dyscalculia. As outlined in Section 2.5.3, Voutsina and Ismail (2007) and Messenger et al. (2007) have reservations about the DS's conclusions with regard to various aspects. Additionally, Gifford and Rockecliffe (2008) reveal that as a research team they "found difficulty in attempting to identify children for longitudinal case studies of 'pure dyscalculia'" (p. 26). In Charmaine's case I felt the need to use more than one tool of assessment as suggested by Gifford (2006) and this revealed that Charmaine had no clue how to add two numbers and was guessing rather than actually working out the sums as had in fact been reported by the first report produced by the DS.

Other questions came to mind. If the rest of the children (not assessed with dyscalculia) were performing so poorly in mathematics but did not have dyscalculia as the DS suggested, what therefore could be the underlying causes for this low attainment in mathematics? Could it be that they have not been taught in a way that fits their learning styles? Is there actually a distinction between mathematics learning difficulties and dyscalculia? The latter conclusion would oppose the fact that these two terms have been used interchangeably in various literature (Section 2.2) and would agree with emergent literature using the term 'dyscalculia' to refer to a *specific* difficulty with numeracy (Butterworth and Yeo, 2004; Chinn, 2004; Bird, 2009). However, could it be that children may have mathematics learning difficulties but not dyscalculia as the latter is more severe than the former and does that affect teaching strategies? I shall attempt to explain some of my personal reflections with regard to this matter.

From the experience gained through this research project, I tend to concur with what Gifford and Rockecliffe (2008) conclude; "It is problematic, if not impossible, to isolate the factors which contribute to severe mathematics difficulties" (p. 26). Shedding light on what is the cause of a mathematics difficulty will be very hard unless it becomes biologically certain that a specific part of the brain functions well or malfunctions according to whether there is a deficiency in mathematics or otherwise as research has started to exhibit (Section 2.3.1). Such conclusions would allow a brain scan to diagnose the presence of dyscalculia or otherwise and since one would be able to view dyscalculia through a positivist lens, the presence of dyscalculia would be diagnosed objectively. However, since so far dyscalculia is socially constructed, its presence or absence is still very subjective to the tools used for assessment and to the person/s performing the same test/s.

My working position is that no matter what the underlying causes of difficulties in mathematics may be, one may argue that individuals' difficulties in mathematics may vary in degree (from mild to severe). This is therefore why I propose that even if the cause of the difficulty is unknown (unless it is evident as in cases of mental disability), one may identify dyscalculia if the learner has severe difficulties with understanding the underlying concepts of numeracy. I will consider that individuals experiencing difficulties with age-appropriate mathematics including handling shapes, data and measure, however copes with the basic numerical concepts, may be identified as an individual with 'mathematics learning difficulties'. As a result, I find it helpful to distinguish between the terms 'mathematics learning difficulties' and 'dyscalculia' as shown in Table 4.1 displayed on the next page.

Mathematics Learning Difficulties

- Low achievement in mathematics related tasks (see Section 2.1 for an explanation of the differences between 'mathematics' and 'numeracy') including tasks related to the handling of shape and measure.
- Can be the result of other learning difficulties, such as: lack of reasoning skills or memory skills.
- Less severe than dyscalculia as basic numerical concepts would have been grasped.
- Can be related to external factors like inappropriate teaching methods and absenteeism from school.

Dyscalculia

- Severe difficulties with grasping basic numerical concepts like number quantification and therefore with numeracy (Butterworth & Yeo, 2004; Bird, 2009; Chinn, 2004; Chinn, 1995; Dowker, 2004 – Section 2.1).
- Not related to external factors as in 'mathematics learning difficulties' but could be directly related to a deficiency in the formation of the brain (Sousa, 2008; Lemer et al., 2003; Piazza et al., 2010; Isaacs et al., 2001 – Section 2.3.1).
- Difficulties related to numeracy can be *co-morbid* (Butterworth & Yeo, 2004; Shalev & Gross-Tsur, 2001; Siegel & Ryan, 1989 - Section 2.4) with other learning difficulties such as dyslexia, dyspraxia and ADHD however the former are not a result of the latter.

Table 4.1: Personal reflections of how the terms 'Mathematics learning difficulties' and 'Dyscalculia' may be used distinctively

Although I make a disctinction, I also believe that intervention strategies which are effective with children with 'dyscalculia' may be as effective with children with 'mathematics learning difficulties' and vice versa. This is found in the literature with regard to other specific learning difficulties such as the structured multisensory literary programmes (e.g. Moats and Farrell, 2005) backed up by Scientific Based Reading Research (SBRR).

In order to get to know the children better, I wanted to have a look at their psychological reports or any other relevant documents as all three had been assessed by a professional. None of the three reports revealed or mentioned dyscalculia. All the attention was placed on the children's literacy difficulties and with only limited importance placed on the difficulties the children were experiencing with numeracy. The subjectivity of actually assessing the learner with a profile of dyscalculia provoked contradictions between the results of the DS and the judgments made by the professionals concerned. The difficulties described in the documents read as 'mathematics difficulties', while I noted that the apparent severe difficulties could be labelled as 'dyscalculia'.

4.3 Profiles of the Subject-Participants

In this section I outline the learners' overall achievement in academic subjects and other areas of development. I also highlight the pupils' family background and parental opinion about their daughter's difficulties. I reveal the scores that each of the three children achieved in the standardised test administered prior to the commencement of the intervention programme and outline the areas identified as needing improvement through *Catch Up*'s formative assessment.

4.3.1 Martina

Martina was a 10-year-old girl in Grade 6. After I identified Martina as a possible participant, I interviewed her mother to understand better whether Martina was actually experiencing such great difficulties in numeracy and mathematics. Martina's mother explained:

> *"in mathematics not that much, she finds greater difficulties in English and reading, in mathematics she had great difficulties at the beginning to learn the tables...in fact now they are allowing her to take the multiplication grid in for exams".*

However, when I later asked her whether Martina studies for her mathematics exam alone, she said that not only does she sit down and study with her but she sends her to a private teacher because she said that otherwise *"she wouldn't cope on her own".* In addition, she revealed that Martina would need constant repetition of the topics being covered. In relation to this she said:

> *"What Martina would need is that everyday you provide her with a flash of every topic...because if you remind her of what she has to do by giving her an example, she then picks up and can work on her own."*

Therefore from the interview it was clear that Martina was a case in which dyslexia and dyscalculia were present together. It was interesting to note that during the interview, the mother mentioned more than once that both her brothers had similar difficulties. Alacaron et al. (1997) and Shalev and Gross-Tsur (2001) find that the siblings of children with dyscalculia also had similar difficulties. I must admit that at the beginning of the interview, when Martina's mother said that Martina did not have many difficulties in mathematics, I felt that the DS had misassessed the child. However, as the interview unfolded it seemed that the child's difficulty in literacy may be greater than that with numeracy, however, the latter was still existent and was being given less importance in comparison to the former. As a result, I decided to proceed and I started the intervention by using the standardised test. Martina's scores on the standardized test are shown in Table 4.2.

Actual age at date of assessment	10 years 7 months
Number age [5]	10 years 6 months
Quotient[6]	96
Percentile (%)[7]	40th

Table 4.2: Martina's scores on the standardised test

Although Martina did well in the test (it resulted that her number age was 10 years 6 months, therefore only one month less than her actual age), the quotient and percentile scored illustrated that there was still room for improvement. In fact the percentile and quotient showed that her mathematics was still below average. Figure 4.6, for example, shows how Martina was not

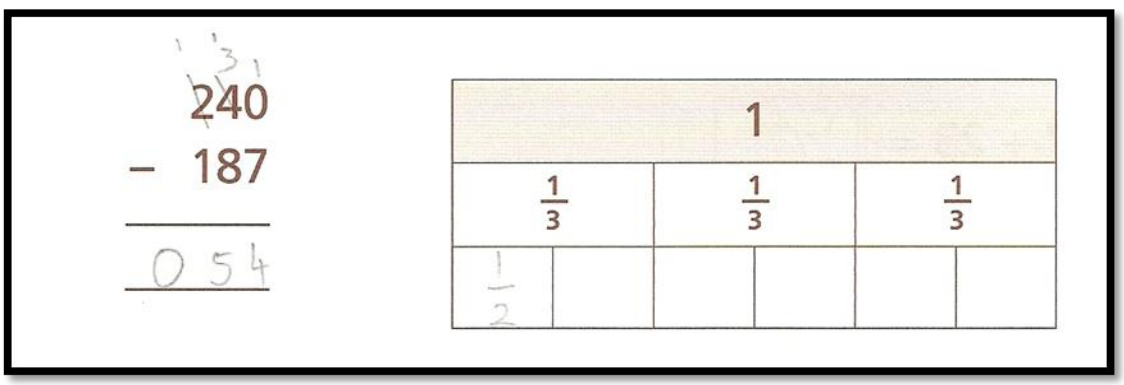


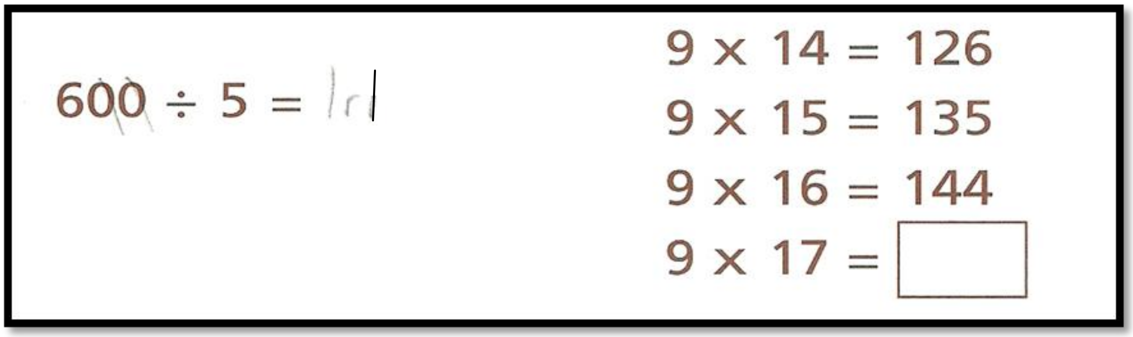
Figure 4.6: A task from the standardised test

able to work out the subtraction sum correctly and did not know how to identify the fractional parts to be marked as 1/6. Additionally, the division task shown in Figure 4.7 illustrates that Martina had no idea how to work out the operation.

[5] The number age is deduced by comparing the child's raw score in the test to her actual age through a given table in the manual of the standardised test.

[6] The quotient symbolises the child's ability in mathematics in a range between 72 (lowest) and 119 (highest). A quotient between 72 and 96 signifies that the child has 'special needs' in mathematics.

[7] The percentile (%) illustrates a score out of hundred where the child is at after comparing the raw score to the child's actual age. A percentile between the 30th and the 3rd shows that the child has 'special needs' in mathematics.


$600 \div 5 =$ lrl

$9 \times 14 = 126$

$9 \times 15 = 135$

$9 \times 16 = 144$

$9 \times 17 = \boxed{}$

Figure 4.7: A division and multiplication task found in the test

As a result, I decided to proceed with the *Catch Up Numeracy* formative assessment to see whether Martina really had weak areas in some of the basic components of numeracy. The assessments revealed loopholes in Martina's acquisition of the 10 basic numeracy skills and concepts. Table 4.3 represents the numeracy components which Martina found most difficulty with when being assessed, as well as the number range with which she could cope in those components.

Numeracy Component	Number Range Reached
Counting On	1-5
Counting Back	1-5
Word Problems	0-8
Translation: Number Words to Objects	1-5
Derived Facts: Identical	None
Derived Facts: Commutative	None
Derived Facts: N+	None
Derived Facts: N-	None
Remembered Facts	None

Table 4.3: The numerical components needing most development and the level reached so far (Martina)

Other components like ‘adding objects’ and ‘subtracting objects’ also needed development, however, she could cope with these components at least up to the number range from 0 to 10, so the components in Table 4.3 are the ones that had to be prioritised.

4.3.2 Charmaine

Charmaine was also 10-years-old and in Grade 6. Charmaine was experiencing very severe difficulties in numeracy which was why her previous mathematics teacher referred her to me. In addition, when I started teaching Charmaine mathematics myself, I too realised that her difficulties with numeracy were severe and that intervention was crucial. As explained in Section 4.2, the DS did not clearly report whether Charmaine had dyscalculia or otherwise, however, my professional judgment permitted me to decide that her great difficulties could not be other than somehow related to dyscalculia. In order to confirm to what extent Charmaine was experiencing difficulties in mathematics I interviewed her mother. When asked whether Charmaine had always experienced difficulties with numeracy/mathematics and at what age had she noticed this, she replied, *“I realised immediately that Charmaine had difficulties with mathematics and numeracy, because her sister had similar difficulties...so I took her to the same professionals that I had taken her sister to.”* This reply not only confirmed Charmaine’s difficulties in numeracy but also showed that Charmaine’s sister too had similar difficulties to hers. This again correlates to what research has shown so far as outlined in Sections 2.3.2 and 4.3.1. The interview with Charmaine’s mother revealed other important information. Charmaine’s mother informed me that Charmaine had very low self-esteem as she was constantly seeking her reassurance. With regard to Charmaine’s difficulties in other subjects she said, *“Charmaine copes with Maltese well, she needs a bit of help in English but does cope with the rest, her greatest difficulties are with mathematics.”* This continued to indicate that Charmaine’s difficulties were somehow related to dyscalculia. I asked Charmaine’s class teacher about Charmaine’s progress in other areas of development and verified her mother's comments. Charmaine had moderate dyslexia as reported in her psychological report and as I could identify from some of her work which her class teacher showed me. This again illustrates the co-morbidity of dyslexia and dyscalculia (Butterworth and Yeo, 2004). When Charmaine's mother was asked whether Charmaine finds difficulty with concepts like time she replied as follows:

> *"It is only now that she is learning how to read the clock...she keeps asking me what time it is and I have been showing her repeatedly how to read the clock...she is trying to read it herself now...she finds most difficulty with ten to and ten past etc...but she has learned how to read five to seven for example because that is the time the van picks her up in the morning."*

This concurs with the fact that children with dyscalculia find great difficulties with understanding concepts like time and money as highlighted by Bird (2009, Section 2.2) and that this will impinge on their lives.

When I carried out the standardised test with Charmaine, the results clearly indicated an enormous difficulty with numeracy. Her scores are illustrated in Table 4.4.

Actual age at date of assessment	10 years 3 months
Number age	8 years 0 months
Quotient	75
Percentile	5th

Table 4.4: Charmaine's scores on the standardised test

Charmaine performed at the 5th percentile, more than two years less than her chronological age. She was not yet conversant in symbols and language related to the four basic operations. This can be seen in Figures 4.8 and 4.9 which illustrate some of the work Charmaine did during the standardised test in which all instructions were read out to her.

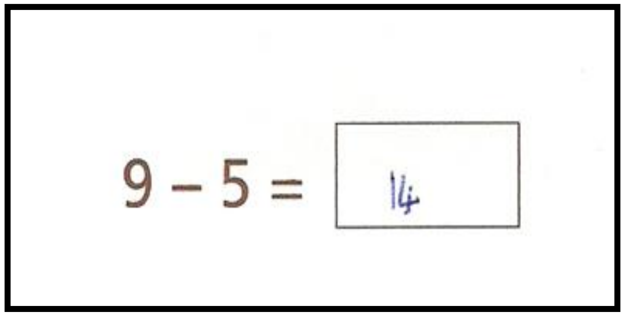


Figure 4.8: A task from the Basic Number Screening Test and Charmaine's answers

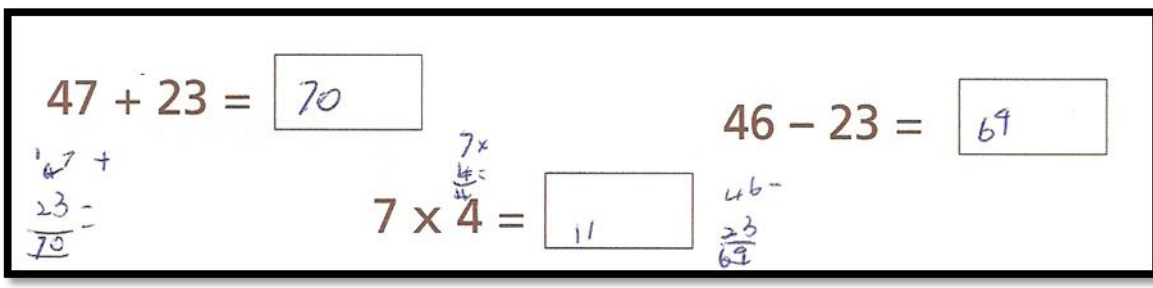


Figure 4.9: Charmaine's answers to an addition, a subtraction and a multiplication sum taken from the standardised test

These figures illustrate how she wasn't able to recogise the symbols of multiplication and subtraction and added instead. However, they did demonstrate that Charmaine could add. Her lack of symbol recognition was in itself evidence that the child was actually experiencing dyscalculia and that intervention was imperative. Carrying out *Catch Up*'s formative assessment with Charmaine continued to reveal the essential numeracy components which Charmaine had not yet grasped. Table 4.5 shows the numeracy components which Charmaine could not cope with in a number range between 0 and 10.

Numeracy Component	Number Range Reached
Counting Back	0 – 8
Counting Objects	0 – 8
Adding Objects	1 – 5
Adding Tens and Units	0 – 8
Subtracting Tens and Units	0 – 8
Ordinal Numbers	None
Word Problems	0 – 8
Translation: Objects to Numbers	None
Translation: Numbers to Objects	None
Translation: Number words to Objects	1 – 5
Translation: Number words to Numbers	None
Derived Facts: Identical	None
Derived Facts: Commutative	None
Derived Facts: N+	None
Derived Facts: N-	None
Estimation	1 – 5
Remembered Facts	None

Table 4.5: The numerical components needing most development and the level reached so far (Charmaine)

As can be seen, the weak components are numerous. These areas were then given priority in the intervention sessions.

4.3.3 Victoria

Victoria was 7-years-old and in Grade 3. She was an only child. Victoria was very bubbly and had mild difficulties with focusing her attention in a particular task. Her Inclusion Co-ordinator had told me that she was experiencing great difficulties with numeracy. This was confirmed by Victoria’s class teacher. The

DS also yielded a profile of dyscalculia. Victoria's mother noted, *"mathematics is the subject giving her most trouble."* She explained that she had been taking Victoria to Inspire (a foundation for children with physical, mental and learning disabilities) only for lessons with the programme 'Numicon' as Victoria needed to visualise in order to understand numerical concepts better: *"she has no idea of what the numerical concept of 10 is for example...she cannot understand that the number 10, for example, is made up of 10 units."* This corroborates with Chinn's (2004) definition of dyscalculia. Moreover, it confirms Bird's (2009, p.2) explanation that learners with dyscalculia "have no feel for numbers at all". When asked whether Victoria finds difficulties with the concepts of time and money, Victoria's mother stated,

> *"she confuses euro with dollars...because she hears dollars being used in cartoons, she says dollars...for example they are going to have an outing next week and she came to me and asked me for four dollars instead of four euro (the parent smiled, paused and continued); she also still has difficulties with time, she finds it difficult to read the clock."*

All the information provided from the interview confirmed that Victoria was truly a learner with dyscalculia needing an intervention programme to help her overcome some of her difficulties. I decided that she was a suitable third participant for this study. As with the other pupils, I administered the standardised test. The scores can be seen in Table 4.6.

Actual age at date of assessment	7 years 3 months
Number age	6 years 3 months
Quotient	87
Percentile	20th

Table 4.6: Victoria's scores on the standardised test.

Whereas the actual age of the child at the date of assessment was 7 years 2 months, her number age was below 7 years. Her raw score was 2, whilst to reach the number age of 7 years she had to score 5. I refer to this here because the standardised test is for children between 7 and 12 years of age and only gives number ages accordingly. Therefore, in Victoria's case I had to work out her number age using ratios. Such workings allowed me to infer that Victoria was probably performing as a 6-year-old. This is because every one score symbolises three months of age. Additionally, the percentile and quotient displayed that Victoria needed help as she was at the 20th percentile showing that her performance was below average. The quotient attained was that of 87 which places her with the children identified by the manual as having 'special needs' in mathematics. Victoria was not able to work out a simple subtraction sum. She added rather than subtracted, either because she did not recognise the symbol, or because she could not subtract (Figure 4.10).

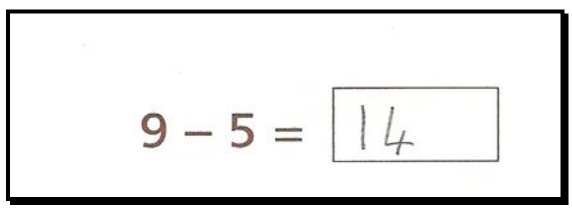


Figure 4.10: Part of Victoria's test showing an incorrect answer to a subtraction sum

Moreover, Victoria was unable to continue a given sequence of numbers possible because of a difficulty with sequencing (Figure 4.11).

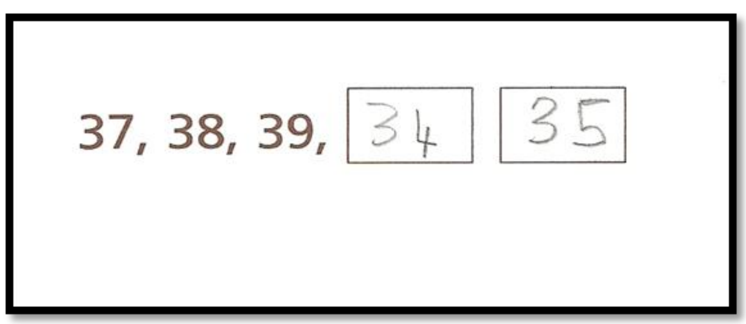


Figure 4.11: A task in which Victoria had to continue the sequence

The *Catch Up Numeracy* formative assessment gave me a clearer picture as to which areas of numeracy Victoria was finding most problematic. In Table 4.7 I represent the components of numeracy which I needed to prioritise in Victoria's case. I also exemplify which levels of number range the child had reached.

Numeracy Component	Number Range Reached
Counting Verbally	1 – 5
Counting On	1 – 5
Counting Back	None
Counting Objects: Order Irrelevance	None
Subtracting Objects	1 – 5
Adding Tens and Units	0 – 8
Subtracting Tens and Units	None
Ordinal Numbers	None
Word Problems	None
Translation: Objects to Numbers	None
Translation: Numbers to Objects	None
Translation: Number words to Objects	None
Translation: Number words to Numbers	None
Derived Facts: Identical	None
Derived Facts: Commutative	None
Derived Facts: N+	None
Derived Facts: N-	None
Estimation	1 – 5
Remembered Facts	None

Table 4.7: The numerical components needing most development and the level reached so far (Victoria)

4.4 The Intervention Sessions

After the preliminary interviews and assessments, my study continued by carrying out 20 intervention sessions with each of the three learners over a period of three months. The intervention sessions were an eye opener in two main ways. On the one hand, they allowed me to personally experience and observe traits which all the three children displayed throughout the sessions and which may therefore be traits of children with dyscalculia. On the other, they permitted me to determine which intervention strategies were most effective with these learners and therefore may also be beneficial for other learners with dyscalculia. Whilst at the end of this chapter I shall discuss the results of the final assessments and whether these illustrate any improvement on the learners' part, I shall now focus on all the key issues observed during the sessions. Although one must be very cautious in generalising due to the very small sample being dealt with in the research, I hope that such a discussion will reveal some interesting and important observations which may be beneficial to educators and other professionals encountering learners with dyscalculia as well as to the learners themselves.

4.4.1 Finger Counting as a Compensatory Strategy

Research shows that learners with dyscalculia have great difficulties with retrieving number facts (Chinn, 2004; Dowker 2004). Throughout the sessions, it was evident that the three participants of this study, even though of different ages, could not retrieve number facts including simple addition facts like bonds of 10. I constantly observed the children using their fingers to count. Finger counting was being used as a compensatory strategy for their inability to recall number facts. This observation is similar to that made by other researchers (Geary, 2004; Hopkins and Lawson, 2006; Jordan and Montani, 1997; Ostad and Sorensen, 2007). The process of actually learning to directly retrieve the answer to simple addition sums, is a multi-faceted developmental process (Hopkins and Lawson, 2006). As a result, before children are able to recall answers deliberately, they must "gain important conceptual knowledge of numbers and construct increasingly more efficient counting strategies" (Hopkins and Egeberg, 2009, p. 215). Children with dyscalculia tend not to develop this crucial knowledge of numbers and ability to count efficiently like the rest of their peers. Whereas research conducted by Torbeyns et al. (2004) shows that they do actually develop it at a later stage, other literature suggests that children with dyscalculia may in fact have a deficit in this area and may never be efficient at retrieving such facts (Jordan & Montani, 1997).

During the sessions held with Martina, who seemed to have less difficulties with numeracy when compared to the other two participants, I could constantly observe her using her fingers. Her fingers seemed to give her the confidence she needed to work out the tasks I gave her. On one occasion, I asked her not to use her fingers in order to work out some simple addition and subtraction sums and her reaction was clearly one of frustration. Martina was aware of her finger counting strategy to retrieve number facts. In fact, during the first session we had together I asked Martina how she would explain to her friend how to count from one number to another e.g. counting on from 7 to 10. She said, *"I would tell them to count them with their fingers."* However, I then asked her, *"what if they run out of fingers as they must count to a number bigger than 10?"* She got confused and finally replied, *"they could do it on a piece of paper."* I think that she gave the latter reply because that is what she does. When she needs to add 46 and 32 for example, she writes them in a vertical sum so that she can still use her fingers to add 2 and 6 and then the tens. Similarly Charmaine was also constantly observed using this finger counting strategy. Whenever I asked her to find the answer to a sum, she would take out her fingers, decide whether to add or remove fingers and then give me an answer.

In Victoria's case, it was evident that finger counting was crucial for her to work out a simple addition or subtraction task. In fact, when during one of the sessions we pretended to be at the supermarket and she needed to subtract 5 from 10, she not only used her fingers but removed five fingers by counting her fingers one by one rather than actually simply removing one whole hand. Although such compensatory strategies allow learners to get to the answer, they make individuals more prone to errors and highly slows the speed at which children carry out a mathematical task. Slow processing was one of the greatest issues with Victoria and the other two participants due to this reliance on their fingers. Bird (2009) underscores this characteristic in dyscalculic learners. As I felt that this difficulty with retrieving number facts should be targeted as soon as possible, especially with the older children, I immediately started working with Charmaine and Martina on the component of 'remembered facts' as per the *Catch Up Numeracy* programme. We played games together using simple subtraction and addition sums like snap, matching card games in which the child had to match the answer to the sum and other activities (See Appendices D2 and D3) through which the children would memorise these basic facts. Both Martina and Charmaine did actually memorise these basic number facts and were able to recall them when needed throughout the subsequent sessions. The children not only noticed that they could finally work out the sums mentally rather than rely on their fingers, but also commented about this new skill they had acquired. During the ninth session with Martina, she told me:

> *"the teacher at school tells us that in the exam if, for example, we have 5 plus 2 we must add them on our fingers...so that if, for example, we might be getting it wrong, we still get it correct."*

However, when I pointed out that if she knew the facts well it would be faster to work it out mentally, she said that she would still check it using her fingers to make sure. Smiling, she then added, *"but now I am much faster at working out sums mentally so I* [with emphasis] *can do them."* Similar behaviour was observed in Charmaine. Whereas in the first sessions she had no idea of how to add or subtract, she could now add and subtract simple sums (like 5 + 3 and 7 – 4) mentally. I noticed that this raised her self-esteem. When in session 10 we were doing an activity in which she had to throw two dice and add up the scores, she did this with no hesitation. I not only praised her but asked, *"Are you feeling* *you are faster now at adding?"* She said, *"Yes!"* Then I added, *"Do you feel more confident at working out addition sums?"* With no hesitation she said, *"Yes! A lot!"* Charmaine might have answered as expected in this circumstance, however, her increased self-esteem was observed on other occasions. During another session with Charmaine, the Assistant Head of School came into the room in which we were doing an activity. Charmaine was giving the answers to different sums which she had to work out mentally as fast as possible. Even though the Assistant Head was present, she still continued working out the sums correctly without using her fingers. Additionally, when during the 14th session, we were subtracting objects and I first asked her to predict the answer, her predictions were mostly correct and when asked how she worked them out she proudly said *"I worked them out mentally".*

As a result of the above observations, I concluded that through fun and multi-sensory activities, children with dyscalculia are taught basic number facts which they can retrieve when necessary. Such an acquisition would not only give the children further confidence at working out simple sums without relying on other compensatory strategies like finger counting but would lessen the amount of time spent on tasks thus minimising the difficulties concerned with slow processing, both with regard to simple sums and more complex sums like 435 + 324 in which simple addition occurs several times. My findings conform to what Torbehyns et al. (2004) suggest in their research, namely, that learners with dyscalculia will eventually grasp the knowledge needed for retrieving number facts if they are explicitly taught these same number facts and memorise them. As most dyscalculic learners have difficulties with memory, this may be one of the reasons why they would not have grasped such fundamental knowledge. Therefore direct and strategic intervention is crucial.

4.4.2 The Fundamental Role of Metacognition

Metacognition is instrumental in developing higher order thinking in children. It has also been described as crucial in the learning of mathematics (Borkowski, 1992; Carr & Biddlecomb, 1998; De Clercq et al., 2000; De Corte et al., 2000). Furthermore, metacognition is embraced by the Vygotskian school of thought. This indeed played a crucial role in the unfolding of the intervention sessions. As *Catch Up*'s numeracy programme suggests, the children were asked questions with regard to *prediction*, *process* and *reflection* when adequate. I could observe that the posing of such questions which enhanced and developed metacognitive reflective strategies including *prediction, revising, selecting, checking and evaluation* (Montague et al., 2000) always had a positive result. These questions would allow me to guide the children within their Zone of Proximal Development (ZPD) illustrating how language “becomes the teacher’s instrument for building models of the child’s or the student’s thinking” (Sierpinska, 1998, p.32). Questions posed made it possible for me to guide the child in a scaffolded manner from what the child knew to what she had the potential to know. One occasion in which metacognition was used fruitfully was the situation which occured with Victoria and is presented in Table 4.8.

Component	Counting Backwards
Number Range	0 – 10
Activity	**<u>Land on Ten</u>** The child is to step on a particular number as shown in figure 4.12 (she landed on 3). She then had to pick a card which would ask her to move back a number of spaces (e.g. count back 2). She had to count back two and land on the appropriate number.  Figure: 4.12: Victoria landing on the number 3 during this activity
Miscue	Victoria kept making the mistake of counting the number she was already on. For example if from 3 she had to move back 2 spaces, she would say the answer was 2 instead of 1.
The Metacognitive dialogue which took place	Myself: *You are on 3...actually move two steps backwards...what number did you land on?* Victoria: *1.* Myself: *So what mistake were you making?* Victoria: *Because I was counting the three...I have to start counting from the number before the three.* Myself: *Ok, let's try it with another number. Land on 8. Step back 4 spaces. What number do you think you will land on?* Victoria: *4*. Myself: *How did you work that one out?* Victoria: *I didn't start counting from 8...I started from number 7...I always have to start counting from the previous number.*

Table 4.8: A dialogue showing how metacognition can help guidance within ZPD

The ‘review and introduction’ phase of the session, in which metacognitive skills were enhanced by asking questions about previous sessions, allowed me to latch on to what had been covered and that which was to come. The children always responded very well to this phase of the session. Sometimes I was astonished with how they explained what we had done during the previous session. They would explain this very well using the mathematical language which I would have used during the previous session. For example, on one occasion I asked Victoria what we had done during the previous session. Confidently she replied, *“we were counting on from one number to another number”*. Such an answer suggests that not only did the ‘review and introduction’ phase of the session remind the child of what she had learned previously so that the actual session would be scaffolded on what is known, but it was also important in allowing me to assess whether the child had grasped the language introduced during the previous session and whether she would have any misconceptions about what was taught.

When the children were asked questions about prediction, they were always ready to engage in higher order thinking and provide an answer. Through reflective questions, the children were then asked to think about their prediction. This again facilitated the scaffolding process as many times the children would go back to their work and identify any miscues. The fact that they would have discovered their own miscue and solved it themselves would then allow them to remember that miscue in future sessions. For example, during a session with Victoria, I asked her to think about what mistake she was making during the previous session when she had to count back from a given number to zero. She specifically said, *“I kept forgetting to say the zero last time* [we met]*”.*

Another positive aspect of posing metacognitive reflective questions was that they provided an insight into the way each individual learner learnt. This is in line with the constructivist idea regarding the great importance of getting to know the child well. Patterson (2004a, 2004b) notes, “a constructivist approach assumes that before you start, and while you are teaching, you try to get to know your children both as persons and as learners" (cited in Bartolo et al., 2007, p.111). When I asked the children how they would explain a particular concept to a friend who did not know it, they normally replied suggesting the way in which they knew it or would like to learn it. When Charmaine and I were working on the 'remembered facts' component and were memorising simple addition and subtraction sums, I asked her how she would tell another child to learn them. She said *"I would tell her to study them and teach them to others."* I later got to know that Charmaine likes studying by pretending that she is teaching the concept to an imaginary class. Her mother said that she spends hours pretending to teach some dolls how to work out sums or other material. I kept this in mind during future sessions as at times I asked Charmaine to pretend I did not know the topic and that she was going to teach it to me. Such a strategy was useful as whilst she taught me, I could understand if she had any misconceptions and whether she truly had understood the concept. Similarly to Martina, as illustrated in the previous section, she suggested that her friend use her fingers to complete simple addition tasks because that is what she would do.

Metacognition can be an essential tool in allowing children with dyscalculia to be self-aware of their cognitive knowledge and take control over strategies which allow them to regulate and monitor their performance (Carlson & Bloom, 2005). Additionally, metacognition is fundamental in guiding these learners in their ZPD so that they are helped in moving from the actual stage of development to their potential developmental stage. Higher order questioning techniques may also provide insight to the different and unique ways in which these individuals learn so that their learning styles and patterns may be accommodated and used in a fruitful manner to help them overcome some of the barriers they are currently experiencing in their acquisition of numerical concepts and skills.

4.4.3 Affective Gains

The affective domain has a great impact on the learning process of dyscalculic learners. It is imperative, therefore, that any intervention strategies carried out with such learners not only raise their self-esteem and confidence to reduce anxiety but also provide enjoyment so that the children are instrinsically motivated to engage in mathematical tasks as motivation is a key aspect of the affective domain (Silver, 1985). In the *Catch Up* intervention programme, these two key matters are given great importance. The mathematics activities which are suggested for intervention are fun games which will allow the children to actually enjoy doing mathematics. Sternberg (1983) concludes “for student samples restricted in range with respect to ability, differences in motivation may account for large shares of the observed differences in performances” (p. 10). Therefore such fun activities, which provide intrinsic motivation, may be responsible for some of the achievements undertaken.

One of the activities which Victoria enjoyed best was the supermarket role-play which we carried out. She kept asking me to repeat the activity during subsequent sessions. With Charmaine and Martina, the activities they preferred were card games like snap or matching a sum to its answer against the clock. Even in this case, the children would keep asking me to replicate the activities. Since they enjoyed the activities, their attitude towards mathematics did change. They would express this themselves by passing comments like *‘this is a real lot of fun’* (Victoria), *‘can we do this again?’* (Martina), *‘Oh no! Is the session over already?’* (Charmaine). Moreover, during an informal conversation I had with Charmaine’s mother after conducting the sessions, she told me that before the sessions had been carried out, Charmaine would have dreaded having to engage in any mathematical tasks including any mathematics homework she was given. She revealed that now Charmaine was very enthusiastic about doing her mathematics homework and that she had really started to love the subject. Silver (1985) suggests that although motivation “is not a sufficient condition for adequate intellectual performance, it may be a necessary condition” (p. 254).

Apart from encouraging practitioners to constantly give positive feedback to learners, the Catch Up programme also recommends that in every session the educator and learner put down their comments about how the learner performed during the sessions. On several occasions, I would write encouraging comments and the children would draw something or use a rubber stamp to show that they did well. They probably felt more confident with drawing because all three girls, to some degree, had literacy difficulties. I now understand that asking the children to comment on their own progress was providing them with skills related to meta-affect. As highlighted by DeBellis & Goldin (2006), "*meta-affect* refers to affect about affect, affect about and within cognition about affect, and the individual's monitoring of affect through cognition" (p. 136). This means that the pupil is engaged in tasks in which s/he must reflect about his/her affective self subcategorised as *emotions*, *attitudes*, *beliefs* and *values*. Much research has hypothesised that meta-affect is the most important aspect of the affective domain (Gomez-Chacon, 2000; Goldin, 2000). During the sessions, I percieved that the learners loved to complete the 'comments' section. Victoria especially liked this section. Figures 4.13 and 4.14 illustrate how she completed this section on two separate occasions.

Figure 4.13: Commentary section taken from Victoria's 17th session

Figure 4.14: Commentary section taken from Victoria's 19th session

In these figures, I had put in the comments whilst Victoria had done the rubber stamps and drew around them to show how she felt with what she had learnt. Her drawings made her feel good about herself, and by the end of the sessions, Victoria's attitude towards mathematics had a positive shift allowing her to engage more confidently and enthusiastically in numerical tasks.

Even though the other two participants were older than Victoria, this age difference did not reduce their amount of enjoyment in completing this section. Figures 4.15 and 4.16 illustrate the commentary section taken from Charmaine's and Martina's work respectively.

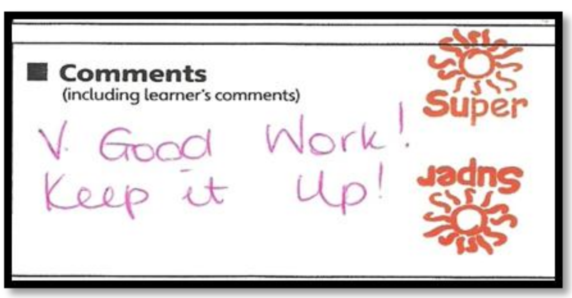


Figure 4.15: Charmaine's commentary section (session 10)

Figure 4.16: Martina's commentary section (session 6)

In Figure 4.15, it was Charmaine's idea to use rubber stamps whilst I wrote the comments. In Figure 4.16, I wrote the first comment whilst Martina wrote the statement *"I am Good!"* These comments reflected their positive attitude towards the intervention sessions. They also increased their self-esteem and helped them to reflect upon what they *could* do in mathematics rather than what they could not.

Another effective strategy which I feel also gave the children essential extra attention was the fact that the sessions were conducted on a one-on-one basis. Although some theories regarding inclusion suggest that children follow lessons in class all the time, from my experience I have come to believe that, if individual children with dyscalculia don't mind, they may be taken out of the mainstream class for short periods every week for direct instruction to help support this inclusion in class. This conforms with research on intervention for dyslexia (Taylor et al., 1999). Such one-on-one intervention allows strategies employed to be adapted to the individual needs of the learner and allow the educator to carry out particular tasks which s/he would not be able to do in class, such as activities like 'land on 10' and 'clapping to counting verbally'. Furthermore, individual sessions allow the learners to receive the educator's full attention which I believe also contributes to increasing the childrens' self-esteem. The subjects of this study responded well to the one-on-one nature of the sessions. During the second session, Victoria had commented that she preferred having her friend with her as she does when she goes for complementary sessions in literacy. However, after a while she got used to me and I could tell that she felt important when I went to her class to take her for the sessions. With regard to Charmaine and Martina, they were always very keen to have the one-on-one sessions provided. After such observations, I must highlight that "affect may [thus] empower or disempower students in relation to mathematics" (DeBellis & Goldin, 2006, p. 134), so it must be thought of as a fundamental tool in successful learning processing.

4.4.4 Focusing on Mathematics Vocabulary

The importance of acquiring a *mathematics register* (Halliday 1978) has been brought to the fore in Section 2.2.1. It has also been underscored that it is imperative that learners with dyscalculia are specifically taught mathematics language including terms and their meaning (e.g. ‘difference’ meaning subtraction) and symbols (e.g.+, - etc.). When I began conducting the sessions with the three participants, I immediately noticed that mathematics terminology and symbols had not been acquired by either Victoria or Charmaine. Victoria had great difficulties with identifying mathematical symbols. For example when given the sum ‘5 – 3’ she would get confused at what the ‘-’ (minus) symbol meant. As suggested by Henderson et al. (2003), I repeatedly worked on helping Victoria to enhance her repertoire of mathematical terms, symbols and meaning. This was done by using visual aids such as flashcards with the terms introduced and by providing ample opportunity for Victoria to actually use the terms introduced during the particular session. For example in session 4, we first played an activity in which she picked two numbers and I would tell her *‘count on ___’* (see Appendix E1). The term was put on yellow cards so that she could visualise it. A picture of these cards is shown in Figure 4.17.

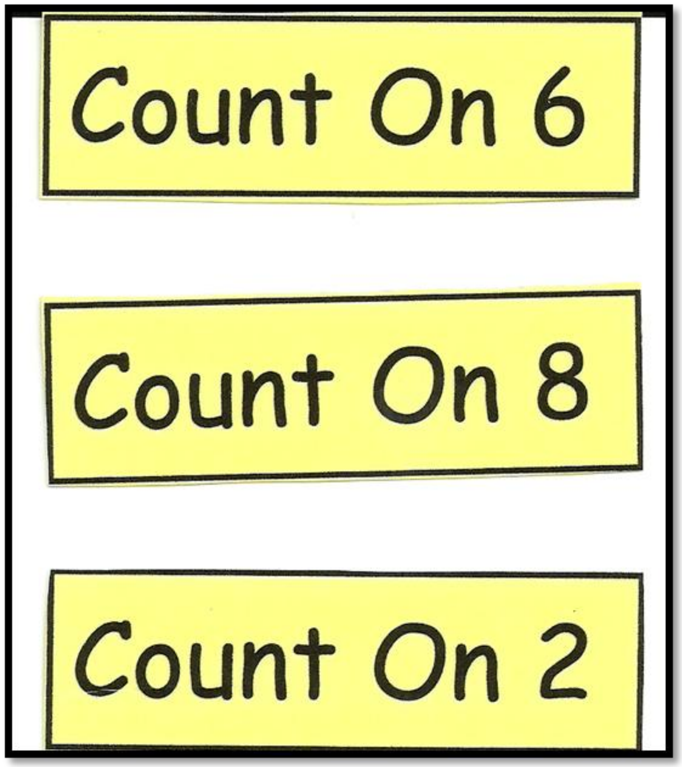


Figure 4.17: Sample flashcards used to place emphasis on mathematics vocabulary

I then allowed her to ask me to count on from one number to another using the correct terminology. These tools were indeed effective because during the subsequent session when I asked Victoria what we had done, she replied, *'we were counting on from one number to another number'* (session 5) showing that the emphasis on the terms 'counting on' had been useful.

Similar methods were also employed with the other participants and these seemed to be effective. In the third session with Martina I asked: *"what were we doing in the last session?"* At first she replied *"numbers",* however, she then added, "we were counting up." I tried to challenge her further by asking *"what can we say instead of counting up?"* She confidently replied, *"counting on",* showing that she could recall and use the mathematics vocabulary used in the previous session. Similarly, during the sessions about derived facts carried out with Martina, I constantly used the appropriate mathematical terms including ‘identical’ sums and ‘commutative’ sums (e.g. 4 + 3 = 7 so 3 + 4 = 7). She did use the expressions in subsequent sessions and found it much easier to explain why one number sentence would actually allow her to solve another. Charmaine also enhanced her bank of mathematical terms, symbols and meanings. She explained in correct mathematical language what we had done during previous sessions. For example in the fifth session, she said, *“we worked on addition and subtraction sums with numbers from 0 to 8.”* In the preliminary sessions, she was hesitant about stating what a symbol was called or meant. In the following sessions, she was more confident with using such terms allowing her to complete the tasks given with greater ease.

I concluded that learners experiencing dyscalculia should be exposed to the terms, symbols and meanings comprising such a register on a daily basis. This exposure should ideally be multi-faceted. The children may experience it visually through appropriate flashcards and charts which could be placed in a setting which the child uses frequently. They may experience it auditorily through the emphasis placed on such terms by the educator throughout the interaction process. This complies with Vygotsky’s idea that language is a fundamental tool needed for the learner to reach the Zone of Potential Development within the ZPD. Furthermore, as suggested by Townend and Turner (2000), from the above observations, I can conjecture that learners with dyscalculia would highly benefit from interactive situations in which they are given the opportunity to put into practice the mathematical register acquired on a frequent basis.

4.4.5 Number Inversion and Directional Confusion

During the intervention sessions, both number inversion and directional confusion were observed. As literature suggests (e.g. Bird, 2009; Ott, 1997, Chinn and Ashcroft, 2007), these two features are key characteristics of learners with dyscalculia. Although I found that number inversion was less common than directional confusion, the former was still observed with one of the participants. During one of the sessions, I asked Martina for her home telephone number. Surprisingly, she wrote it down but inverted the first two numbers. This illustrates that not only did Martina have difficulty with remembering or putting onto paper the correct sequence of her telephone number, but that such a deficit could impinge on her daily life. Similarly when writing the sequence of a given set of numbers, Victoria correctly said that '16' was next in the set of number, but then actually wrote '61'. Such inversions may therefore lead to errors which could be avoided if teaching is targeted towards eliminating them.

Directional confusion was observed during various sessions carried out with both Victoria and Charmaine. Victoria would confuse the direction in which she had to write specific numbers. For example, she would write 'Ɛ' instead of '3' or 'Γ' instead of '7'. She would only realise after I drew her attention to the matter through reflective questions. In Charmaine's case, I could still observe that sometimes she confused the numbers' direction, however, she would then amend her own error without me prodding her. As the sessions unfolded, I noticed that both Victoria and Charmaine confused the directionality of numbers less often. By the end of the sessions, Victoria would notice, without me prompting, that she had written the number incorrectly, whilst Charmaine rarely made such mistakes. This may have resulted from an increased exposure to the numbers through visual aids like the flashcards used. It could also be the outcome of such specific intervention in which the opportunity to write numbers was given during most sessions through the 'linked recording' section.

As a result of my observations, I felt that these two difficulties encountered by these learners should be directly intervened upon. It is crucial that if a dyscalculic learner is identified as having such difficulties, from an early age, they are repeatedly asked to write the numbers using a vast array of activities so that they memorise in a tactile and visual manner how the numbers should be written. It would help the children if they are exposed to visual resources which constantly illustrate the number sequence and direction in the classroom. Additionally, it would be beneficial if the children had the opportunity to memorise number directionality through multi-sensory activities, such as writing the numbers in the sand and therefore actually ‘feeling’ the way in which the number should be written.

4.4.6 Other Reflections and Observations

Through this research project I have learnt a fundamental lesson. Namely, that any intervention must begin by actually getting to know the learner. This should be done through observations and reflections so that the intervention programme created is tailor-made for the child’s needs. It is fundamental that educators observe and take into consideration children’s learning patterns (Johnston, 1998), cognitive and learning styles, as well as general attributional styles (Weiner, 1985) and mathematical thinking styles (Chinn, 2009) when developing activities and planning assessments. Additionally, as suggested by Johnston (1998), “to find the answer to who the learner is, you need to know what is going on in the learner’s mind when learning is occuring” (p.20). In fact, as illustrated in Appendix E, I did not use the same activities for all three children but adapted activities accordingly. From my daily contact with Martina during mathematics lessons, I had perceived that she was highly confluent and sequential, and therefore I adapted lessons for her needs. For example, I gave her the opportunity to create her own word problems as I knew she would enjoy this. Martina was also more of a ‘grasshopper’ type of learner in mathematics (Chinn, 2009). She looked at patterns, estimated, enjoyed investigations and preferred using the cuisenaire rods. The activities used were therefore adapted to suit this thinking and learning style. On the other hand, I observed that Charmaine was different. She was more sequential and in fact I only used the activity in which she had to create word problems once as I could see that she was not comfortable with the activity. Charmaine was an ‘inchworm’ type of learner and worked sequentially and followed procedures. I always made sure to explain the activity well in a sequential manner to ensure that she felt comfortable. Since I was not in contact with Victoria on a daily basis, it was more difficult for me to get to know the child. However, as the sessions with Victoria unfolded, I perceived that she was confluent and technical. Her confluence was taken into consideration through activities such as that of the role play at the supermarket. She could be labelled as a ‘grasshopper’ type of learner as she was an intuitive thinker and enjoyed investigations. Even though the children’s learning and thinking styles were accomodated as much as possible, through metacognition I guided the children to enhance their least dominant learning patterns (Johnston, 1998) and develop more flexible thinking styles (Chinn, 2009).

I could observe that the most effective way in which all three were succeeding was by providing them with multisensory activities that allowed ample space for the five senses to be involved in the learning process. The multisensory teaching of mathematics favours a constructivist approach to the learning of mathematics and thus allows pupils to be actively involved in their learning process. As put forward by Gurganus (2007), “Mathematics is inherently related to a philosophy promoting active, hands-on learning; student interaction; scaffolding of higher-order understanding; meaningful and authentic contexts; and developmental, spiraling, and interrelated content” (p. 51). From my observations, this seems to be especially true with children experiencing dyscalculia. As a result, the activities selected for the sessions were mostly multisensory. Some were oral: such as the role-play and picking two numbers to count on from one number to the other, some were visual: like the snap game and the ‘Make 5’ game, and some were kinaesthetic. The latter included the ‘Land on 8/10’ activity and the ‘hanger’ activity (Appendix E). In this approach, manipulative resources are essential as also noted by Lerner and Johns (2009), “manipulative materials enable students to see, to touch and to move objects” (p. 487). As a result, the children responded very well to the use of pasta shells, counters, dice, the cuisenaire rods, flashcards and other such multisensory teaching aids. Such tools also allow the educator to provide different modes of representing the same concept to ensure that the learning process is multi-faceted.

Another successful strategy was that of modelling (Bandura, 1977, 1986). Modelling allows the learners to actually visualise how the task is to be carried out so that s/he can later try it out themselves. During the ninth session with Charmaine, the following dialogue took place during the first part of the session:

> Myself: *"We are going to be couting objects during this session. I am going to show you a number of cubes and I want you to count them out aloud. Look at how I want you to do it...*[I took out five cubes]*...How many cubes are there? 1, 2, 3, 4, 5. There are five.* [I took out seven cubes]. *How many cubes are there?*
>
> Charmaine: *"1, 2, 3, 4, 5, 6, 7. There are 7."*

This is one example of how modelling was used effectively. Another sample is the dialogue carried out between myself and Martina during the fourth session whilst I introduced the 'Slippery Paper Clip' activity:

> Myself: *"This is a very naughty paper clip.* [I showed Martina a strip with the numbers from 0 to 10 and a paper clip on the number 7] *It doesn't like to stay in the same place for longer than a few seconds. It likes to move around. At the moment it's on the number 7, so I am going to count back to 0 from 7. 7, 6, 5, 4, 3, 2, 1, 0. Now you are going to do it yourself. It slipped to the number 5.* [I moved the paper clip to 5] *Count back to 0.*
>
> Martina*: "4, 3, 2, 1, 0."*
>
> Myself: *"Wait. Where did the paper clip slip to?"*
>
> Martina: *"5 so 5, 4, 3, 2, 1, 0".*

Modelling has been identified as a fundamental learning strategy to be implemented with children who have a nemesis in the learning of mathematics (Deshler, 2003; Mainzer et al., 2003). Other strategies identified include providing elaborate explanations, engaging in dialogues with the learners and asking questions about processing. All these strategies have been employed in the intervention programme carried out, therefore aiming at a more successful performance on the learners' part.

After providing a detailed account of the strategies which seemed to have been most successful with the three dyscalculic learners, I shall move on to quantitatively evaluate the effect, if any, the intervention programme had on the three participants. I shall also qualitatively interpret the results and conjecture possible strategies which may also be useful with other learners experiencing dyscalculia. However one must take into account that all learners have their own learning profile and that what works with one learner with dyscalculia may not do so with another.

4.5 Comparing Results: Past and Present

This section quantitatively compares the results the children scored in the standardised test before the intervention programme and their achievement in the same test after the programme was carried out. Further, it illustrates the performance of the children in some areas of the formative assessment prior to the intervention programme and how these changed when the assessment was administered after the completion of the 20 sessions as part of the *Catch Up Numeracy* programme.

In Tables 4.9, 4.10 and 4.11, I illustrate the scores obtained by each child in the standardised test before the start of the programme and their scores after the intenvention strategies used. Additionally, I display the scores obtained in particular components during the *Catch Up* formative assessment at the beginning of the programme and the same scores at the end.

MARTINA			
Standardised Test			
Pre-Test		**Post-Test**	
Number age	10 years 6 months	Number age	10 years 6 months (+/- 0)
Quotient	96	Quotient	96
Percentile	40th	Percentile	40th

Catch Up Formative Assessment		
Numeracy Component	**Pre-Assessment Level**	**Post-Assessment Level**
Counting On	1 – 5	0 – 20
Counting Back	1 – 5	0 – 10
Word Problems	0 - 8	0 – 15
Translation: number words to objects	1 – 5	0 – 18
Remembered Facts	1 – 5	0 – 15
Derived Facts: Identical	None	0 – 20
Derived Facts: Commutative	None	0 – 20
Derived Facts: N+	None	0 – 20

Table 4.9: Martina's pre-test and post-test results

VICTORIA			
Standardised Test			
Pre-Test		**Post-Test**	
Number age	6 years 3 months	Number age	6 years 9 months (+ 6 months)
Quotient	87	Quotient	96
Percentile	20th	Percentile	40th

Catch Up Formative Assessment		
Numeracy Component	**Pre-Assessment Level**	**Post-Assessment Level**
Counting Verbally	1- 5	0 – 20
Counting On	1 – 5	0 – 15
Counting Back	None	1 – 5
Counting Objects	0 – 10	0 – 18
Order Irrelevance	None	0 – 20
Subtracting Objects	1 – 5	0 – 20
Adding Tens and Units	0 – 8	0 – 15
Subtracting Tens and Units	None	0 – 15

Table 4.10: Victoria's pre-test and post-test results

<table>
<tr><th colspan="12"><u>CHARMAINE</u></th></tr>
<tr><td colspan="12"><u>Standardised Test</u></td></tr>
<tr><td colspan="6">Pre-Test</td><td colspan="6">Post-Test</td></tr>
<tr><td colspan="3">Number age</td><td colspan="3">8 years 0 months</td><td colspan="3">Number age</td><td colspan="3">9 years 6 months
(+ 18 months)</td></tr>
<tr><td colspan="3">Quotient</td><td colspan="3">75</td><td colspan="3">Quotient</td><td colspan="3">87</td></tr>
<tr><td colspan="3">Percentile</td><td colspan="3">5th</td><td colspan="3">Percentile</td><td colspan="3">20th</td></tr>
<tr><td colspan="12"></td></tr>
<tr><td colspan="12"><u>Catch Up Formative Assessment</u></td></tr>
<tr><td colspan="4">Numeracy Component</td><td colspan="4">Pre-Assessment Level</td><td colspan="4">Post-Assessment Level</td></tr>
<tr><td colspan="4">Counting Back</td><td colspan="4">0 – 8</td><td colspan="4">0 – 18</td></tr>
<tr><td colspan="4">Counting Objects</td><td colspan="4">0 – 8</td><td colspan="4">0 – 20</td></tr>
<tr><td colspan="4">Adding Objects</td><td colspan="4">1 – 5</td><td colspan="4">0 – 20</td></tr>
<tr><td colspan="4">Adding tens and units</td><td colspan="4">0 – 8</td><td colspan="4">0 – 10</td></tr>
<tr><td colspan="4">Subtracting tens and units</td><td colspan="4">0 – 8</td><td colspan="4">0 – 10</td></tr>
<tr><td colspan="4">Ordinal Number</td><td colspan="4">None[8]</td><td colspan="4">1 – 5</td></tr>
<tr><td colspan="4">Word Problems</td><td colspan="4">0 – 8</td><td colspan="4">0 – 10</td></tr>
<tr><td colspan="4">Remembered Facts</td><td colspan="4">None</td><td colspan="4">0 – 8</td></tr>
</table>

Table 4.11: Charmaine's pre-test and post-test results

Through these scores it is evident that Charmaine made the greatest improvement with an overwhelming number age difference. Whereas in the original test Charmaine's number age was identified as being that of an 8-year-old, the latter test showed that she had acquired the skills which a child aged 9 years 6 months would have. This signifies that in only three months, Charmaine managed to make an improvement which usually takes place in 1 year and 6 months. This result demonstrates that with appropriate intervention strategies

[8] None means that the child did not manage to get any correct answers in that component.

learners with dyscalculia can make enormous advances. Moreover, it is clear that Charmaine managed to progress in all of *Catch Up*'s numeracy components. In the 'counting verbally' component, the improvement was great. Since the assessment of this component is oral, I have no written work as evidence. In the pre-assessment Charmaine could not recall any number facts of addition or subtraction. In Figure 4.18 one can see Charmaine's ability to add and subtract within the number range of 0 to 10.

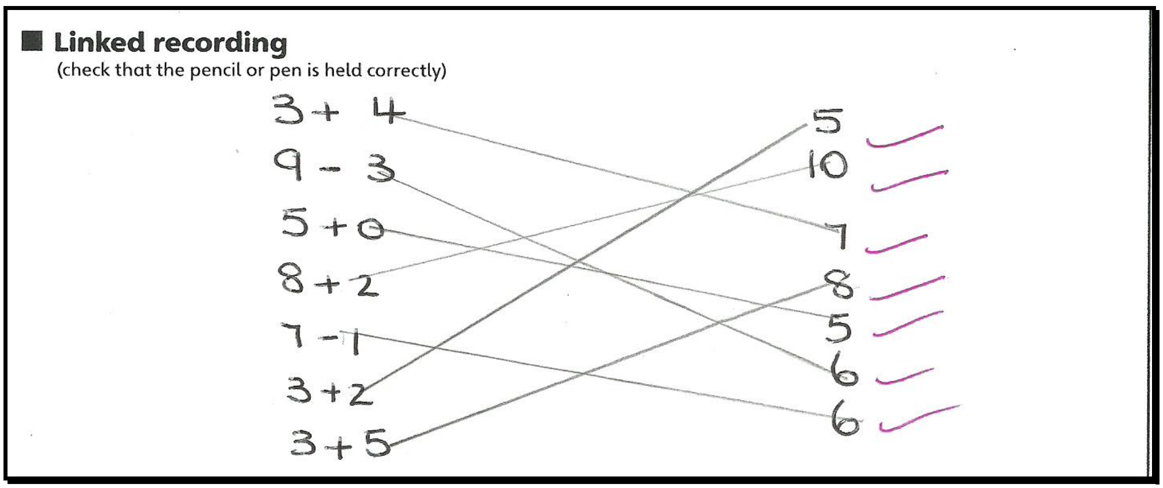


Figure 4.18: Charmaine's linked recording section (session 4)

Even if in the post-assessment she did not manage to achieve at least until the number range 0 to 10, the linked recording section illustrated that she could work out such sums (Figure 4.18). Charmaine also made marked improvement in the numeracy component of 'ordinal numbers'. Again even though she scored a range from 1 – 5 in the post-test, during the linked recording (see Figure 4.19) she managed to complete the ordinal numbers correctly within the range from 0 to 8 alone.

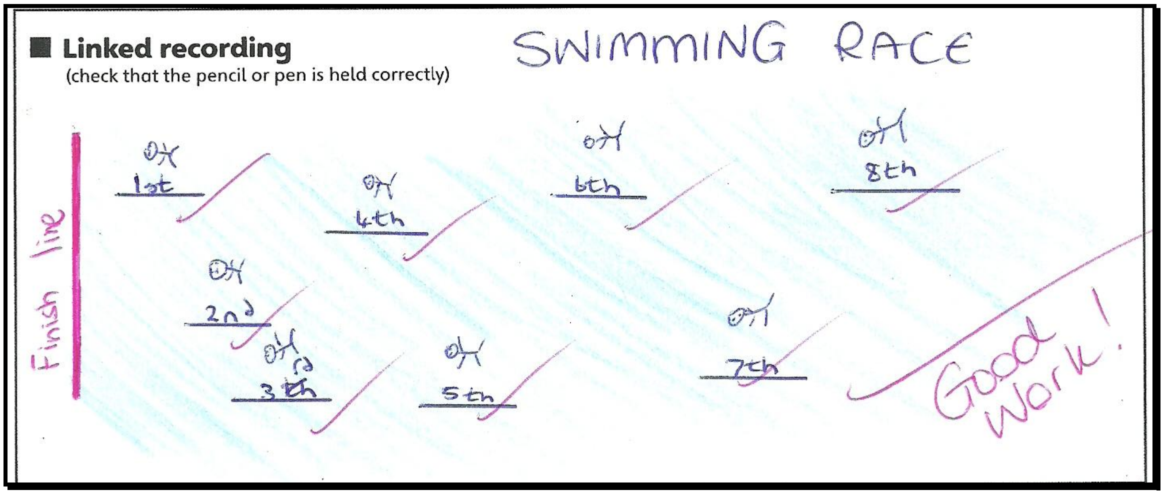


Figure 4.19: Charmaine's linked recording section (Session 20)

Such discrepancies between Charmaine's achievement could be either attributed to the fact that she was anxious during assessment or that she might have forgotten what she learnt in the particular session which took place much earlier. Charmaine might have also been still within the scaffolding stage in reaching her full potential development. With regard to the 'adding objects' component, again great development can be perceived. Figure 4.20 illustrates how Charmaine performed in the linked recording section during the last session targeting this component (session 11).

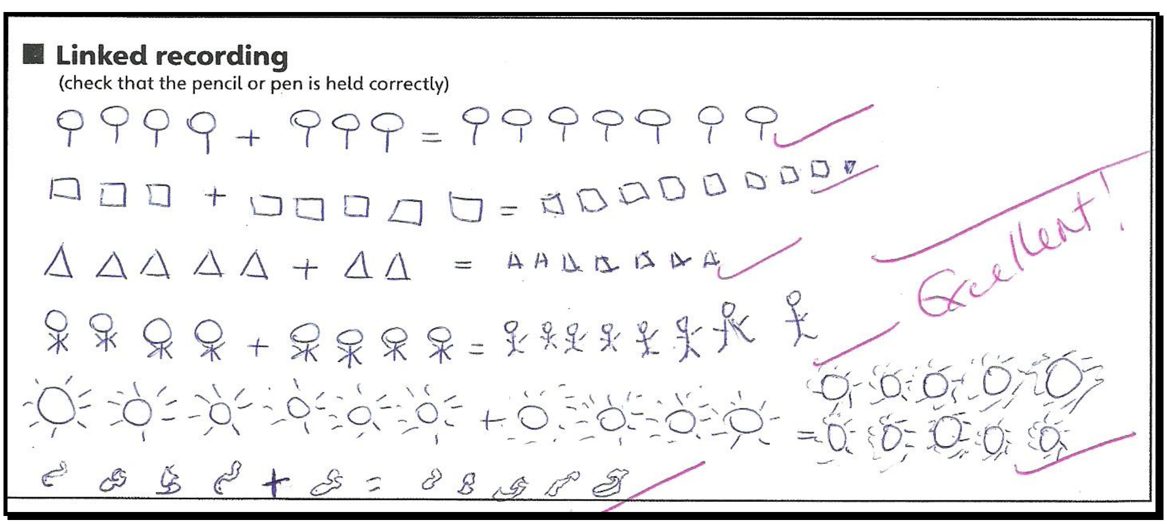


Figure 4.20: Charmaine's linked recording section (session 11)

Charmaine managed to count objects up to 20 in the post-assessment which was carried out orally.

In Victoria's case, there also seemed to be improvement. Victoria's number age was 6 years 3 months prior to the programme. After the programme, Victoria performed at a number age of 6 years, 9 months. Victoria had gained 6 months of standard learning of mathematics in only three months. A month of standard learning of mathematics involves 20 hours of learning. During the months of intervention the children had 22 hours of learning mathematics. This suggests that the extra 5 hours of specific intervention sessions (20, 15-minute sessions) plus the 50 hours of standard learning allowed her to gain six months in less than three months. Since Victoria attended Numicon sessions on a weekly basis, this may also have impinged on her achievement. Having said so, this result is, however, still evidence that suitable intervention can allow dyscalculic learners to succeed.

Victoria's pre-test in the sub-components of 'counting verbally' and 'counting on' showed that she could only do these within the range of 1 to 5. In the post-test, Victoria managed to widen this range a lot. Figure 4.21 demonstrates how Victoria managed to complete a sequence by counting on from one number to another within the number range 0 – 8.

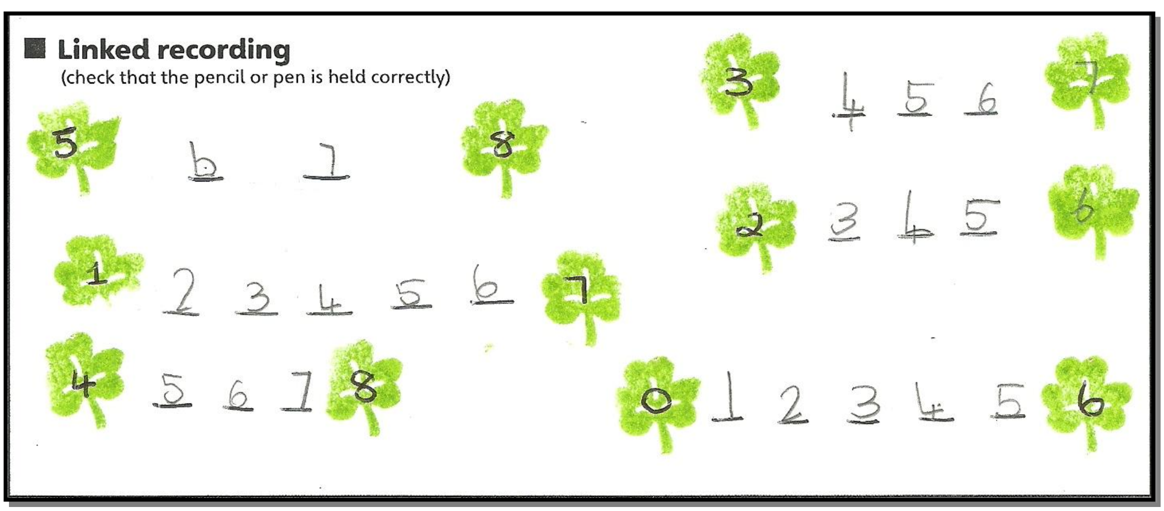


Figure 4.21: Victoria's linked recording section (session 4)

During the post-test, which was done orally, she managed to count on from 0 to 20 and from one number to another within the range from 0 to 15. This shows that Victoria had truly acquired the basic numeracy facts worked upon. Furthermore, in the pre-assessment Victoria did not manage to achieve any of the subtraction sums with tens and units successfully. This component improved as well. In Figure 4.22, one can see how Victoria managed to subtract tens and units within the number range of 0 to 10 successfully, illustrating her progress further.

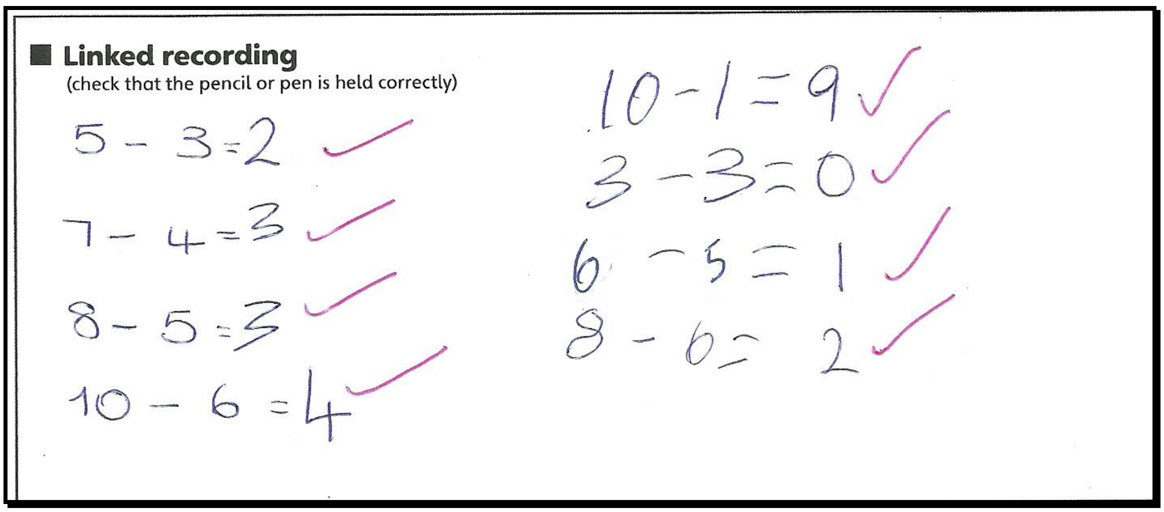


Figure 4.22: Victoria's linked recording section (session 19)

Martina's case was a bit different. Martina's number age did not change. This could be attributed to a number of reasons. One of my main concerns was that the post-test may not have given a true picture of the child's achievement. Martina appeared to feel that she did not have to put so much effort into completing the second test. She seemed over-confident when doing the test and, in fact, got some of the answers that were correct in the first test incorrect in the second. Figure 4.23 exhibits the same sum and how the child answered it in the pre-test and the post-test.

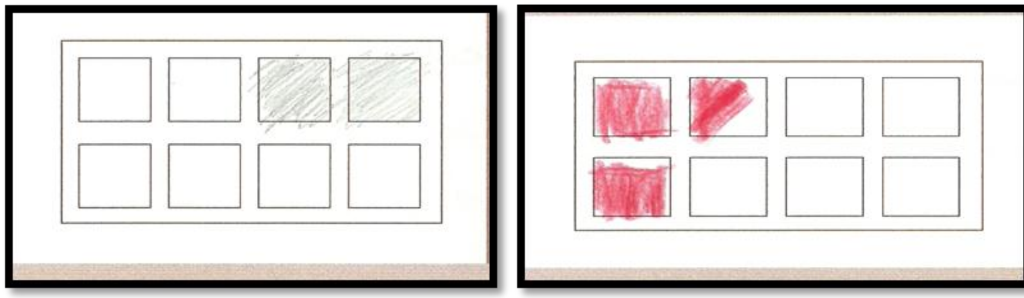


Figure 4.23: Pre-test (left) and post-test (right) answers to shading in a quarter of the boxes

However, even though the test did not prove that Martina had made any improvement, I felt that she did improve in terms of confidence with doing mental mathematics without using her fingers and found more enjoyment in engaging in mathematical tasks. Additionally, the results she obtained in the *Catch Up* formative assessment (Table 4.9) illustrate that whereas during the pre-test she did not achieve high levels in particular numeracy components, during the post-assessment she showed a marked improvement. An example of good progress is evident between the result obtained in the pre- and post- assessments with regard to the numeracy component of 'counting back'. As shown in Figure 4.24, during the sessions Martina learnt to count back from 0 to 10 confidently.

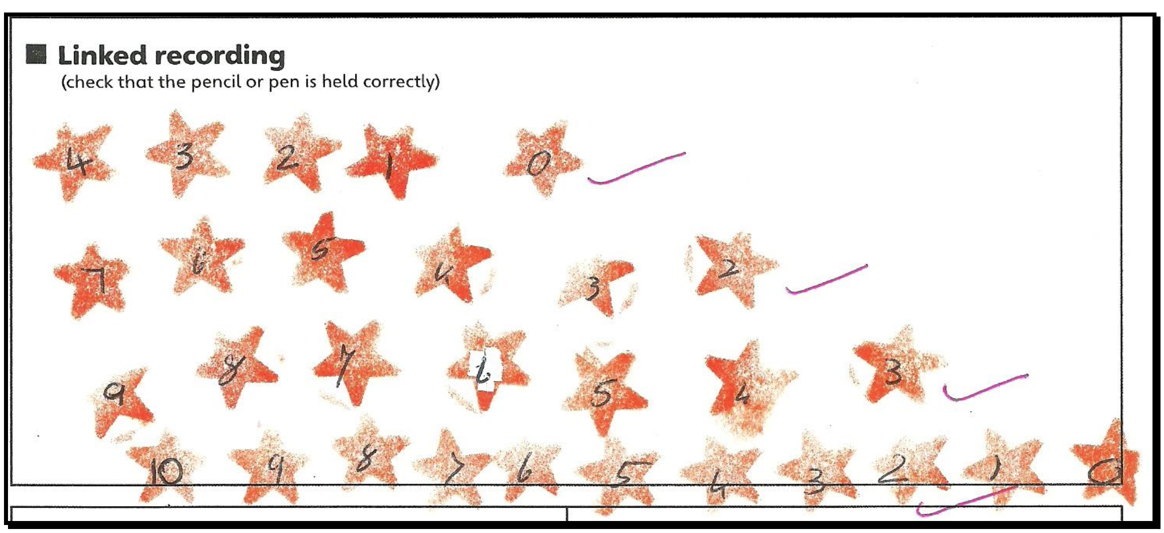


Figure 4.24: Martina's linked recording section (session 4)

In the oral assessment carried out after the intervention, Martina showed that she could now count on from 0 to 10 confidently. Another area in which improvement was evident was that of word problems. Throughout the sessions Martina not only enjoyed inventing her own word problems but also liked solving them. Figure 4.25 illustrates two problems which Martina made up and which she then solved.

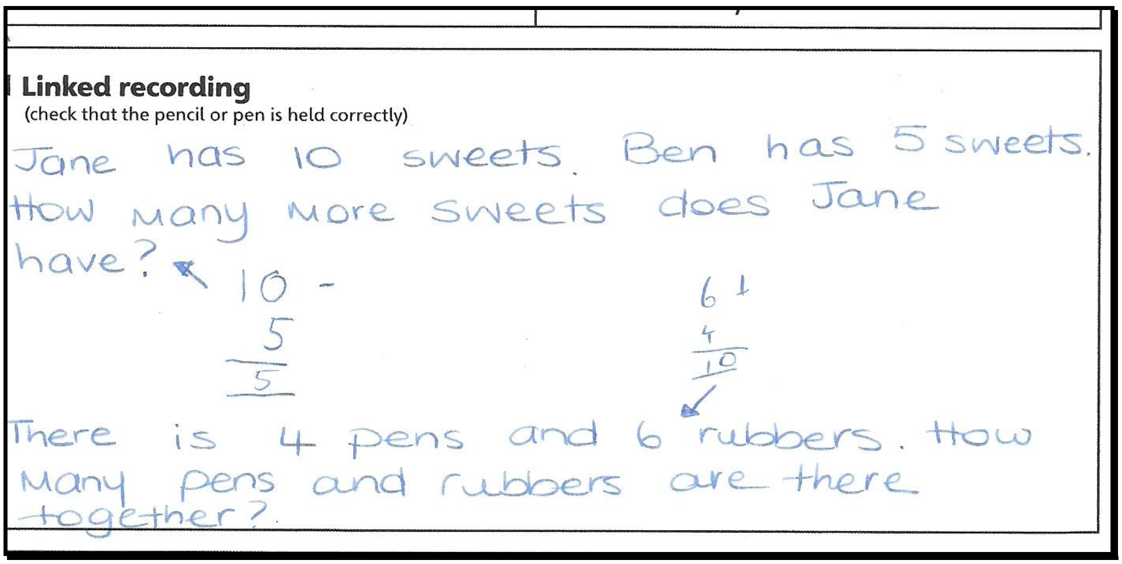

Linked recording
(check that the pencil or pen is held correctly)
Jane has 10 sweets. Ben has 5 sweets. How many more sweets does Jane have?
10 -
5
5
6 +
4
10
There is 4 pens and 6 rubbers. How many pens and rubbers are there together?

Figure 4.25: Martina's linked recording section (session 10)

Martina's improvement was also evident in the 'derived facts' component. It was impressive how in the post-test she was able to show such development. Whereas in the pre-test Martina had not managed to complete any tasks in relation to the 'derived facts' component, Figure 4.26 demonstrates that Martina could find another three facts deriving from the number sentence given.

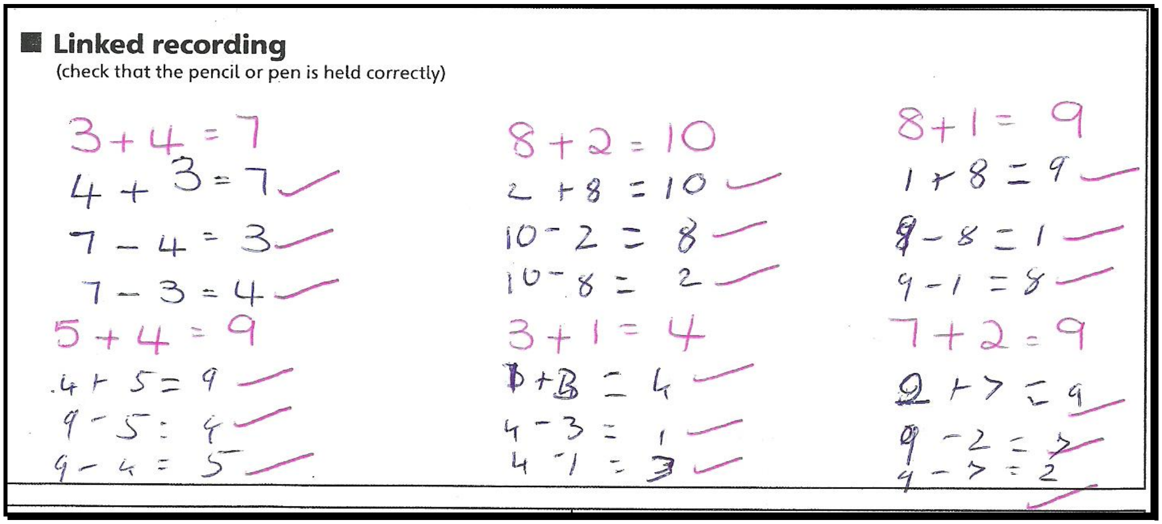


Figure 4.26: Martina's linked recording session (session 19)

A general observation seems to conclude that the intervention programme was highly effective in helping all three participants to achieve higher levels of attainment in the skills necessary for the indicated numeracy components. Moreover, although the programme only targeted a number range between 0 and 10, in many components all learners managed to achieve a level of 0 – 20. This indicates that these learners with dyscalculia had lacunae in the acquisition of basic number concepts and skills and that when such gaps are developed, as was the case with the intervention programme, they form a bridge to allow further learning. This may also be the case with other learners with dyscalculia. Additionally, it was evident that the children were now applying the skills learnt to a wider number range. This was another positive outcome of the intervention programme because as outlined by Lerner and Johns (2009), "students [with difficulties in mathematics] must learn to generalise a skill to many situations" (p. 501). Such an application would indeed permit dyscalculic learners to make greater progress in a shorter period of time.

In the final chapter I shall summarise the results achieved through this research project as well as point out crucial recommendations which should be taken into consideration in the creation and implementation of any intervention programme with children experiencing dyscalculia. Furthermore, I shall acknowledge the limitations of my research endeavour and provide suggestions for much needed further research in this field.

Chapter 5

Conclusion

5.1 Summary of Results

This research has given rise to important observations crucial in the development of any intervention programme to target the difficulties encountered by dyscalculic learners. The positive outcomes of the *Catch Up Numeracy* intervention programme have been twofold. On one hand, children have indeed acquired fundamental skills and concepts in numeracy which they had not yet developed. On the other, their attitude towards engaging in mathematical tasks has successfully been changed from a negative one to one which is more serene. These results corroborate other research both using the *Catch Up Numeracy* prorgamme (Evans 2007, 2008), as well as another programme which focuses on akin numerical and conceptual knowledge as the ones selected by *Catch Up* (Kaufmann et al., 2003). As accentuated by the latter researchers, “according to teachers and parents, all children in the experimental group showed an obvious learning transfer, both with respect to achievement levels and with respect to their attitude toward mathematics” (p. 569). The results obtained in this study with three learners agree with those gained by Evans (2007, 2008) and Kaufmann et al. (2003). These seem to evidence that with an appropriate intervention programme, learners with dyscalculia can make substantial improvement and can therefore be guided to reach their full potential.

The most significant improvement in this research was obtained by Charmaine. In a span of three months she improved 18 months. Additionally, the other learners also made marked progress in different aspects. This makes me question the local education system with regard to the lack of intervention provided to children with dyscalculia or difficulties in mathematics. The intervention programme carried out with the three girls helped them to cope better with the learning of mathematics. It is therefore vital that a systematic approach to providing intervention for children with dyscalculia is put into place and set up as soon as possible because early intervention is vital for these children (Hanley, 2005; Bryant, 2005; Sarama & Clements, 2004). Unfortunately, learners with dyscalculia are not being given the importance they deserve and the necessary tools to overcome their barriers to learning mathematics, to succeed in the subject as well as to grasp the necessary tools which are essential for everyday living.

5.2 Recommendations for Teaching

Since the subject-participants responded constructively to the sessions developed in accordance to *Catch Up*'s intervention programme, I recommend that any programme developed to provide the direct instruction of mathematics to learners with dyscalculia contains the following:

- It must contain a thorough pre-assessment which will allow the educator to get to know the child's strengths and weaknesses in various components of numeracy. Such an assessment must be the foundation on which any intervention is based.

- Any intervention must be specific. It must target, in a scaffolded manner, one weakness at a time.

- The strategies adopted during sessions must be multisensory allowing the child to progress within their ZPD. They must also guide the child through the diverse modes of representation.

- Tactics selected are to be set up in accordance with the learner's unique individuality.

- It is imperative that learners with dyscalculia are actually provided with the basic skills which they would not have as yet acquired so as to be able to fill any lacunae which are not allowing them to make further progress.

- It is also focal that such learners are engaged in metacognitive processes in order to develop their higher order thinking and be steered towards reflecting about their learning process. Various opportunities for review and repetition should also be provided.

- Intervention programmes should ensure that essential mathematical language is intentionally tapped into and that instruction provided allows ample chance for learners to make use of such language.

Another aspect which should be considered in the development of an intervention programme should be the affective domain. Children need to receive constant positive feedback and must be encouraged at all times. Such encouragement would allow the children to overcome the frustration and apathy they would have developed due to previous failures. Furthermore, it would help them develop a better view of themselves and of the subject of mathematics. Throughout the programme the children are also to be engaged in activities of meta-affect.

5.3 Limitations and Suggestions for Further Research

The fact that the intervention programme was carried out with only three learners can be viewed as a limitation in terms of generalizability. However, the qualitative, in-depth nature of this research has allowed me to conduct observations and reflections which I would not have made in a quantitative form of study. Additionally, the issue that the children were all females could also be seen as another limitating factor. Another variable which might have obscured whether the children's achievement was solely due to the intervention programme per se was that the learners were being exposed to everyday schooling and that therefore this latter factor may also have contributed to the children's achievements. Moreover, Martina attended private tuition and Victoria went to Numicon lessons at Inspire. The fact that I relied on my observations to determine the dominant learning patterns of the children rather than carry out the Learning Combination Inventory may also be considered as a limitating factor. Lastly, I acknowledge that had a greater number of sessions been carried out with the learners, a clearer picture of the success achieved by the intervention programme could have been established.

In view of the above, I feel that further research is necessary. When compared to the amount of available research about other learning disabilities such as dyslexia, studies about dyscalculia are more limited. Consequently, more research may be carried out with regard to the explicit nature of dyscalculia and how this differs from the nature of other difficulties experienced in the learning of mathematics. Studies may also seek to define dyscalculia more clearly so that appropriate assessment methods may be developed based on this definition. Additionally, due to a prevalence of 3.6 - 6.5% of any population found to be experiencing severe difficulties with mathematics (Lewis et al., 1994), more research about effective intervention programmes could be invested in. Such research could be longitudinal, providing a clear picture of the children's attainment throughout a longer period of time. Future research may also increase the awareness of the stakeholders of education, including the senior management team (SMT) of schools, teachers and parents. Lastly, all this research could demonstrate the importance of helping learners with dyscalculia overcome some of their difficulties in learning mathematics because the numerical and conceptual knowledge of mathematics is crucial to one's daily living and future career expectations (Bynner and Parsons, 1997; Poustie, 2000; Butterworth and Yeo, 2004).

5.4 A Concluding Note

This research endeavour has allowed me to grow personally and professionally. It has been an enriching experience that has indeed impinged on my pedagogical perspectives. Attending the National Conference in Dyscalculia was in itself a great reward. Furthermore, being trained to conduct an intervention programme for children with difficulties in mathematics, which is currently being used beyond local borders, was an experience that has certainly marked my professional development. Most importantly, this professional endeavour has given me the opportunity to develop first-hand experience of working with children who are experiencing dyscalculia and to work with intervention strategies which could permit me to carry out my job more professionally and to cater for all the learners who are entrusted to my care. I hope that this study not only adds on to the limited body of research currently available about dyscalculia but that it sheds light upon crucial characteristics which should be taken into consideration when selecting an appropriate intervention programme for children with dyscalculia. Ultimately, I wish this study to be an eye opener to those in authority who I believe should invest in carrying out more detailed studies about the manifestations and the identification of dyscalculia as a recognised condition, so that children with dyscalculia can finally receive the much needed and deserved guidance to be able to succeed in mathematics.

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Appendix A

Appendix A1: Checklist presented by Chinn (2007, p. 6)

1 = never anxious **2** = sometimes anxious **3** = often anxious
4 = always anxious

1 Working out the tip for the waiter in a restaurant. ____
2 Working out the prices of things when you are abroad. ____
3 Checking the cost of your shopping. ____
4 Working out 20% off in a sale. ____
5 Checking your change when shopping. ____
6 Working out the cost of a holiday. ____
7 Adding the four prices … £5.99 + £10.99 + £19.99 + £3.95 on a mail order form. ____
8 Reading a train timetable. ____
9 Working out your weekly budget. ____
10 Checking which mobile phone deal is the best value. ____
11 Converting your weight in stones to kilograms. ____
12 Having to recall a maths fact quickly (such as 6 × 9). ____
13 Understanding the odds for a bet on the Grand National. ____
14 Writing a cheque. ____
15 Checking the VAT amount on a Builder's bill/invoice. ____
16 Working out your pay rise when you are told it will be 3.25%. ____
17 Checking your credit card bill. ____
18 Working out how much weedkiller you need to use in a 5 litre sprayer. ____
19 Changing the quantities in a recipe for 4 when cooking for 6 people. ____
20 Remembering your maths lessons at school. ____

Add up your total score (OK, I know that is doing some maths!)

Look at page 7 to learn more about your score TOTAL ______

Appendix A2: Checklist produced by Henderson et al. (2003, p. 84)

Identification Checklist

NAME: ____________________ DOB: ______________ DATE: ____________________

Personal Issues

Has very high levels of fear and anxiety when it comes to Maths	
Lacks confidence- even when they produce the correct answer	
Worries about working more slowly and inaccurately	
Will often adopt avoidance strategies	
Often develops 'learned helplessness' strategies	
Often presents messy work	
Gets mixed up with left and right	
Dislikes whole group interactive sessions	
Has difficulties with everyday skills requiring Maths, e.g. Money, time, planning	

Numbers and the Number System

Has difficulty linking mathematical words to numerals	
Has difficulty transferring from the concrete to abstract thinking	
Has difficulty understanding mathematical concepts	
Has difficulty copying numbers correctly	
Has difficulty with place value	
Reverses or inverts numbers	
Finds remembering Maths rules and formulae difficult	
Finds sequencing the order and the value of numbers difficult	
Can have difficulty up and down the number line	
Is inconsistent from day to day in what they know and can do	
May have difficulties reading the analogue clock, and understanding and relating to the passage of time	

Calculations

Has difficulty aligning numbers in the correct columns	
Is confused about which basic symbols to use	
Is not confident and avoids estimating and checking answers	
Has difficulty learning times tables and often are never able to achieve automatic recall of table facts	
Has difficulty dealing with money and time	
Has difficulty using a calculator	

Appendix B

Appendix B: Information Letter and Consent Form for Parents

Ms. Esmeralda Zerafa

School's Address

29th September, 2011

E-mail address: esmeralda.zerafa@gmail.com

Dear Parent/s and/or Guardian/s,

I am currently reading for a Master Degree in Education at the University of Malta and specialising in Responding to Student Diversity. As part of this course I will be conducting a study regarding Dyscalculia. This project will deal with identifying this specific difficulty in mathematics. The assessment will be a computer-based mathematics test, called the Dyscalculia Screener. This will be conducted during school hours. Afterwards, I would also like to conduct a programme to reinforce the basic concepts and skills, with the children found to have this particular difficulty. Therefore once the assessment takes place, I will inform you of the results. I will also indicate whether your daughter should follow the programme which I shall be offering (free of charge) in order to revise and reinforce her mathematics.

Kindly note that all assessments will be carried out individually by myself and <u>all</u> information will be kept in strict confidentiality and will only be viewed by myself in order to establish an appropriate programme should the need arise.

Please fill in the form below stating whether you would like your child to participate in this study and, should there be the need, for your child to participate in a programme to reinforce basic mathematic concepts and skills. I thank you in advance for your support. For any queries you might have, please do not hesitate to contact me through a note, an e-mail or a phone call at school.

Yours truly,

Ms Esmeralda Zerafa B.Ed. (Hons.)
Grade 6 Maths Teacher

Ms. Esmeralda Zerafa

Indirizz tal-iskola

29 ta' Settembru, 2011

Indirizz elettroniku: esmeralda.zerafa@gmail.com

Għeżież ġenituri/gwardjani,

Jien qiegħda nagħmel Master Degree fl-Edukazzjoni li jispeċċjalizza fil-mod ta' kif l-għalliema għandha twieġeb għad-diversità fil-klassi. Parti minn dan il-kors tinvolvi l-istudju tas-suġġett tad-'Dyscalculia'. Id-'Dyscalculia' hija diffikultà fil-matematika. L-istudju se jgħinni biex possibilment nidentifika din id-diffikultà f'numru ta' tfal. L-assessjar sabiex din l-identifikazzjoni ssir jinkludi prova fuq il-kompjuter li tissejjaħ 'Dyscalculia Screener'. Dan l-assessjar isir fil-ħinijiet tal-iskola. Wara dan il-pass jien nixtieq nagħmel numru ta' lezzjonijiet mat-tfal sabiex intejjeb il-ħiliet tat-tfal fil-kunċetti bażiċi tal-matematika. Għaldaqstant, wara l-assessjar jien se ninfurmakom dwar ir-riżultat ta' wliedkom u ngħidilkom jekk it-tifla tagħkom għandhiex tieħu sehem fil-lezzjonijiet li nkun se noffri (mingħajr ebda ħlas).

Nixtieq nenfasizza li l-assessjar isir minni biss b'mod individwali u l-informazzjoni kollha li tinġabar se tinżamm b'mod kunfidenzjali u se tintuża minni biss sabiex noħloq programm ta' lezzjonijiet f'każ ta' bżonn,

Jekk jogħġobkom qed nitlobkom timlew il-formola li tinsab hawn taħt fejn tgħidu jekk tixtiqux li t-tifla tagħkom tieħu sehem f'dan l-istudju, kif ukoll fin-numru ta' lezzjonijiet wara l-assessjar jekk insib li għandha bżonn isaħħaħ ċertu ħiliet bażiċi fil-matematika. Nirringrazzjakom bil-quddiem tal-għajnuna tagħkom. Jekk ikollkom xi mistoqsijiet jekk jogħġobkom ikuntatjawni permezz ta' nota li tibgħatu mat-tifla tagħkom, e-mail jew telefonata l-iskola.

Dejjem tagħkom,

Ms. Esmeralda Zerafa B.Ed. (Hons.)
L-Għalliema tal-Matematika tas-sitt sena

Consent Form for Parents/Guardians

Name of the person doing the research: Ms. Esmeralda Zerafa

Address: **School's Address**

Contact No.: **School's Telephone Number**

The purpose of the study is to target any difficulties in mathematics that children may encounter.

I shall be collecting my information by:
a. asking your child to work out some tasks in mathematics on the computer and;
b. asking your child to participate in a number of enjoyable activities I am going to organise to help her understand better the topics she finds difficulties with (if there would be the need).

I shall be using the information to create suitable activities which will allow your daughter to understand mathematical topics better and I will be writing the results in my masters dissertation.

I **guarantee** that:
(i) Your child's real name will not be used in the study.
(ii) Only the supervisor and examiners will be able to see the information I have gathered.
(iii) Your child will remain free to stop taking part in the study at any time and for whatever reason. In the case your child decides to stop taking part, all the information gathered will be destroyed.
(iv) I will not try to deceive your child in any way whilst collecting the information.
(v) I will let you know what I have discovered through my research in writing or orally.

I agree to the conditions.
Name of Pupil: ________________________ Class: _______________
Name of Parent/s or Guardians: ____________________________________
Signature/s: ____________________ Date: __________

I agree to the conditions.
Researcher: ________________________ Date: __________

<u>Formula għall-Kunsens tal-Ġenituri/Gwardjani</u>

Isem min se jagħmel l-istudju: Ms. Esmeralda Zerafa

Indirizz: **Indirizz tal-iskola**

Contact No.: **Numru tat-telefon tal-iskola**

L-istudju se jsir sabiex niskopri d-diffikultajiet li l-istudenti qegħdin isibu fil-matematika u niprova ngħinhom jegħlbuhom.

Jien se niġbor l-informazzjoni billi:

a. nitlob lit-tifla taħdem xi eżerċizzji tal-matematika fuq il-kompjuter u
b. nitlobha tieħu sehem f'numru ta' attivitajiet li se norganizza sabiex ngħinha telgħeb diffikultajiet f'topiks partikolari (jekk dan ikun meħtieġ).

L-informazzjoni miġbura se tintuża biex noħloq attivitajiet addattati li jgħinu lit-tifla tifhem aktar it-topiks partikolari. L-informazzjoni se tintuża ukoll għat-teżi li għandi nikteb bħala parti mill-*masters.*

Garanzija:
Jien se nimxi ma' dawn ir-regolamenti:
(i) M'iniex se nuża l-isem veru tat-tifla fl-istudju.
(ii) Is-superviżur u l-eżaminaturi biss se jkunu jistgħu jaraw l-informazzjoni miġbura.
(vi) It-tifla fil-libertà li tieqaf mir-riċerka x'ħin trid u għal kull raġuni. F'każ li tieqaf, kull oġġett rekordjat u informazzjoni miġbura tinqered mill-ewwel.
(vii) Bl-ebda mod it-tifla m'hi ser tiġi mqarraq fil-proċess tal-ġbir ta' informazzjoni.
(viii) Se tkun taf il-konkluzzjoni tal-istudju bil-kliem jew bil-kitba.

Naqbel ma' dawn il-kundizzjonijiet imsemmija fuq.
Isem l-istudent: ________________________ Klassi:_______________
Isem il-ġenitur/i/gwardjan/i: ___________________________________
Firma tal-ġenitur/i/gwardjan/i: ____________________Data: __________

Naqbel ma' dawn il-kundizzjonijiet imsemmija fuq.
Firma tar-Riċerkatur: _________________________ Data: __________

Appendix C

Appendix C: Information Letter and Consent Form for Children

<u>Consent Form</u>

Dear Pupil,

I shall be conducting a study about particular difficulties which children may experience in mathematics. I would like you to be one of the participants of this study. First I will ask you to complete a number of mathematical tasks in the form of activities on the computer. Then, if I find that you are having particular difficulties with specific tasks, I shall be conducting a number of fun sessions which will help you to understand better those topics through games and other activities.

If you would like to participate in this study please sign below.

Thank you for your help,

Ms Esmeralda Zerafa
Grade 6 Maths teacher

Formola għall-Kunsens

Għażiża Studenta,

Jien se nagħmel riċerka dwar diffikultajiet partikolari li tfal jistgħu jkollhom fil-matematika. Nixtieq li int tkun waħda mill-parteċipanti ta' dan l-istudju. L-ewwel se nitolbok tagħmel numru ta' eżerċizzji tal-matematika fuq il-kompjuter. Dawn se jkunu qishom logħob. Imbagħad jekk minn dawn l-eżerċizzji nara li għandek bżonn għajnuna partikolari f'xi topiks bażiċi, jien se nagħmel xi lezzjonijiet mimlija logħob sabiex ngħinek tifhem aktar dawk it-topiks li int ma tantx tkun fhimt.

Jekk tixtieq taċċetta l-istedina tiegħi biex tieħu sehem f'dan l-istudju jekk jogħġbok iffirma hawn taħt.

Grazzi tal-għajnuna tiegħek,

Ms Esmeralda Zerafa
L-Għalliema tal-matematika tas-sitt sena

<u>Consent Form for Participating Children</u>

Name of the person doing the research: Ms. Esmeralda Zerafa

Address: **School's Address**

Contact No.: **School's Telephone Number**

The purpose of the study is to target any difficulties in mathematics that children may encounter.

I shall be collecting my information by:
a. asking you to work out some tasks in mathematics on the computer and;
b. asking you to participate in a number of enjoyable activities I am going to organise to help you understand better the topics you find difficulties with (if there would be the need).

I shall be using the information to create suitable activities which will allow you to understand mathematical topics better and I will be writing the results in my masters dissertation.

I **guarantee** that:
(i) Your real name will not be used in the study.
(ii) Only the supervisor and examiners will be able to see the information I have gathered.
(iii) You will remain free to stop taking part in the study at any time and for whatever reason. In the case you decide to stop taking part, all the information gathered will be destroyed.
(ix) I will not try to deceive you in any way whilst collecting the information.
(x) I will let you know what I have discovered through my research in writing or orally.

I agree to the conditions.
Name of Pupil: ______________________
Signature: ___________________ Date: _________

I agree to the conditions.
Researcher: _______________________ Date: _________

Formula għall-Kunsens tat-Tfal

Isem min se jagħmel l-istudju: Ms. Esmeralda Zerafa

Indirizz: **Indirizz tal-iskola**

Contact No.: **Numru tal-iskola**

L-istudju se jsir sabiex niskopri d-diffikultajiet li l-istudenti qegħdin isibu fil-matematika u niprova ngħinhom jegħlbuhom.

Jien se niġbor l-informazzjoni billi:

a. nitolbok taħdem xi eżerċizzji tal-matematika fuq il-kompjuter u
b. nitolbok tieħu sehem f'numru ta' attivitajiet li se norganizza sabiex ngħinek telgħeb diffikultajiet f'topiks partikolari (jekk dan ikun meħtieġ).

L-informazzjoni miġbura se tintuża biex noħloq attivitajiet addattati li jgħinuk ukoll tifhem aktar it-topiks partikolari. L-informazzjoni se tintuża ukoll għat-teżi li għandi nikteb bħala parti mill-*masters.*

Garanzija:
Jien se nimxi ma' dawn ir-regolamenti:
(i) M'iniex se nuża l-isem veru tiegħek fl-istudju.
(ii) Is-superviżur u l-eżaminaturi biss se jkunu jistgħu jaraw l-informazzjoni miġbura.
(xi) Inti fil-libertà li tieqaf mir-riċerka x'ħin trid u għal kull raġuni. F'każ li tieqaf, kull oġġett rekordjat u informazzjoni miġbura tinqered mill-ewwel.
(xii) Bl-ebda mod m'int ser tiġi mqarraq fil-proċess tal-ġbir ta' informazzjoni.
(xiii) Se tkun taf il-konkluzzjoni tal-istudju bil-kliem jew bil-kitba.

Naqbel ma' dawn il-kundizzjonijiet imsemmija fuq.
Isem l-istudent: ______________________
Firma: ___________________ Data: _________

Naqbel ma' dawn il-kundizzjonijiet imsemmija fuq.
Firma tar-Riċerkatur: _______________________ Data: _________

Appendix D

Appendix D: Questions used for Semi-Structured Interviews with Parents

Questions for Parent/s

- Has your child always had difficulties with mathematics?
- Does she find particular difficulties in other subjects?
- How does she feel during exams/tests especially when preparing for a maths exam/test?
- Which mathematical topics does she feel most comfortable with?
- Does she find difficulties with mathematical concepts such as money and time?
- Does your child do her Maths homework alone at home?
- If not, what do you observe her doing whilst completing given tasks?
- Do you think that your child needs to be given extra help in particular Maths topics? If yes, which are these topics?

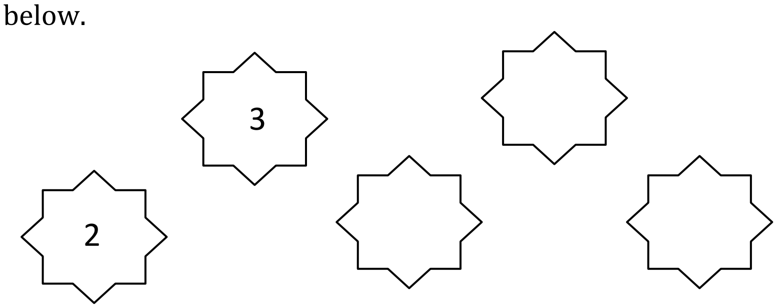
Mistoqsijiet għall-Ġenitur/i

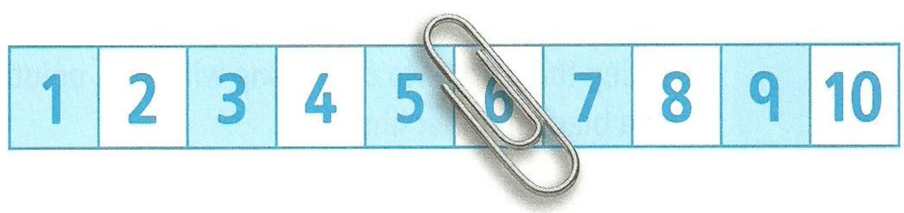
- It-tifla tiegħek/tagħkom minn dejjem kienet issibu diffiċli s-suġġett tal-matematika?
- Għandha diffikultajiet f'suġġetti oħra tal-iskola?
- Kif tħossha waqt eżami/test speċjalment qabel meta tibda tipprepara għall-eżami jew test tal-matematika?
- Liema topiks tal-matematika tħossha l-aktar komda fihom?
- Għanda xi diffikultajiet partikolari, per eżempju fit-topiks tal-flus u l-ħin?
- It-tifla waħedha tagħmlu x-xogħol tad-dar?
- Jekk le, x'tosservaha tagħmel waqt li tkun qiegħda tagħmel dan ix-xogħol magħha?
- Taħseb li t-tifla għandha bżonn aktar għajnuna f-topiks partikolari tal-matematika? Jekk iva, liema huma dawn it-topiks?

Appendix E

Appendix E1: Lesson Notes for the Sessions Held with Victoria

The activities adapted or taken from resources provided by Catch Up or other sources have been acknowledged. The rest of the activities are my own work.

Session No.	1
Component and Number Range Covered	Counting Verbally: Counting Verbally 0 – 8
Review & Introduction	Introduce the component and the related Maths vocabulary including *count*, *count on*, *count upwards* and *number line* using flashcards.
Numeracy Activity	Model counting from 0 to 8 out loud. Ask the child to clap along with you whilst you say the numbers pointing to the steps on a blank number line. Invite the child to say the numbers with you and clap at the same time. (Activity adapted from a suggestion in the Catch Up file, p. 7.34)
Linked Recording	Ask the child to complete a number track given as illustrated below. 

Session No.	2
Component and Number Range Covered	Counting Verbally: Counting Verbally 0 – 10
Review & Introduction	Review what you had done during the previous session through the activity in which you counted and clapped together. Explain that now you will be working with a bigger number range. Revise all the related vocabulary.
Numeracy Activity	Carry out the **'Slippery Paper Clip'** from Catch Up's file (p. 7.35). Use a strip of paper with the numbers from 0 to 10 and a paper clip as can be seen in the figure below (taken from Catch Up's file, p. 7.35). Attach the paper clip over a number on the paper clip. Explain that this is a naughty paper clip and that it keeps moving forward. Ask the child to count from a number to another number as you move the 'slippery' paper clip. 
Linked Recording	The child is to complete a given sequence of numbers by filling in the missing numbers.

Session No.	3
Component and Number Range Covered	Counting Verbally: Counting On 0 – 8
Review & Introduction	Review counting verbally by asking the child to place a given set of numbers (from 0 to 8) that have been mixed up in the correct order. Ask her to count from 0 to 8 as she places the cards.
Numeracy Activity	Play a Board Game with the child. The child is to pick two numbers and count on from one number to the other number. If she does this correctly, she can throw the two dice and move on the board as required. Through this activity the child would not only be counting from one number to another but would be counting on as she moves her counter from one space to another.
Linked Recording	Ask the child to stamp five different sets of stars made up of a different number of stars. Each time she is to complete the set with any sequence she chooses by counting on from any number to another number between 0 to 8.

Session No.	4
Component and Number Range Covered	Counting Verbally: Counting On 0 – 8
Review & Introduction	To review what has been covered so far, ask Victoria to place the numbers between 0 and 8 in the correct way. Then ask her to count on from 0 to 8. Also invite her to clap as she says the numbers. Review the related Maths vocabulary.
Numeracy Activity	Ask the child to pick two numbers from a given pile of cards. She is to count from one number to another and everytime she gets the sequence correct she gets a point. Carry out the activity until the child has gotten 10 points.
Linked Recording	Ask the child to pick two numbers from the pile of cards given. Write the 2 numbers in the linked recording section. The child is to write down the numbers between the given numbers.

Session No.	5
Component and Number Range Covered	Counting Verbally: Counting On 0 – 8
Review & Introduction	Go through what you would have covered during the previous session. Show her the 'linked recording' section to remind her of what had been done.
Numeracy Activity	**Land on 8:** Adapted from the On-Line resources provided to the members of the Catch Up community. In this activity the numbers from 0 to 8 are laid on the floor like tiles. The child is to step on a number. She then picks a number from a given set and moves on the 'number tiles' accordingly to see where see 'lands'.
Linked Recording	Give the child various sequences which she must complete. To make the activity more fun, write the numbers inside stamped leaves.

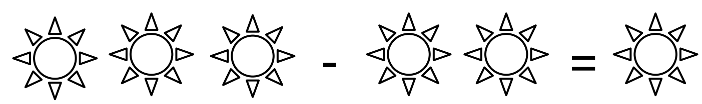
Session No.	6
Component and Number Range Covered	Counting Verbally: Counting On 0 – 10
Review & Introduction	Ask the child about what had been covered during the previous session. Review the related vocabulary. Explain that you are going to be working with a wider range of numbers during this session. Ask the child to place the 'number tiles' used during the previous sessions in the correct sequence on the floor.
Numeracy Activity	**Land on 10**: Conduct the activity in a similar manner as activity used in the previous session. This time however, for every step Victoria makes, drop a coin so that she links the noise to the movement. (Adapted from the Catch Up On-Line Resources available to trainees)
Linked Recording	The child is to pick two numbers. She is to count on from one number to another whilst you write down the sequence. After a while switch roles so that she can rehearse asking you to count from one number to another using the correct expression.

Session No.	7
Component and Number Range Covered	Counting Verbally: Counting On 0 – 10
Review & Introduction	Ask Victoria to recall what had been covered during the previous session. Review important vocabulary. Remind Victoria of the miscue she was making during the previous session which was that of counting the number she was standing on when moving along the floor tiles.
Numeracy Activity	Take out a number track and place a counter over any number. Ask the child to pick a 'count on' card. Observe the child as she counts on from the number with the counter. Remind her not to count the number the counter is on already.
Linked Recording	Ask the child to pick a number and a 'count on' card. The child is to 'count on' from the number picked (in accordance to the 'count on' card) and write down the respective sequence of numbers.

Session No.	8
Component and Number Range Covered	Counting Verbally: Counting Back 0 – 8
Review & Introduction	Explain that you are going to be counting back within the number range from 0 to 8. Introduce important related terms like *count back, backwards, count down* and *number sequence*.
Numeracy Activity	Use **Land on 8** however this time illustrate how now she must move on the floor tiles in the backwards fashion. Model the task and then ask the child to pick a 'count back' card and move accordingly on the floor tiles. (Adapted from Catch Up's On-Line resources from trainees)
Linked Recording	Victoria is to pick two numbers and write the sequence from the largest number to the smallest number. Remind her that you are counting backwards.

Session No.	9
Component and Number Range Covered	Counting Verbally: Counting Back 0 – 8
Review & Introduction	Review the component and what had been done during the previous session. Reveal that you are going to be counting back from 8 to 0 again. Go through counting back using the **'slippery paper clip'** activity used in session 2.
Numeracy Activity	Count out aloud backwards. Take turns by either saying a number each as you count backwards from 8 to 0 or you could say one previous number whilst Victoria says two. (Catch Up resource file, p. 7.34)
Linked Recording	Write the numbers from 0 to 8. Ask the child to track along the numbers backwards (circling them in a continuous manner) whilst counting aloud. Ask her to track the numbers between different pairs of numbers.

Session No.	10
Component and Number Range Covered	Counting Verbally: Counting Back 0 – 10
Review & Introduction	Ask the child to pick two numbers. The child is to count from one number back to the other number.
Numeracy Activity	The child is to throw two dice. The number 6 is to be covered on the dice. Ask the child to count back from the total of both dice to 0 each time. Show her the number track to help her.
Linked Recording	Continue the numeracy activity carried out but record the sequences in the 'linked recording' section. Draw stars for Victoria to follow their path and write the numbers inside them.

Session No.	11
Component and Number Range Covered	Counting Verbally: Counting Back 0 – 10
Review & Introduction	Remind Victoria of what had been covered during the previous session. Explain that you are going to continue rehearsing counting backwards. Ask her to put the number cards after each other from 0 to 10 and then ask her to count back from 10 to 0.
Numeracy Activity	Use the Cuisenaire one-unit rods to illustrate that counting back is another form of subtraction. Show this by giving different examples. For example 5 – 3 = ? From 5 you move (or remove) 3 to get the answer 2. (Activity taken from Primary National Strategy which is part of the On-line activities presented by Catch Up to its trainees)
Linked Recording	Give Victoria some stamps. Ask her to use the stamps to represent subtraction sums. For example: 

Session No.	12
Component and Number Range Covered	Counting Objects: Order Irrelevance 1 – 5
Review & Introduction	Introduce the new component regarding the order irrelevance of counting objects. Introduce key words: *add*, *adding*, *predict*, *rearrange* and *group*.
Numeracy Activity	Place a number (1 – 5) of pasta shells in front of the learner. Count the pasta shells together. Ask the learner to predict how many objects there would be if we started counting from another point and to check by actually counting. Repeat the activity until Victoria is convinced that the number always remains the same. (Activity adapted from Catch Up Resource File)
Linked Recording	Do 5 sets of stamps each with 5 stamps. Draw an arrow which will illustrate where Victoria is to start counting the stamps.

Session No.	13
Component and Number Range Covered	Counting Objects: Order Irrelevance 0 – 8
Review & Introduction	Remind Victoria of what had been covered during the previous session. Ask her to count a number of objects, to predict how many there would be if you started from somewhere else and to count again.
Numeracy Activity	Ask the learner to pick a number card. Ask her to represent the number with counters. Ask her to count the counters. Tell her to predict how many there would be if she started counting from somewhere else. Repeat the activity.
Linked Recording	Continue with the numeracy activity above. In the 'linked recording' section record the prediction of count, the real count and what Victoria says the answer would be if she started to count from a different point.

Session No.	14
Component and Number Range Covered	Counting Objects: Order Irrelevance 0 – 10
Review & Introduction	Remind Victoria of what had been covered during the previous session. Ask her to count a number of objects, to predict how many there would be if you started from somewhere else and to count again.
Numeracy Activity	Ask the learner to throw two dice (both with the number 6 covered). Ask her to count how many dots there are on both dice together. Tell her to predict how many there would be if she started counting from somewhere else. Repeat the activity.
Linked Recording	Continue with the numeracy activity above. In the 'linked recording' section record the prediction of count, the real count and what Victoria says the answer would be if she started to count from a different point.

Session No.	15
Component and Number Range Covered	Counting Objects: Subtracting Objects 0 – 8
Review & Introduction	Review work done during previous session then introduce today's session. Model a subtraction task with the pasta shells. Introduce the key words like minus, subtract, difference between and take away with flashcards. Also emphasise the symbol for subtraction (-) as Victoria has difficulties with this.
Numeracy Activity	Create some subtraction sums together. Solve the subtraction sums using the objects (the pasta shells). Ask her to predict answer and check whether she was right.
Linked Recording	Subtraction sums represented through objects.

Session No.	16
Component and Number Range Covered	Counting Objects: Subtracting Objects 0 – 10
Review & Introduction	Go through the work done during the previous session. Ask the child to pick some subtraction sums from a given pile and represent them with objects. She is then to give the correct answer to the sum illustrating it with objects. Rehearse related vocabulary and reveal number range 0 – 10.
Numeracy Activity	Pretend you are at a supermarket. The child must pay for items using one unit cuisenaire rods. E.g. a pencil costs 3 rods. The child will start at 10 and subtract 3. Ask her how many rods she has left every time. She then buys something else, so does 7 – 4 for example. When she runs out of rods, tell her that its the weekend and that she receives her pocket money. Continue the activity.
Linked Recording	Victoria is to work out some subtraction sums. First she must predict the answer. Then represent each one with pasta shells and check whether her answers were correct.

Session No.	17
Component and Number Range Covered	Hundreds, Tens and Units: Subtracting Tens and Units 1 – 5
Review & Introduction	Introduce the topic by saying that you will be doing subtraction of tens and units. Reveal the number range and again point out important vocabulary: *minus, take-away, find the difference* and *subtract*. Illustrate these words through the subtraction chart.
Numeracy Activity	Create subtraction sums and check them out with the pasta shells. Record the Victoria's prediction of the answer and then check if she was right.
Linked Recording	Give Victoria some subtraction sums within the number range. She is to work them out and then check the answer with the pasta shells.

Session No.	18
Component and Number Range Covered	Hundreds, Tens and Units: Subtracting Tens and Units 0 – 8
Review & Introduction	Go through sums covered so far. Remind Victoria about what you were doing during the previous session. Create a subtraction sum together and work it out. Reveal the new number range (o to 8) and go through the key words again.
Numeracy Activity	Ask the learner to find the difference between two numbers on a number line by counting from the higher number back to the lower number using loops. Repeat until Victoria has understood.
Linked Recording	Give Victoria some number lines and she is to work out some subtraction sums using the given number lines.

Session No.	19
Component and Number Range Covered	Hundreds, Tens and Units: Subtracting Tens and Units 0 – 10
Review & Introduction	Review the previous session and explain that you are going to be working on subtraction again. Illustrate that you will be using the number range 0 – 10. Ask Victoria to subtract one number from another number using the number line to remind her of what had been done.
Numeracy Activity	Use the number line again. This time from 0 to 10. Ask Victoria to subtract one number from another using the number line.
Linked Recording	Do a similar exercise as the one done during the previous session. This time ask Victoria to invent some subtraction sums herself. Ensure that she places the largest number at the front.

Session No.	20
Component and Number Range Covered	Hundreds, Tens and Units: Subtracting Tens and Units 0 – 10
Review & Introduction	Explain that for the last time you are going to do subtraction. Ask Victoria some subtractions sums and see if she can work them out. Rehearse important vocabulary.
Numeracy Activity	Shuffle two sets of number cards. One with subtraction sums and one with their answers. Tell Victoria that you have mixed them up by mistake and that you need her to match the answers to their sums again. Check the way she sets them together.
Linked Recording	Give Victoria a matching exercise to complete which is similar to that done in the numeracy activity. Victoria must match the sums with the correct answers.

Appendix E2: Lesson Notes for the Sessions Held with Charmaine

The activities adapted or taken from resources provided by Catch Up or other sources have been acknowledged. The rest of the activities are my own work.

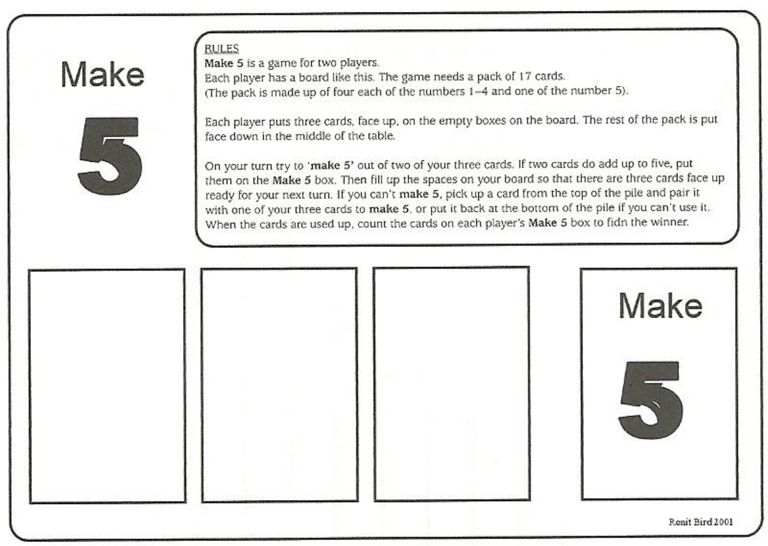
Session No.	1
Component and Number Range Covered	Counting Verbally: Counting Back 0 – 10
Review & Introduction	Introduce the component and the relevant vocabulary e.g. *backward, count back, count down*. Explain that you will be working with a number range from 0 to 10.
Numeracy Activity	Ask the child to pick a number. She must count back from the number picked to '0'.
Linked Recording	The child will be asked to fill in sequences of numbers in a backwards position with the missing numbers.

Session No.	2
Component and Number Range Covered	Remembered Facts 1 – 5
Review & Introduction	Introduce what remembered facts are. Give examples of number sentences which Charmaine should know. Explain that you will be working with the number range from 1 to 5.
Numeracy Activity	Find addition and subtraction sums together. Write each sum of a flashcard and write its answer at the back of the flashcard. Remember to use only numbers between 1 and 5. Use the term 'number sentences' to refer to the sums and their answers. Go through the set of chosen sums. Each time ask the child to work out the sum on the front of the flashcard and to check it with the answer at the back.
Linked Recording	Give Charmaine the same number sentences chosen. She is to write the correct answer to the sums given.

<table>
<tr><td>Session No.</td><td>3</td></tr>
<tr><td>Component and

Number Range Covered</td><td>Remembered Facts

1 – 5</td></tr>
<tr><td>Review & Introduction</td><td>Go through the number facts chosen during the previous session. Verify whether the child still remembers the answers to the sums chosen.</td></tr>
<tr><td>Numeracy Activity</td><td>Play the Make 5 Game found in Bird (2007, p.4). Each player puts three cards, face up, on the empty boxes on the board. The rest of the pack is face down in the middle of the table. On your turn try to ‘make 5’ out of two of your three cards. If two cards add up to 5, put them on the Make 5 box. Then fill up the spaces on your board so that there are three cards face up, ready for your next turn. If you can’t make 5, pick up a card from the top of the pile and pair it with one of your three cards, or put it back at the bottom of the pile if you can’t use it. When the cards are used up, count the cards on each player’s Make 5 box to find the winner. The template from the book was used and can be seen below (taken from Bird, 2007, p.5)


</td></tr>
<tr><td>Linked Recording</td><td>Give Charmaine a the same sums chosen for her to answer. Repetition is necessary to help the child remember the answers.</td></tr>
</table>

Session No.	4
Component and Number Range Covered	Remembered Facts 0 – 8
Review & Introduction	To review the work done during the previous session go through the cards with the number sentences chosen so far. Revise the related Maths vocabulary.
Numeracy Activity	Play a board game. The child is to throw two dice. Ask her to say the answer to a chosen number sentence from the flashcards. If she says it correct she moves according to the dice. If the answer is not correct, she moves half the points gained on the dice. Play the game until Charmaine gets to the end.
Linked Recording	Give Charmaine mixed subtraction and addition sums as per her flashcards with missing numbers. Some sums will have the first number left out, others the middle number and others the answer.

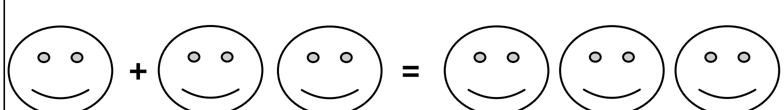
Session No.	5
Component and Number Range Covered	Remembered Facts 0 – 8
Review & Introduction	Review the number sentences covered so far. Ask Charmaine the sums on one side of the flashcards and each time check together whether her answer was correct by looking at the answer at the back. To make it a bit more challenging, challenge her to say the answers to all the flashcards in less than a minute. It is important that Charmaine does not use her fingers.
Numeracy Activity	Play the board game again as in the previous session. Ask her to say the answer to the sums she is having most difficulties with.
Linked Recording	Give her similar sums to those done in the previous session.

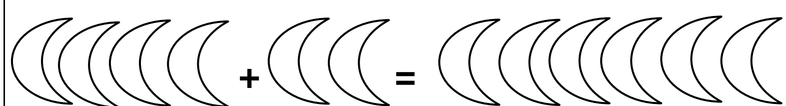
Session No.	6
Component and Number Range Covered	Remembered Facts 0 – 10
Review & Introduction	Go through the cards that Charmaine has been studying. Again challenge her by including the time factor.
Numeracy Activity	**Target Making 10 Game** (Adapted from Catch Up Resource File). Place different groups of pasta on the table. Tell the child to add the necessary pasta shells to make 10. Add new sentences to the flashcards done already including numbers 0 – 10.
Linked Recording	Ask the child to write 6 bonds of 10 as per the numeracy activity carried out.

Session No.	7
Component and Number Range Covered	Remembered Facts 0 – 10
Review & Introduction	Go through the flashcards with the sums Charmaine should be studying. Do it in the form of a game. Each time Charmaine get a card right she gets a point. Tell her that she had to try and get the highest number of points possible.
Numeracy Activity	Play a snap card game. Prepare two sets of cards. One set must have the sums on them whilst the other set must have the matching answers. Shuffle the cards and give them out. You are to say snap every time a sum and its matching answer are revealed after each other. The player who says snap takes the pile of cards on the table. Repeat. The winner is the player with the pack of cards at the end of the game.
Linked Recording	Give Charmaine a matching exercise which she must complete by matching the sums to the correct answers.

Session No.	8
Component and Number Range Covered	Remembered Facts 0 – 10
Review & Introduction	Go through the number bonds covered already by using the number track. Ask Charmaine to give a number which added to another makes 10.
Numeracy Activity	Carry out the hanger activity adapted from the suggested activity by Catch Up (Resource file, p. 7.71) called **Number Pairs.** Ask the child to reproduce the number sentences according to how the pegs are placed on the hanger. First do all the addition sums as per Charmaine's flashcards, then do all the subtraction sums. Model one of each. This activity allows the child to develop a visual representation of the number sentences being studied so that memorising them is easier.
Linked Recording	Allow free exploration with the Cuisenaire rods. Use the rods to give the child some number sentences that she has already covered. The child is to write the number sentence and the answer to it. She is then to check it using the rods. At the end, carry out the **Number Trains** activity on the Cuisenaire Rods Manual (p. 10). In this activity, she is to make up 'trains' using different rods and saying what the trains made up add up to. Ask her to create two trains.

Session No.	9
Component and Number Range Covered	Counting Objects: Counting Objects 0 – 8
Review & Introduction	Introduce the new component and reveal the number range which will be covered. Model some tasks of counting objects using the white cubes of the Cuisenaire rods. Focus on important vocabulary such as *add, adding, altogether* and *combine.*
Numeracy Activity	As suggested by the Catch Up resource file (p. 7.38) ask the child to select the correct number of pasta shells shown on a chosen number card. Ask her to count again to check.
Linked Recording	Create groups of stamps. Ask Charmaine to count them and write the number in each set beneath them.

Session No.	10
Component and Number Range Covered	Counting Objects: Adding Objects 0 – 10
Review & Introduction	Go through counting objects (as per previous session) by again asking the child to pick a number and represent it with objects. Introduce the new component and go through important words like *add, plus, adding, put together, counting up* and *total.* Also place emphasis on the symbol for addition (+).
Numeracy Activity	Ask Charmaine to throw a die and count as many objects as shown on the face of the die. Then she is to throw another die and is to count that number of objects. She is then to add the objects represented from the first die to those of the second to create a number sentence. She is finally to count all the objects together. Repeat as needed.
Linked Recording	Create number sentences of addition using objects. Charmaine is to answer using objects too. E.g. 

Session No.	11
Component and Number Range Covered	Counting Objects: Adding Objects 0 – 10
Review & Introduction	Go through what was covered during the previous session and explain that now you are going to use the range 0 to 10. Demonstrate by re-doing the activity with the dice done during the previous session.
Numeracy Activity	Represent the addition number sentences on the cards created for the remembered facts sessions . Ask Charmaine to illustrate each fact with objects and to add up the objects to get the correct answer.
Linked Recording	Ask the child to draw objects as per a number of number sentences given. E.g. **4 + 2 = 6** 

Session No.	12
Component and Number Range Covered	Hundreds, Tens and Units: Adding Tens and Units 0 – 10
Review & Introduction	Introduce the new component. Review number comparisons as per the assessment presented by Catch Up. Show the child two numbers and ask her to indicate which is the greatest.Explain that you will be working with the numbers from 0 to 10. Introduce key words like *hundreds, larger, less, less than* and *bigger than*.
Numeracy Activity	Create addition sums with the Cuisenaire rods. Record the sums done on a paper. Each time ask the child to predict what the answer will be. Then compare the prediction to the actual answer asking her questions about whether her prediction was correct.
Linked Recording	Give the child different addition sums which she must work out. Allow her to use the rods if she needs to.

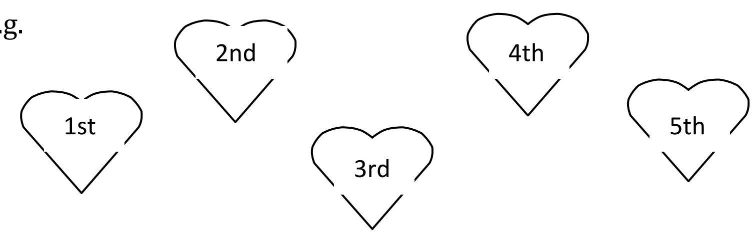
Session No.	13
Component and Number Range Covered	Hundreds, Tens and Units: Subtracting Tens and Units 0 – 10
Review & Introduction	Remind Charmaine of what you had done during the previous session. Use the rods to create some addition sums as a reminder. Explain that you will be subtracting tens and units during this session with numbers between 0 and 10. Revise the key words *minus, subtraction, take away, smaller* and *smaller than*.
Numeracy Activity	Conduct a similar activity as the one done in the previous session. Create subtraction sums and ask the child to predict the answer. The child is then to check her prediction with the correct answer.
Linked Recording	Give Charmaine some subtraction sums to work out. If she has any difficulties she can use the rods to help her find the correct answer.

Session No.	14
Component and Number Range Covered	Hundreds, Tens and Units: Subtracting Tens and Units 0 – 10
Review & Introduction	Give Charmaine some subtraction sums and ask her to work them out. Represent them using the rods to remind her about what you did during the previous session.
Numeracy Activity	Use a number line. Point to two numbers on a number line and ask the learner to find the difference between these two numbers using the number line. Work out other subtraction sums using the number line. (Activity adapted from Catch Up resource file, p. 7.48)
Linked Recording	Write some subtraction sums and ask Charmaine to represent them on given number lines. She is to write the correct answer next to each sum.

Session No.	15
Component and Number Range Covered	Hundreds, Tens and Units: Subtracting Tens and Units 0 – 10
Review & Introduction	Revise what was covered during the previous session by drawing number lines and asking Charmaine to use them to work out some subtraction sums.
Numeracy Activity	Play a card game. The child is to match different subtraction sums to the correct answers. Give the rods and pasta shells to the child and explain that she can use any if she gets confused and cannot work out the answer.When the child finishes off, check them together. Re-shuffle the cards and this time tell her that she must do the matching exercise in a stipulated amount of time.
Linked Recording	Give the child some subtraction sums to work out. To challenge her ask her to create two subtraction sums of her own whose answer must be the numbers you give her.

Session No.	16
Component and Number Range Covered	Word Problems 0 – 10
Review & Introduction	Read out a problem and ask Charmaine to represent it using the rods or pasta shells as she prefers. Use the Word Problems assessment produced by Catch Up to introduce the component.
Numeracy Activity	Make up three word problems and ask Charmaine to make up two. Represent the word problems Charmaine created with manipulative and discuss the answer together. This will serve as modeling as she then is required to do the same with your word problems. Ask her to predict the answer and then actually check it. Emphasise important key words that will help her to choose the correct operation to solve the problem.
Linked Recording	Ask Charmaine to work out three word problems after representing them with manipulatives. Record her answers.

Session No.	17
Component and Number Range Covered	Word Problems 0 – 10
Review & Introduction	Go through the work covered during the previous session. Explain that you will be doing something similar so that she feels more confident with problems. Repeat that the number range will be that between 0 and 10.
Numeracy Activity	Go through the last few word problems in the assessment produced by Catch Up for this target level. Explain that you will be using pasta shells to work them out as she seems more confident with pasta shells. Tell her that first she has to predict what the answer to the problem is and that then check it with the shells. Repeat with different problems.
Linked Recording	Give Charmaine two problems. She must first predict what the answer will be, then she must work it out and use the pasta to check her answer. Ask Charmaine to write her own problem. Solve it together.

Session No.	18
Component and Number Range Covered	Ordinal Numbers 1 – 5
Review & Introduction	Explain that we will be going through ordinal numbers. Ordinal numbers are used to describe someone's or an object's position. Go through the ordinal number cards representing the key words: *first (1st), second(2nd), third(3rd), fourth (4th)* and *fifth (5th)*.
Numeracy Activity	**Pole Position** (activity adapted from Catch Up resource file). Use a number track. Start counting from the 4th on to the 5th. Illustrate how to write these positions using the ordinal number cards (a template of which are provided by Catch Up). Then explain that the first three are different, 1st, 2nd and 3rd. Put some objects in a row. Ask Charmaine to label, using the ordinal number cards, the positions of the objects. Ask her to say them out aloud. Make sure she uses the correct language.
Linked Recording	Stamp objects in different rows. Charmaine is to write their position inside them. E.g. 

Session No.	19
Component and Number Range Covered	Ordinal Numbers 0 – 8
Review & Introduction	Review activity done previously. Go through number cards again and make sure she remembers positions covered (1st – 5th). Conduct a similar activity as that done previously to review. Explain that during this session you are going to use the positions between the 1st and the 8th.
Numeracy Activity	Ask the learner to set out and say the position of some objects using ordinal numbers. Put the ordinal number cards in a pile, face down. Ask the learner to take a card and to put the card alongside the object that corresponds to the card.
Linked Recording	Draw a row of 8 objects. Ask child to pick an ordinal number card. Say mark the 6th, 8th etc. according to the card picked.

Session No.	20
Component and Number Range Covered	Ordinal Numbers 0 – 10
Review & Introduction	Go through the work done during previous sessions about ordinal numbers. Place some objects in a row and ask Charmaine to mark their position. Explain that you will be using the range from the 1st to the 10th.
Numeracy Activity	Place ten objects in a row. The learner is to pick an ordinal number card and mark the correct object according to the card picked. At the end ask Charmaine to say all positions.
Linked Recording	Draw 10 objects and ask Charmaine to write as (1st, 2nd etc.) and say the position of all the objects. At the end ask her to write the position in number words too (first, second, etc.)

Appendix E3: Lesson Notes for the Sessions Held with Martina

The activities adapted or taken from resources provided by Catch Up or other sources have been acknowledged. The rest of the activities are my own work.

Session No.	1
Component and Number Range Covered	Counting Verbally: Counting On 0 – 8
Review & Introduction	Use the assessment provided by Catch Up to review counting on from one number to another number. Introduce important key words such as *count on* and *count verbally*.
Numeracy Activity	Ask the child to pick two numbers from a given pile of numbers. She is to count from one number to the other.
Linked Recording	A similar activity is done as the one in the numeracy activity. Ask the child to pick two numbers, record them and then ask her to complete the sequence by filling in the numbers between the given two numbers.

Session No.	2
Component and Number Range Covered	Counting Verbally: Counting On 0 – 10
Review & Introduction	Shuffle the number cards from 0 to 8. Ask the child to place them after each other as fast as possible. Revise counting on from 0 – 8. Add the numbers 9 and 10 to the cards and explain that during this session you will be counting on with numbers from 0 to 10. Rehearse vocabulary.
Numeracy Activity	Throw three dice. One will show the start point for counting. The added score of the other two will be the finishing point. The child is to count from one point to the other. Challenge the child by asking her to count in 2s from one number to another.
Linked Recording	Give two numbers in stars and leave a number of blank spaces between them. Ask the child to fill in the blanks. E.g.  Also ask the child to count on from one number to another orally to ensure she is able to do this.

Session No.	3
Component and Number Range Covered	Counting Verbally: Counting Back 0 – 8
Review & Introduction	Use the Catch Up assessment and ask the child to count back from one number to another. Remind her of what counting back means and inroduce key vocabulary like *count back, backward* and *count down.* Also reveal the number range 0 to 8.
Numeracy Activity	**Land on 10** (Adapted from Catch-Up's on-line resources). In this activity the numbers from 0 to 10 are laid on the floor like tiles. The child is to step on a number. She then picks a number from a given set and moves back on the 'number tiles' accordingly to see where see 'lands'. Repeat with several numbers.
Linked Recording	Martina is to pick two numbers and write the sequence backward from the largest number to the smallest number.

Session No.	4
Component and Number Range Covered	Counting Verbally: Counting Back 0 – 10
Review & Introduction	Review counting backwards using the 'Slippery Paperclip Activity' (taken from Catch Up resource file, p. 7.35) Place the paper clip on a number on a strip of paper containing the numbers from 0 to 10. Ask the child to count back from that number to 0 each time. Rehearse important vocabulary.
Numeracy Activity	Play a Board Game. Ask the child to pick two numbers. She is to throw two dice. She then picks two number cards from a pile at the centre and counts back from the largest number to the smallest. If her sequence is correct she moves accordingly, if not she gets have the points on the dice.
Linked Recording	Martina has to complete a given sequences of numbers by counting backwards. Challenge her by giving her two tasks in which she must count back in 2s to complete the sequence.

Session No.	5
Component and Number Range Covered	Remembered Facts 1 – 5
Review & Introduction	Explain that you will be learning some number sentences with the numbers in the range from 1 to 5. Ask her to give you some examples of addition and subtraction sums with the numbers 1 to 5. Introduce the term *'number sentence'.*
Numeracy Activity	Place some number sentences on one side of the table and their answers on the other. Ask the child to match the sum with its answer. Model the task first. Then explain that she must match them as fast as possible. Then mix the piles up again and tell the child to try to match them in only 2 minutes.
Linked Recording	Martina will complete a matching exercise similar to that done during the session. She must match the sums with their answers.

Session No.	6
Component and Number Range Covered	Remembered Facts 0 – 8
Review & Introduction	Go through the flashcards with the number sentences covered during the previous session. Cover the answers to the sums and see whether Martina remembers the answers. Reveal that you will be working with the numbers between 0 and 8.
Numeracy Activity	Use a hanger with 8 pegs to create number sentences with the child. Each time record the number sentences on flashcards to be able to refer to them later. Create both addition and subtraction sums with numbers from 0 to 8.
Linked Recording	Ask the child the addition and subtraction sums created with the numbers from 0 to 8. She is to write them down and write the correct answer to them. Keep a timer to challenge the child.

Session No.	7
Component and Number Range Covered	Remembered Facts 0 – 10
Review & Introduction	Go through the cards with the number sentences covered so far. Make sure that she knows them well and that she doesn't use her fingers but recalls them.
Numeracy Activity	Play a snap card game. Prepare two sets of cards both with the numbers from 0 to 10. Explain that snap is done when two numbers that together make 10 are placed on top of eachother. The player to say snap first takes the pile of cards on the table. The winner is the player with all the cards at the end of the game.
Linked Recording	Ask the child to write seven bonds of ten in the linked recording section.

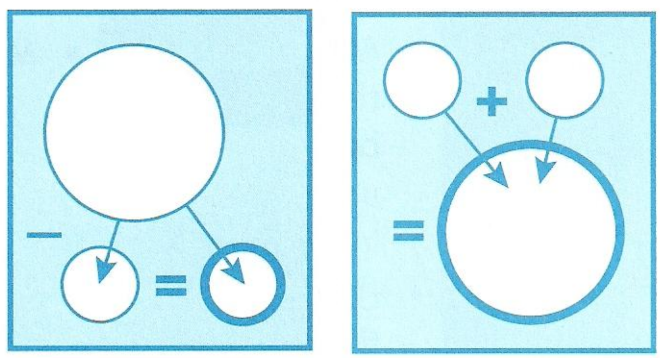
Session No.	8
Component and Number Range Covered	Remembered Facts 0 – 10
Review & Introduction	Go through all the cards with the number sentences covered through a game. Ask the child to stand on a floor tile. Everytime she gives the correct answer to a sum she can move on to another tile. Challenge her to walk across all the tiles as quickly as possible.
Numeracy Activity	Use Cuisenaire rods to represent the number sentences created so far so that the child can visually memorise the answer. Add some more subtraction sums to the set of flashcards done already.
Linked Recording	Place the pile of flashcards with the number sentences face down. Ask the child to pick a card. Read the sum out aloud. The child is to write it down in the appropriate section and complete it by writing the correct answer.

Session No.	9
Component and Number Range Covered	Word Problems 0 – 10
Review & Introduction	Revise all the number sentences covered for Remembered Facts to make sure that Martina is revising them. Introduce the new component of Word Problems and the number range which is going to be used.
Numeracy Activity	Go through the word problems found in the Catch Up file as part of the assessment. Represent each problem with the Cuisenaire rods since Martina liked these a lot. Ask questions of prediction and then ask Martina to match her predicted answer to the correct answer.
Linked Recording	Martina is to work out 2 'change' type of word problems. She is then to create her own problem. Solve it together.

Session No.	10
Component and Number Range Covered	Word Problems 0 – 10
Review & Introduction	Review the work done during the previous session. Go through the key words. Remind Martina the number range (0 – 10). Read out a problem and ask Martina to represent it using the rods. Discuss how you should solve it.
Numeracy Activity	Ask the learner to solve different types of word problems using the numbers from 0 to 10. Point out specific language in the problems that help her to choose which operation she should use.
Linked Recording	Martina is to create three word problems. She is to read them out to you, represent them with the rods and then write the operation as well as the answer to the particular problems.

Session No.	11
Component and Number Range Covered	Word Problems 0 – 10
Review & Introduction	Go through the last set of problems from the Catch Up assessment and use manipulatives to solve them to remind Martina of what had been done. Introduce today's session about word problems and tell Martina that today you will not be using manipulatives to work out the problems but only to check them. Remind her of the number range. Also rehearse specific words pointed out during the previous sessions to help her choose the operation to use.
Numeracy Activity	Ask Martina to invent three problems as she enjoyed this activity during the previous session. Create another three yourself then swap problems and try to solve each other's word problems. When you are both finished with the task, check the six solutions together using manipulatives.
Linked Recording	Write three problems. Read them out to Martina and go through the steps for solving them together. Check them out with the rods at the end.

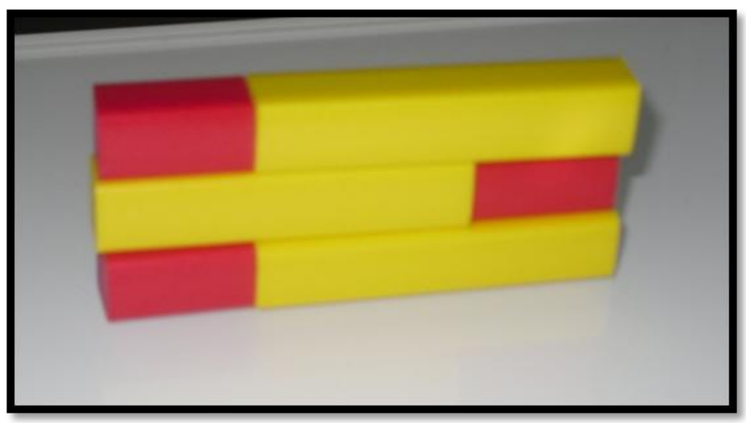
Session No.	12
Component and Number Range Covered	Translation: Number Words to Objects 0 – 8
Review & Introduction	Introduce the component. Illustrate how number words are objects. Use a problem used in the previous session to illustrate this. Introduce important key words such as *add, added to, change, divide* and *equals*. Also introduce number range.
Numeracy Activity	Go through the Catch Up assessment for Translation from number words to objects. Read out the problem and Martina is to translate it to objects using the pasta shells. Example: Mark has two pencils, Olivia has three pencils so together they have five pencils. Martina is to translate this by showing that two pasta shells and another three together make five.
Linked Recording	Read out some word problems with numbers from 0 to 8. Martina is to use the stamps to represent the number words read out.

Session No.	13
Component and Number Range Covered	Translation: Number Words to Objects 0 – 10
Review & Introduction	Review the previous session by reading out a problem to Martina and asking her to represent it using the pasta shells.
Numeracy Activity	**Drag n' Drop Activity** (adapted from Catch Up file, p. 7.59). The child is to represent some problems by translating them to objects on the given 'addition mat'. Do the same with subtraction sums on the 'subtraction mat'. Pictures of the mats can be seen below. These have been taken from Catch Up's file, p. 7.59) 
Linked Recording	Draw some items and their prices. Ask Martina to draw the amount of coins needed to buy particular items as per the prices you would have given her.

Session No.	14
Component and Number Range Covered	Derived Facts: Identical 1 – 5
Review & Introduction	Explain that you are going to be moving on to another component. Say that some sums can be worked out by knowing other sums. E.g. if you know that 5 + 0 = 5, then you know that 5 + 0 = 5 because they are identical sums. Emphasise the word identical and explain that during this session you will be working on identical sums with the number from 1 to 5.
Numeracy Activity	Use the rods to illustrate derived facts that are identical. Give different examples so that the child sees that the same two rods give the same answer. Carry out the task with different addition and subtraction sums with the numbers so that the answer is a number from 1 to 5.
Linked Recording	Give Martina different pairs of identical sums. One of the sums from each pair must have missing numbers which she must find out by using the other sum.

Session No.	15
Component and Number Range Covered	Derived Facts: Identical 0 – 8
Review & Introduction	Go through what you had done during the previous session using the range 1 – 5. Use rods to represent identical number sentences. Introduce the new number range.
Numeracy Activity	Ask the child to suggest number sentences which have an answer between 0 and 8. Write these down on two different cards. Lay out the cards on the table. Ask the child to pair up the identical sums. If there is time left, once the activity is over, play snap with the same cards. A player can say snap when two identical sums are thrown after eachother.
Linked Recording	Matching the identical sums and filling up some missing numbers in the same sums by using the identical sum.

Session No.	16
Component and Number Range Covered	Derived Facts: Identical 0 – 10
Review & Introduction	Review what has been done during the previous session by reproducing two identical number sentences using the Cuisenaire rods. Rehearse important key words like *identical* and *derived facts*.
Numeracy Activity	Play snap using the identical number sentences in the number range from 0 to 10 as you didn't manage to during the previous session.
Linked Recording	Write sentences like: If 4 + 3 = 7, then 4 + 3 = _____ If 5 + _____ = 7, then 5 + 2 = 7 Ask Martina to complete the sentences by using derived facts.

Session No.	17
Component and Number Range Covered	Derived Facts: Communtative 1 – 5
Review & Introduction	Review the work done with identical sums. As an ice-breaker, play snap again because Martina really enjoyed it. Introduce the new derived facts and emphasise the meaning of the word *commutative* and the words *more than* and *less than*.
Numeracy Activity	Carry out the activity **Another Brick in the Wall** (found in Catch Up file, p. 7.63). Ask Martina to build the first row of bricks using rods. The wall must be 7cm long. Give her a 2cm rod and a 5cm rod. Martina is to build the first row. When ready, explain that she must build the second row with the same amount of bricks but in a different position (as seen in the photograph below). Explain that if 2 + 5 = 7 then 5 + 2 = 7. These sums are commutative. The numbers before the equal sign change place but the answer remains the same. 
Linked Recording	Give Martina communtative sums with missing numbers which she must complete by using derived facts.

Session No.	18
Component and Number Range Covered	Derived Facts: Commutative 0 – 8
Review & Introduction	Review the concept covered during the previous session. Remind key words and show that you will be working with the range 0 to 8.
Numeracy Activity	Matching Activity – the child is to match two different piles of number sentences which are commutative. She must illustrate which sums would help her answer each other.
Linked Recording	Matching exercise. To compliment the numeracy activity done, the child is to match the commutative sums given in the linked recording section. Also, some sums are to be left with missing numbers so that she completes them using the derived facts covered.

Session No.	19
Component and Number Range Covered	Derived Facts: Communtative 0 – 10
Review & Introduction	Review the work done during the previous session by using the cards used for the matching game to play snap. Snap is done when two sums which are commutative are thrown after eachother. Explain that you are going to be working with similar sums but with the number range 0 – 10.
Numeracy Activity	Ask Martina to say an addition or subtraction number sentence. Ask her to bring out at least another two related facts. E.g. 5 + 4 = 9, so 5 + 4 = 9 and 4 + 5 = 9. (Adapted from Catch Up On-line resources **Number facts to 10 that I know**)
Linked Recording	Martina is to think of a subtraction or addition sum and write it down in a coloured pen. She is then two write three derived facts from that sum. Repeat the exercise 6 times.

Session No.	20
Component and Number Range Covered	Derived Facts: N+ 1 – 5
Review & Introduction	Go through work covered during the previous sessions. Do a similar exercise to that done in the linked recording section of the previous session. Explain that there is another way in which we can use one sum to solve another. Give an example: If 1 + 3 = 4, then 1 + 4 = 5. Introduce the term N+ to show that here we add one to the answer because one of the digits has 1 more.
Numeracy Activity	Use the rods to illustrate sums as in the review and introduction section. Together create sums in which the N+ concept is used using the rods.
Linked Recording	Give Martina some sums and ask her to write their pair e.g. you give her 3 + 1 = 4, and she must write 3 + 2 = 5.