Using information and communication technology to support Grade 6 learners with dyscalculia

by

Lindi-Anné Cronjé

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MASTER EDUCATIONIS

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Department of Educational Psychology
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SUPERVISOR

Professor Ronél Ferreira

CO-SUPERVISOR

Professor Gerrit Stols

PRETORIA

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I dedicate this dissertation to the following very important people in my life:

My husband, Pieter and my children, Nardus, Andrie, Abrie and Liné. Thank you for your ongoing support, love, encouragement and understanding of the time and effort needed for my dissertation.

My mom, Nonnie Steenkamp who became seriously ill and passed away during the time I was working on the dissertation.

All learners who are challenged through their school careers, struggling with Mathematics, because of dyscalculia.

DECLARATION OF ORIGINALITY

I, Lindi-Anné Cronjé (student number 16309368), declare that the dissertation "**Using information and communication technology to support Grade 6 learners with dyscalculia**" which I hereby submit for the degree Masters Educationis in Learning Support, Guidance and Counselling at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution.

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Lindi-Anné Cronjé 31 March 2020

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CC

Ms Bronwynne Swarts

Prof Ronel Ferreira

Prof Gerrit Stols

This Ethics Clearance Certificate should be read in conjunction with the Integrated Declaration Form (D08) which specifies details regarding:

- Compliance with approved research protocol,
- No significant changes,
- Informed consent/assent,
- Adverse experience or undue risk,
- Registered title, and
- Data storage requirements.

DECLARATION FROM LANGUAGE EDITOR

I HATE
MISTEAKS

TK LANGUAGE SERVICE
EDITING | PROOFREADING | TRANSLATION
Prof. Dr. Tinus Kühn
+27 82 303 5415 | tinus.kuhn@gmail.com

29 March 2020

TO WHOM IT MAY CONCERN

I, the undersigned, hereby declare that the master's dissertation titled **Using information and communication technology to support Grade 6 learners with dyscalculia** [excluding the appendices] by **Lindi-Anné Cronjé** has been edited for grammar errors.

It remains the responsibility of the candidate to effect the recommended changes.

Prof. Tinus Kühn

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ABSTRACT

Dyscalculia implies difficulty in acquiring mathematical skills and requires intervention that focuses on the acquisition of the necessary basic mathematical skills. Against this background the purpose of this study was to investigate how Grade 6 learners with dyscalculia may be supported by implementing an Information Communication Technology (ICT) intervention, with a specific focus on number sense and basic mathematical skills. I followed a nomothetic quantitative approach and employed a quasi-experimental design, using a pre-test, followed by an ICT intervention and then a post-test with a small sample of Grade 6 learners that displayed learning difficulties in Mathematics. I combined convenience and purposive sampling to identify two full-service primary schools and utilised non-probable and purposive sampling to select 24 participants, randomly assigning them to either an experimental or control group.

Following implementation of the six-week ICT intervention, the scores of all pre- and post-test were documented as data. For the ICT intervention, I used *the Number Race* application, the *Sheppard Software* mathematical applications, more specifically *Math Lines* (addition, multiplication), *Math Man* (rounding, addition, multiplication), *Pop the Balloon* (add and order), and *The Rockseries.* I then completed non-parametric data analysis by utilising the Statistical Package for the Social Sciences (SPSS 25) to test the formulated hypotheses and draw conclusions about the possible value of the ICT intervention.

The findings of the study indicate that an ICT intervention can have (i) a positive effect on some aspects of number sense with learners experiencing difficulties in Mathematics, however, (ii) although an improvement in mathematical skills was evident, it was not statistically significant. Better results may be possible when additional software are included or more time is spent on such an ICT intervention to teach basic mathematical skills like adding, subtracting and multiplying after the improvement of number sense.

KEY CONCEPTS

- Dyscalculia
- Information Communication Technology
- Intervention strategies
- Mathematical skills
- Non-parametric
- Number sense
- Quantitative research.

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CHAPTER 1 – OVERVIEW OF THE STUDY

1.1 INTRODUCTION

Numbers are an inseparable part of all people's lives. Children grow up in an environment where numbers are used to count, to measure, to tell the date and time, to buy and sell (Rousselle & Noël, 2007). According to Price and Ansari (2013), all people require a degree of mathematical or computational competence to uphold themselves in the world. More specifically, in today’s world, people are required to be able to process numerical information to cope with everyday activities, such as interpreting financial and medical statements (Price & Ansari, 2013).

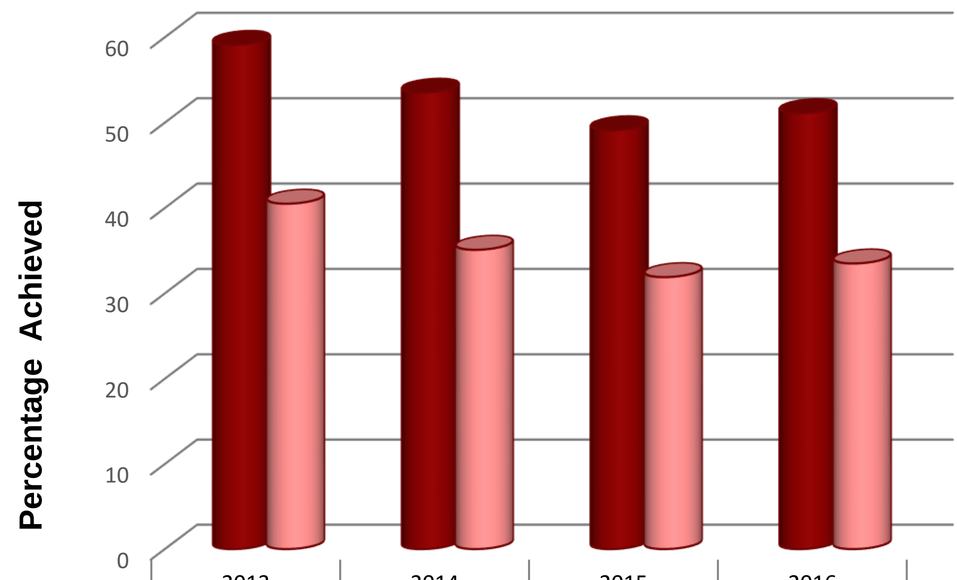
In South Africa, all learners enrol for either Mathematics[1] or Mathematical Literacy as part of their school subjects to obtain a National Senior Certificate (Department of Basic Education, 2015b). South African school Mathematics focuses on Algebra, Geometry, Trigonometry, Statistics, Financial Mathematics and Probability. Mathematical Literacy is more of an *everyday life applications* subject that consists of mathematical problems people are exposed to in their daily lives, such as how much petrol is needed to get from point A to B and how much it will cost, how much paint is required to paint a house, taking care of finances, interpreting graphs, handling data, probability, etc. Learners who experience difficulty with Mathematics can thus enrol for Mathematical Literacy that aims to equip them with the mathematical skills they require in the adult world.

Many learners, however, fail Mathematical Literacy in South Africa. The National Senior Certificate Diagnostic Report of 2016, published by the Department of Basic Education, indicates that in 2013 87,1% of the learners enrolled for Mathematical Literacy passed the subject. This pass rate dropped to 71,3% in 2016, which means that 28,7% of the learners enrolled for Mathematical Literacy could not even obtain 30%[2] for this subject that deals with everyday life calculations (Department of Basic

[1] In this study Mathematics relates to the subject Mathematics that is part of the school curriculum in South Africa, while mathematics is used when relating to the science or concepts of mathematics
[2] In South Africa, learners from Grade 10 to Grade12 require a final mark of 30% or more to pass Mathematics or Mathematical Literacy.

Education, 2016). Such statistics highlight the importance of ongoing research in the field of performance in mathematics, the reasons for poor performance and how this may be improved.

Even though many post Grade 12 programmes require Mathematics at Grade 12 level as an entry requirement, only 51,1% of South African learners that enrolled for Mathematics in 2016 passed the subject in Grade 12, in comparison to the 59,1% in 2013. Furthermore, only 33,5% passed Mathematics in 2016 with marks above 40%, whereas in 2013, 40,5% passed with 40% or more (Department of Basic Education, 2016). Closely related, the percentage of learners who enrol for Mathematics is also declining. In 2015, 39,5% of all learners who enrolled for the NSC examination enrolled for Mathematics; yet in 2017, the percentage declined to 38,9% and in 2018 to 37,4%. These statistics indicate that learners continually experience difficulty in passing Mathematics, as captured in Figure 1.1 (Department of Basic Education, 2016; 2017).



	2013	2014	2015	2016
% who achieved 30% and above	59,1	53,5	49,1	51,1
% who achieved 40% and above	40,5	35,1	31,9	33,5

Figure 1.1: Overall achievement in Mathematics for the period 2013 to 2016 (Department of Basic Education, 2016)

As already stated, the poor performances of learners in Mathematics and Mathematical Literacy remain to be a challenge for the South African Department of Basic Education, and merit ongoing research on the reasons for such performance. One possible cause for poor Mathematics performance is dyscalculia that is a phenomenon that requires ongoing research in terms of possible support and interventions that may assist learners suffering from it. In today's world and against the background of contemporary developments, the question arises as to how Information and Communication Technologies (ICTs) and ICT-applications may be utilised in support of learners with dyscalculia (Butterworth, Varma & Laurillard, 2011).

1.2 RATIONALE FOR UNDERTAKING THE STUDY

In my capacity as Departmental Head of the FET[3]-phase at a school for learners with physical and learning disabilities in South Africa, I assist learners and parents with subject choices for this phase. Over the years, I have seen that many learners do not cope with Mathematics up to Grade 9 and experience great difficulty in obtaining the required 40% to pass the subject at this level. This situation generally causes anxiety for learners and their parents when they learn that they are required to continue with the subject and enrol for either Mathematics or Mathematical Literacy in Grades 10 to 12. More and more parents finding themselves in this situation turn to psychologists to assess their children for dyscalculia in an attempt to obtain a concession for the learners from the Department of Basic Education to be allowed to take another subject instead of Mathematics or Mathematical Literacy. This option is, however not always in the best interest of the learner, as people require a basis of Mathematics or Mathematical Literacy to function optimally in everyday life in modern society.

Being a Mathematics and Computer Application Technology teacher, I am often involved in discussions where teachers from both mainstream and special needs schools express concern about the rising number of learners who are diagnosed with dyscalculia and subsequently experience difficulty in passing Mathematics as well as their grades. In the South African educational system, these learners will progress to Grade 10 at the end of the senior phase, without being required to enrol for the compulsory Mathematics or Mathematical Literacy (Department of Basic Education, 2015b). In this regard, point 33 of the Concessions no 2(a) (iii) of the National Policy pertaining to the Programme and Promotion Requirements of the National Curriculum Statement Grades R–12, 2015 (p. 43) states that:

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[3] Further Education and Training, which refers to the Grades 10 to 12 phase in the South African school system.

> *(iii) Learners who have been diagnosed to have a mathematical disorder such as dyscalculia may be exempted from the offering of Mathematical Literacy or Mathematics, provided that another subject from Group B is offered in lieu of Mathematical Literacy or Mathematics.*

As a result, these learners start their adult life without mathematical skills that may support them when entering the labour market. In my view, more can perhaps be done at an earlier stage to assist learners to feel more comfortable when required to work with numbers in the real world, so that they can at least enrol for Mathematical Literacy without experiencing mathematics anxiety. The statistics and background support this argument.

It follows that ongoing research is required on potential ways of identifying learners who experience difficulty with mathematics at an early age, before they enter the senior phase, thus in Grade 6 at the latest. Furthermore, the need to intervene as early as possible is central with a view to assisting learners in overcoming or minimising the mathematical barriers they experience, whatever the causes may be, and thereby improving their chances to pass Grade 9 Mathematics. To this end, I argue that early identification and intervention may enable more learners to enrol for Mathematics as a subject in Grade 12, or at least master Mathematical Literacy, even if special applications and technologies are required to assist them in obtaining general calculation competence.

According to White Paper 7 on e-Education, Information Communication Technologies (ICTs)[4] have the potential to improve the quality of instruction and learning in the general classroom. As such, the Department of Basic Education (2004) recommends the use of ICTs as part of the learning process. In addition to this background and national recommendation, my decision to investigate the possible use of ICT as intervention strategy was furthermore based on my experience that learners generally enjoy working with technologies as part of the learning that takes place in class.

[4] Any technological hardware or software such as computers, tablets, mobile telephones, computer programs, applications (Apps), etc (Consult Section 1.6.2).

Learners may regard such an intervention as playing with computers and applications, rather than view it as curriculum-driven work.

The growing availability and affordability of mobile devices, such as tablets and smartphones have resulted in the majority of individuals using these technologies for communication, work, entertainment, when learning or for banking and purchasing purposes (Bano, Zowghi, Kearney, Schuck & Aubusson, 2018). By utilising mobile devices when learning mathematics, the learning process may thus be expanded beyond the classroom (Borba, Askar, Engelbrecht, Gadanidis, Llinares & Aguilar, 2016; Fabian, Topping & Barron, 2018). According to Crompton and Burke (2017), mobile learning takes place when learning is facilitated through the use of multiple contexts, social interactions, and interactions with content while using personal interactive electronic devices. These devices must be portable and easy to use immediately by simply using an on/off button, as, for example, when using tablets and smartphones (Crompton & Burke, 2017).

Taleb, Ahmadi and Musavi (2015) posit that mobile learning (M-learning) can improve individual learners' motivation concerning mathematics, and their participation and involvement in the subject while providing teachers with alternative teaching methods. Leaners generally experience activities where mobile devices are used as engaging, fun and useful, usually resulting in a more positive attitude towards mathematics activities taught through this specific mode (Taleb et al., 2015). Research indicates that learners will in such cases be able to recall topics better and that mobile devices can help them to visualise mathematical concepts, in turn connecting these to the abstract world in support of their remembering mathematical facts (Fabian et al., 2018; Taleb et al., 2015). As such, mobile learning can be regarded as a valuable avenue that may promote the learning of mathematics, more specifically to use it outside the classroom (Crompton & Burke, 2017; Fabian et al., 2018). In undertaking my study, I decided to use laptops, which I provided during the intervention; the assumption was that all the respondents would not necessarily have access to the same smartphones, with some possibly not having smartphones at all.

1.3 PURPOSE AND AIMS OF THE RESEARCH

The purpose of this study was to investigate how Grade 6 learners with dyscalculia can be supported to work with numbers and develop mathematical skills through an Information Communication Technology (ICT) intervention. For the intervention, I selected ICT applications that could address number sense inadequacies and other basic number deficiencies that underlie general mathematical skills. The choice to focus on number sense and basic mathematical skills was based on the fact that they form part of the basis of calculations in mathematics and are part of the mathematical deficiencies underlying dyscalculia; thus, the possible strengthening of number sense and mathematical skills might result in overall better performance in mathematics.

I implemented a pre- and post-test to determine whether or not any improvement in terms of basic mathematical skills and performance occurred following the intervention. The results I obtained have the potential to add to existing theory on suitable interventions in dyscalculia and more specifically, how to incorporate ICT during such interventions.

In undertaking this quantitative study, I was directed by the following specific aims:

- To determine and describe how software, including applications (Apps) may be utilised to support Grade 6 learners with dyscalculia, more specifically in terms of number sense skills.
- To determine and describe how software, including applications (Apps) may be utilised to support Grade 6 learners with dyscalculia, more specifically in terms of basic mathematical skills.

1.4 RESEARCH QUESTIONS

My study was guided by the following primary research question:

How can an Information and Communication Technology (ICT) intervention[5] *support (or not) the achievement in mathematics of Grade 6 learners with dyscalculia?*

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[5] Consult section 3.3.2 in Chapter 3 for more detail.

To address the primary research question, I formulated the following secondary research questions:

- How can software, including Applications (Apps) be utilised to support Grade 6 learners with dyscalculia in terms of number sense skills?
- How can software, including Applications (Apps) be utilised to support Grade 6 learners with dyscalculia in terms of basic mathematical skills?

1.5 HYPOTHESES

The following hypothesis applied to the primary research question:

Hypothesis 1:

This hypothesis aimed to determine whether or not an ICT intervention improved the achievement in mathematics of Grade 6 learners with dyscalculia. The hypothesis was formulated as follows:

- H_0: The performance of Grade 6 learners with dyscalculia in mathematics will not improve following an ICT intervention.
- H_1: The performance of Grade 6 learners with dyscalculia in mathematics will improve following an ICT intervention.

The following hypotheses applied to the secondary research questions:

Hypothesis 2:

The second hypothesis aimed to determine whether or not an ICT intervention had a positive effect on the number sense of Grade 6 learners with dyscalculia. The hypothesis was formulated as follows:

- H_0: The number sense of Grade 6 learners with dyscalculia will not improve following an ICT intervention.
- H_1: The number sense of Grade 6 learners with dyscalculia will improve following an ICT intervention.

The following additional sub-hypotheses related to the possible improvement of specific aspects of number sense:

Hypothesis 2.1:

This sub-hypothesis aimed to determine whether or not an ICT intervention had a positive effect on the *place value* of Grade 6 learners with dyscalculia. The hypothesis was formulated as follows:

- H_0: Performance on place value questions by Grade 6 learners with dyscalculia will not improve following an ICT intervention.
- H_1: Performance on place value questions by Grade 6 learners with dyscalculia will improve following an ICT intervention.

Hypothesis 2.2:

The following sub-hypothesis aimed to determine whether or not an ICT intervention had a positive effect on the *ordering of numerosities according to size* of Grade 6 learners with dyscalculia:

- H_0: Grade 6 learners with dyscalculia's ability to order numerosities according to size will not improve following an ICT intervention.
- H_1: Grade 6 learners with dyscalculia's ability to order numerosities according to size will improve following an ICT intervention.

Hypothesis 2.3:

The following sub-hypothesis aimed to determine whether or not an ICT intervention had a positive effect on *conservation of number* skill of Grade 6 learners with dyscalculia:

- H_0: The conservation of number skill of Grade 6 learners with dyscalculia will not improve following an ICT intervention.
- H_1: The conservation of number skill of Grade 6 learners with dyscalculia will improve following an ICT intervention.

Hypothesis 2.4:

This sub-hypothesis aimed to determine whether or not an ICT intervention had a positive effect on the *sequencing of numbers* of Grade 6 learners with dyscalculia:

- H_0: Performance related to the sequencing of numbers of Grade 6 learners with dyscalculia will not improve following an ICT intervention.
- H_1: Performance related to the sequencing of numbers of Grade 6 learners with dyscalculia will improve following an ICT intervention.

Hypothesis 2.5:

The following sub-hypothesis aimed to determine whether or not an ICT intervention had a positive effect on the *number concept* of Grade 6 learners with dyscalculia:

- H_0: The number concept of Grade 6 learners with dyscalculia will not improve following an ICT intervention.
- H_1: The number concept of Grade 6 learners with dyscalculia will improve following an ICT intervention.

Hypothesis 3:

The third hypothesis aimed to determine whether or not the ICT intervention had a positive effect on the basic mathematical skills of Grade 6 learners with dyscalculia. The hypothesis was formulated as follows:

- H_0: The basic mathematical skills of Grade 6 learners with dyscalculia will not improve following an ICT intervention.
- H_1: The basic mathematical skills of Grade 6 learners with dyscalculia will improve following an ICT intervention

Some sub-hypotheses applied that related to the possible improvement of specific mathematical skills, as indicated below:

Hypothesis 3.1:

This sub-hypothesis aimed to determine whether or not an ICT intervention had a positive effect on the *rounding of numbers* of Grade 6 learners with dyscalculia:

- H_0: The rounding of numbers by Grade 6 learners with dyscalculia will not improve following an ICT intervention.
- H_1: The rounding of numbers by Grade 6 learners with dyscalculia will improve following an ICT intervention.

Hypothesis 3.2:

The following sub-hypothesis aimed to determine whether or not an ICT intervention had a positive effect on the *multiples and factors* of Grade 6 learners with dyscalculia:

- H_0: The performance in questions related to multiples and factors by Grade 6 learners with dyscalculia will not improve following an ICT intervention.
- H_1: The performance in questions related to multiples and factors by Grade 6 learners with dyscalculia will improve following an ICT intervention.

Hypothesis 3.3:

This sub-hypothesis aimed to determine whether or not an ICT intervention had a positive effect on the *addition with carrying skill* of Grade 6 learners with dyscalculia:

- H_0: The addition with carrying skill of Grade 6 learners with dyscalculia will not improve following an ICT intervention.
- H_1: The addition with carrying skill of Grade 6 learners with dyscalculia will improve following an ICT intervention.

Hypothesis 3.4:

The following sub-hypothesis aimed to determine whether or not an ICT intervention had a positive effect on the *subtraction with borrowing* skill of Grade 6 learners with dyscalculia:

- H_0: The subtraction with borrowing skill of Grade 6 learners with dyscalculia will not improve following an ICT intervention.
- H_1: The subtraction with borrowing skill of Grade 6 learners with dyscalculia will improve following an ICT intervention.

Hypothesis 3.5:

The following sub-hypothesis aimed to determine whether or not an ICT intervention had a positive effect on the *multiplication of 3-digit with 2-digit numbers* of Grade 6 learners with dyscalculia:

- H_0: The multiplication of 3-digit with 2-digit numbers skill of Grade 6 learners with dyscalculia will not improve following an ICT intervention.
- H_1: The multiplication of 3-digit with 2-digit numbers skill of Grade 6 learners with dyscalculia will improve following an ICT intervention.

1.6 CONCEPT CLARIFICATION

In this section, I explain the core concepts underlying the study I undertook.

1.6.1 Dyscalculia

The word *dyscalculia* literally means *counting badly* and is composed of the prefix *dys,* which means *badly* in Greek, and *calculia,* which derives from *calculare* or *to count* in Latin (Pirani & Sasikumar, 2013). According to Butterworth (2011), dyscalculia can be regarded as a core deficit in numerosity processing. De Smedt, Noël, Gillmore and Ansari (2013) indicate that such difficulties to relate a symbol to its quantity may predict learning difficulties in the field of mathematics.

Piazza and his colleagues similarly indicate that "developmental dyscalculia is a learning disability that affects the acquisition of knowledge about numbers and arithmetic" (Piazza et al., 2010, p. 33). These authors conclude that dyscalculia primarily results from an impairment of the Approximate Number System (ANS) (Piazza et al., 2010). Closely related, Szücs and Goswami (2013, p. 33) describe developmental dyscalculia as "persistently weak mathematical performance of developmental origin, related to the weakness of some kind(s) of cognitive function(s) and/or representation(s)". Various other views on the concept dyscalculia exist, which I discuss in more detail in Chapter 2. In the context of this study, I regarded dyscalculia as primarily entailing a deficiency in number skills, number sense and numerosity processing that are necessary to develop mathematical skills.

1.6.2 Information and Communication Technology (ICT)

The concept of Information and Communication Technology (ICT) is used to refer to the collection of technologies (hardware) and software (programs and applications) that are available. The concept thus captures the “ways in which microchip technology has permeated many aspects of everyday life” (Drigas & Kostas, 2014, p. 46). In South Africa, the provision and availability of telecommunication infrastructure is growing, which makes the use of educational resources on digital devices such as smartphones, tablets and computers easier. Such resources can be used to improve the quality of instruction and learning, as promoted by the Department of Basic Education (2004).

According to White Paper 7, p. 14, on e-Education, "ICTs can advance higher order thinking skills, such as comprehension, reasoning, problem-solving and creative thinking and enhance employability" (Department of Basic Education, 2004). The use of ICTs in education is furthermore regarded as a potential motivational strategy that can, in turn, enhance productivity (Department of Basic Education, 2004). Closely related, electronic applications (Apps) refer to software and software packages designed for electronic devices, such as computers, laptops, tablets and smartphones. Examples of Apps that can be used for learning include digital collaboration applications, computer-based learning programs, web-based learning programs and virtual classrooms (Ardito et al., 2006; Ariffin, Halim & Aziz, 2017; Bjekić, Obradović, Vučetić & Bojović, 2014). Apps and content for Apps are available through the internet, on compact disc (CD), digital versatile disc (DVD), flash drives or any other medium that can be used to deliver electronic files.

In this study I used different Apps as part of the ICT intervention[6] I implemented with Grade 6 learners, namely *The Number Race* App, originally developed by Anna Wilson (2004) as an intervention for dyscalculia (Wilson, Dehaene, Pinel, Revkin, Cohen, & Cohen, 2006a; Wilson, Revkin, Cohen, Cohen, & Dehaene, 2006b) as well as games from *Sheppard Software* (Sheppard & Chapgar, n. d.) aimed to enhance a fluid sense of number among the respondents. I, for example, included *Math Lines* (adding, multiplying by single digits), *Math Man* (adding, place value, multiplying by single digits), as well as *Pop the Balloon* (count and order, adding and sequencing). Finally, I utilised the *Rockseries* App (RockSeries Educational Software, 2017) to access the lessons on the basics of numbers, values, place value, adding and subtracting in an attempt to correct some of the concepts lost because of dyscalculic tendencies.

1.6.3 Grade 6 learners

In this study, Grade 6 learners include learners in both public and independent schools in South Africa in the sixth grade. According to the South African Schools Act no 84 of 1996 (Department of Basic Education, 1996) a grade refers to a specific part of the educational programme of South Africa that a learner may complete in one school year. Public and independent schools enrol learners from Grade R (reception grade) to Grade 12, with primary schools focusing on Grade R to 7 and secondary schools focusing on Grade 8 to 12.

Learners in Grade 6 are therefore in their seventh year of formal education if they have passed every year and are typically 12 years of age. The concept *learner* relates to a person receiving formal education in terms of the South African Schools Act no 84 of 1996 (Department of Basic Education, 1996).

1.7 PARADIGMATIC PERSPECTIVES

The research aims to understand the world and reality in its context. How researchers look at the world influences their understanding of it (Creswell, 2014; Flick, 2015; Maree, 2016; Mertens, 2015). In this section, I introduce the paradigmatic perspectives

[6] Consult section 3.3.2 in Chapter 3 for the selection criteria and how these relate to mathematics constructs as included in the hypotheses.

I selected for this study, which determined how I viewed the various aspects and data. I provide a more comprehensive discussion in Chapter 3.

1.7.1 Epistemological paradigm: Positivism

I relied on positivism, as I aimed to determine objectively the effect of an ICT intervention on the performance of Grade 6 learners with dyscalculia in mathematics. According to Cohen, Manion and Morrison (2011, p.7), "positivism claims that science provides us with the clearest possible ideal of knowledge". Positivists, therefore, use logical analysis and empirical observations to explain procedures (Flick, 2015; Henderson, 2011), as also applied by me in this study.

My choice of positivism was thus based on this paradigm enabling me to investigate empirically and explain a real event using logical analysis, without influencing the outcome of the research due to personal biases and values (Flick, 2015; Mertens, 2015). I remained objective and merely provided technical support to the participating learners when they used the selected software applications during the intervention. The outcome of the intervention was measured with the aid of an objective test and not in a personal or subjective way by me as a researcher, resulting in the outcome being free from researcher bias.

Positivist research typically entails the testing of hypotheses, which can then be generalised to a defined population (Mouton, 2001) − in this case, Grade 6 learners with dyscalculia. As such, the outcome of the hypotheses testing enabled me as a quantitative researcher to make deductions about the effect of the intervention with the respondents (Mouton, 2001), thereby implying possible application in future in similar contexts and situations.

1.7.2 Methodological approach: Quantitative research

As a positivist, I followed a nomothetic quantitative approach, using a representative though small sample, numerical data and statistical analysis that enabled generalising to the population. I was able to remain objective and follow a structured approach, which was formalised and systematic (Athanasou, Mpofu, Gitchel & Elias, 2012; Cohen et al., 2011; Hoy, & Adams, 2015). Quantitative research is typically unbiased and neutral and entails procedures and methods that have been designed to discover general laws (Cohen et al., 2011). Quantitative research is regarded as formalised because it is generally ceremonious, and as systematic due to its orderly, methodological and logical nature (Flick, 2015; Seabi, 2012). This paradigm is grounded in positivism, empiricism, objectivism and rationalism.

My decision to follow a quantitative approach enabled me to do research where some variables could be controlled to exclude any potential effect of these variables on the outcome of the research (Cohen et al., 2011) in support of validity. As quantitative research aims for the generalising ability of results (Cohen et al., 2011; Flick, 2015; Morgan & Sklar, 2012), the results I obtained on the effect of the ICT intervention on the performance of a sample group of Grade 6 respondents with dyscalculia in mathematics may be repeated and generalised (Flick, 2015), if the investigation is repeated using the same methods under similar conditions (Flick, 2015; Maree & Pietersen, 2016a; Morgan & Sklar, 2012;). As such, other researchers may be able to confirm the results I obtained.

1.8 RESEARCH DESIGN AND METHODOLOGY

In this section, I briefly describe the research process and design, providing key parameters for the nature of the study I completed. I also introduce the sampling, data collection and data analysis procedures I utilised. I discuss these aspects in more detail in Chapter 3.

1.8.1 Broad overview of the research process

As background to my discussion of the various methodological choices I made and the strategies I used to complete this study, I provide an overview of the research process in Figure 1.2.

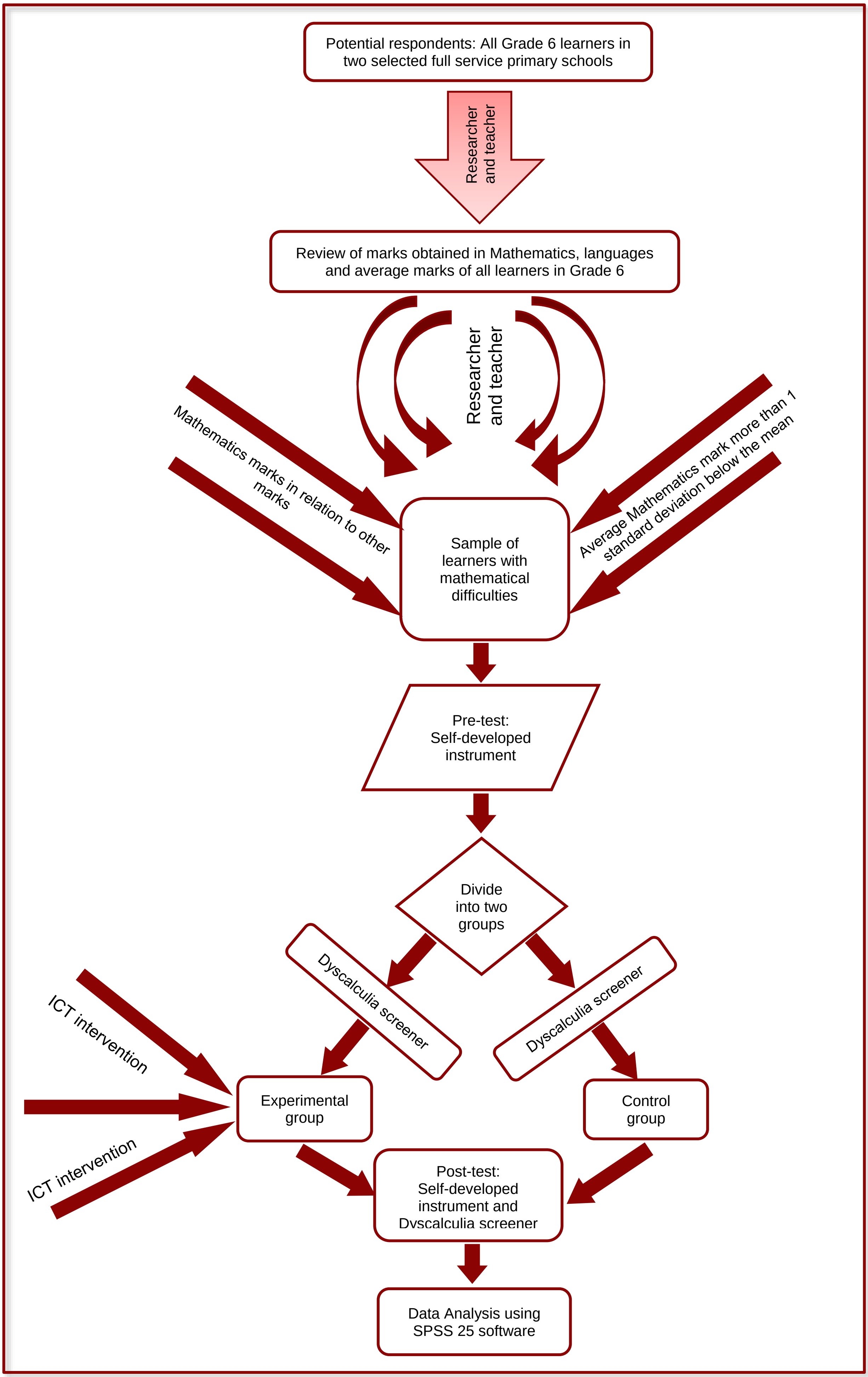


Figure 1.2: Research process

In sampling suitable respondents, teachers at the selected primary schools were requested to assist by identifying learners that performed poorly in Mathematics compared to their performance in other subjects. These learners were then tested using the Butterworth's *Dyscalculia Screener* (2003) to distinguish between learners who displayed impaired number sense inherent to dyscalculia, and those presenting with external mathematical developmental causes preventing them from performing optimally in Mathematics.

Next, all respondents with tendencies towards dyscalculia (initial sample) were randomly assigned to two groups; an experimental group and a control group. The control group continued with normal teaching, while the experimental group participated in the ICT intervention program, which had the potential to affect the dependent variable (Cohen et al., 2011; Maree & Pietersen, 2016b; Seabi, 2012), being the respondents' performance in mathematics. The intervention was followed by a post-test for all respondents of both groups to measure any possible change in the dependent variable (Maree & Pietersen, 2016a) and thereby determine the success, if any, of the intervention (Cohen et al., 2011).

1.8.2 Research design

I, as a quantitative researcher, implemented an experimental design, as the quantitative researcher "controls and manipulates one or more variables, with the aim of determining the cause-and-effect relationship between the variables" (Seabi, 2012, p. 84). I was thus able to observe the effect of the manipulation of independent variables on a dependent variable (Cohen et al., 2011) and use this effect to test the formulated hypotheses and draw conclusions. In this regard, I used a post-test to measure the dependent variable, while carefully controlling the independent variable.

As already indicated, the dependant variable entailed the respondents' performance in mathematics, which could be effected by the ICT intervention I employed. The control variables −covariates − included the respondents' grade level, the time spent on the intervention and the gender of the respondents. The ICT intervention was the independent variable.

In planning and developing the intervention, I identified various applications that I could include in an attempt to support the respondents' performance in mathematics. Firstly, I included *the Number Race* application, developed by Anna Wilson (Wilson et al., 2006a; 2006b). This application focuses on obtaining a fluid sense of number. I simultaneously included selected mathematical games from *Sheppard Software* (Sheppard & Chapgar, n. d.) to allow the learners to practise number lines, place value, sequencing of numbers, smaller and bigger numbers, addition, subtraction and multiplication, using *Math Line*, *Popping the Balloons*, and *Math Man*. I finally selected *Rockseries* (Rockseries Educational Software, 2017), a South African developed application, which consists of interactive lessons on compact disc. These lessons can assist learners in capturing concepts that have been lost because of dyscalculic tendencies.

1.8.3 Sampling and respondents

The target group for this study was Grade 6 learners suffering from dyscalculia. As it was not possible to include all learners with dyscalculia, a sample unit of Grade 6 learners with dyscalculia was taken from two full-service primary schools in the Bojanala District in the North West Province. I conveniently decided to undertake my research in the Bojanala District as I am teaching at a school in this area. Due to my employment at a resource centre school, I was able to access the full-service schools in the district and assist them with their Grade 6 learners with mathematical difficulties. This action is aligned with the requirements of resource centres in South Africa, as stipulated in the Education White Paper 6 (Department of Basic Education, 2001; 2010). As such, I conveniently selected two full-service schools in the district where I am employed due to their accessibility and availability (Creswell, 2014; Maree & Pietersen, 2016b).

In selecting respondents, I utilised non-probability purposive sampling and after that simple random sampling, firstly to identify the sample unit and then the experimental and control groups. I used non-probability sampling by relying on test scores to select the initial sample (Creswell, 2014; Flick, 2015; Maree & Pietersen, 2016b). This was necessary to ensure that I selected respondents that displayed dyscalculic tendencies. As such, the specific type of non-probability sampling I used was purposive sampling, as it was important to select learners with a probable tendency towards dyscalculia (Creswell, 2014; Flick, 2015; Maree & Pietersen, 2016b). Thereafter, I used simple random sampling to assign respondents to the experimental and control groups.

These strategies supported the positivist paradigm and quantitative approach I followed.

1.8.4 Data collection

I collected parametric data, as this kind of data “assumes knowledge of the characteristics of the population, for inferences to be made securely” (Cohen et al., 2011, p. 606). I decided to apply non-parametric statistics to the parametric data, even though it could be less powerful (Cohen, et al., 2011; Flick, 2015), as my sample size was small, due to the low prevalence of developmental dyscalculia. I found ratio scale orders have regular, equal intervals between data points and have a true zero; I was, however, able to rely on powerful statistics for data analysis.

The initial data set was collected through a pre-test, which contained basic questions on the work done in Mathematics in the first term of Grade 6, according to the Curriculum Assessment Policy Statement (CAPS)[7] and the annual teaching plan (ATP) of the North West Education Department. I then used the scores of the pre-test to assign the respondents to the experimental and control groups, by ordering the scores from low to high and randomly assigned the respondents to two groups. I next used descriptive statistics to describe and present the data for the experimental and control groups, as well as between the two groups. During this phase, it was not the performance of the respondents in the pre-test itself that was important, but rather their performance with the rest of the group.

Next, all respondents completed the Butterworth *Dyscalculia Screener* (GL Assessment, n. d.), an instrument that cannot diagnose a learner with dyscalculia, yet can screen learners who display a tendency towards dyscalculia (Butterworth, 2003). The respondents obtained standardised scores for each of the sub-tests of the *Dyscalculia Screener*, and the program provided the ranking of each respondent in each sub-test in terms of stanines.

[7] National school curriculum followed in South African public schools.

Furthermore, I implemented a post-test, in a format similar to the pre-test, to determine the effect of the intervention on the mathematics performance of the respondents with dyscalculia, following completion of the intervention. All respondents in the experimental and control groups completed the post-test for me to compare the performance of the learners who formed part of the experimental group to that of the control group. It is possible that other factors, such as illness, anxiety, emotional barriers, external assistance such as additional classes, etc. may have influenced the post-test results. However, all the respondents were requested to refrain from obtaining additional intervention and support while participating in the research project before their involvement. All respondents received the same mathematical teaching during school hours, for normal classroom teaching to have a minimal effect on the outcome of my study. The gender, age, race and home language of the respondents were furthermore documented as an indication of other factors that could have influenced the findings. Finally, the respondents completed the *Dyscalculia Screener* for a second time at the end of the data collection phase for me to identify any differences in the stanines of the subtests of the screener, and the diagnosis of respondents perhaps having a tendency towards dyscalculia.

The scores that the respondents obtained on the pre-test and post-test provided data on the ratio scale, like marks on a test are capable of having a true zero when implementing this scale (Cohen et al., 2011). Furthermore, I captured the raw data in a Microsoft Excel spreadsheet and then imported it into the Statistical Package for the Social Sciences (SPSS 25) program, relying on available mathematical and statistical functions that can be used to analyse data and indicate relationships. As I am computer literate, I did not foresee any challenges for capturing the data at the onset of the study. When documenting the data, in addition to capturing the respondents' ages, genders and races, I added a column to note anything out of the ordinary, such as illness and/or anxiety that could be observed during the intervention process.

1.8.5 Data analysis and interpretation

Data analysis involves the process of bringing order, structure and meaning to the mass of collected data (Cohen et al., 2011). According to Mouton (2001, p. 108), analysis entails "*breaking up* the data into manageable themes, patterns, trends and relationships". For my study, data analysis thus focused on making meaningful deductions and coming to conclusions that stemmed from the data. In Table 1.1, I provide an overview of the methods of statistics I utilised, with the aid of the statistical analysis software program SPSS 25 at the University of Pretoria. I discuss these in more detail in Chapter 3.

Table 1.1: Overview of data analysis procedures

Data	Analysis strategy	Rationale for including the strategy
Dyscalculia Screener	Performance on the *Dyscalculia Screener* was analysed according to the manual of the screener. Each respondent received a standardised score on each of the subtests of the screener.	The analysis was done in a standardised way to determine whether or not a respondent who displayed difficulty in learning mathematics had a tendency towards dyscalculia.
Pre-test and post-test performance (on their own and together)	Descriptive statistics were used to analyse the marks of the respondents, which were then used for the sample units, being the experimental and control groups.	Calculating the mean of each group on the same test provided information about the group's averages in relation to the other, as well as where each respondent's mark was in relation to his/her own group.
	The mean, quartiles, range, interquartile range, standard deviation and variance of the experimental and control groups were calculated.	The range, interquartile range, variance and standard deviation of each group described the spread of the distribution of marks (Creswell, 2014; Pietersen & Maree, 2016a). The standard deviation was used to standardise each respondent's mark by calculating the standard score (z-score) to compare it to the marks of the other group and also to the marks obtained on the post-test.

Data	Analysis strategy	Rationale for including the strategy
Pre-test and post-test performance (on their own and together)	Hypotheses on the means of the tests of the different groups and the relationship between the different groups were tested.	Hypotheses could be rejected or not, and inferring could be done from sample to population.
	The Mann-Whitney U test for two independent samples was completed for the experimental and control groups for the pre-test as well as the post-test. This test is the non-parametric equivalent of the t-test (Cohen et al., 2011; Pietersen & Maree, 2016d).	I decided to use the non-parametric Mann-Whitney U test rather than the t-test because of the small sample size and due to me not being able to assume a normal distribution. By using the Mann-Whitney U test, the ranks of the two groups could be compared and deductions made about the outcome of the intervention (Cohen et al., 2011; Pietersen & Maree, 2016d).
	The Wilcoxon signed-rank test was used to compare the pre-test and post-test results of the experimental group, thereby comparing two variables in a single sample, for a small sample size (Cohen et al., 2011; Pietersen & Maree, 2016d).	The non-parametric Wilcoxon signed-rank test was used to determine a statistically significant difference or not in the pre-test post-test scores of the experimental group (Cohen et al., 2011; Pietersen & Maree, 2016d). Deductions could then be made about the outcome of the intervention.

1.9 ETHICAL CONSIDERATIONS

Cohen et al. (2011) explain the importance of conducting ethical research, and for no harm to be done to respondents (Brooks, Te Riele & Maguire, 2014; Creswell, 2014; Mertens, 2015; Mertens & Ginsberg, 2009; Mouton, 2001). When respondents are children, a researcher needs to be even more sensitive to their welfare and always keep their best interests in mind (Cohen et al., 2011). All respondents in this study participated voluntarily and they, their parents, the school and the North West Education Department were informed about the purpose, content and procedures of the research to obtain the required permissions and consent prior to commencing with fieldwork. Participants were also informed about the potential benefits of the study (Cohen et al., 2011; Mouton, 2001).

Learners signed a confidentiality agreement, and I assured them that their contributions would be dealt with anonymously. They were requested to respect the anonymity of other respondents and the confidentiality of the research methods, intervention and collected data (Cohen et al., 2011). Respondents were invited to ask questions about the research whenever needed, and I aimed to gain their trust by being open, truthful, respectful, calm, trustworthy and considerate. The respondents, their parents, the school and the North West Education Department would furthermore receive feedback on the outcomes of the research, following completion of the qualification (Mouton, 2001).

A potential ethical dilemma I was cautious of and therefore addressed relates to the control group not initially receiving the intervention. As respondents received their normal Mathematics teaching at school, nobody was harmed, and the intervention program was implemented with the control group as well after the completion of the data collection to provide all the respondents with the same potential benefits. I elaborate on how I respected ethical guidelines in undertaking this study in Chapter 3.

1.10 VALIDITY AND RELIABILITY

It is important that a quantitative researcher attend to quality assurance measures to ensure the validity and reliability of the results (Seabi, 2012). In this section, I briefly discuss validity and reliability and then elaborate on these aspects and how I achieved them in Chapter 3.

1.10.1 Validity

According to Cohen et al. (2011), research is valid when it measures correctly and ethically what it is supposed to measure. A quantitative researcher can improve validity by using appropriate standardised instruments and relying on applicable and proper statistical measures during analysis (Cohen et al., 2011). As I relied on positivism, I aimed to adhere to the positivist principles of controllability, predictability, replicability, context freedom, fragmentation and atomisation of research, derivation of laws and universal statements of behaviour, observability and randomisation of samples

(Cohen et al., 2011). I furthermore attempted to minimise the inbuilt standard error, which is always part of quantitative studies (Cohen et al., 2011). Also, I attended to careful sampling to have homogeneous units as possible.

Throughout, it was important for me to consider possible threats to internal as well as external validity. Internal validity can be ensured when extraneous variables do not influence the results of a study, allowing the researcher to be certain that the results are the outcome of a treatment (Maree & Pietersen, 2016a; Seabi, 2012). Internal factors relevant in the current study include selection bias (where systematic differences in respondents could cause results), history (where teaching in the normal class, additional classes or extra work at home would influence the results), attrition (respondents dropping out of the study), the Hawthorne or placebo effect (respondents' changed behaviour due to their being part of the group, seen in, for example, improved marks) and instrumentation (the possibility of pre- and post-tests not being exactly on the same standard) (Maree & Pietersen, 2016a; Seabi, 2012). By remaining aware of these possibilities, I was able to minimise the influence of these factors on internal validity.

With regard to external validity, I remained aware of the possibility that internal validity can be threatened by factors that may influence the generalisability of results. These factors include bias during sampling, as well as not defining the population accurately (Seabi, 2012). As the population in this study was specialised, a limited population could be used to make conclusions. It was thus important for me to choose the respondents with care in an attempt to obtain a sample as true as possible to the specialised population, being Grade 6 learners with some form of dyscalculia.

1.10.2 Reliability

Reliability in quantitative research is, according to Cohen et al. (2011), the same as consistency, dependability and replicability over time, space and groups of respondents. This means that, if the same research is conducted at another time and place with different respondents, similar results will be obtained (Flick, 2015). In support of reliability in this study, where I included a pre- and post-test, it was important to consider factors such as the time that passed between the tests, the content and difficulty of the tests (with the content and standard having to be similar), and whether or not some respondents could have learned more about the subject on their own due to them wanting to look good, or as a result of their becoming interested or motivated to perform better through their involvement in the research process (Flick, 2015).

This type of reliability is called equivalent reliability (Flick, 2015; Pietersen & Maree, 2016c) and was tested by using statistical strategies such as the Mann-Whitney U test and the Wilcoxon matched-pairs signed-rank test. The internal consistency of the tests was furthermore validated by using the Cronbach Alpha and Spearman Correlation Coefficient in support of reliability (Cohen et al., 2011; Flick, 2015). In addition, I aimed to enhance reliability by excluding scores that are very different from the other scores, thus omitting the outliers.

In summary, statistical procedures carried out to investigate the research questions are important in quantitative research. It is furthermore essential to determine on which level statistical significance will be determined, for example on the 1% or 5% level of significance. I used SPSS 25 software to analyse the data in a reliable way. Chapter 3 offers a more comprehensive discussion of the statistical procedures that I utilised in support of reliability.

1.11 OUTLINE OF THE DISSERTATION

The chapters in this dissertation are structured as stipulated below.

Chapter 1: Overview of the study

Chapter 1 provides some background and a brief overview of the study I undertook. I explained the rationale and purpose of the study and formulated research questions and hypotheses. I also clarified key concepts and provided an overview of the paradigmatic choices I made. I presented a broad overview of the research design, sampling procedures, data collection and data analysis strategies. I also introduced the ethical considerations I considered, and explained briefly validity and reliability measures.

Chapter 2: The literature review

In Chapter 2 I discuss existing literature that relates to the focus of my study. To this end, I explain dyscalculia and what the condition entails, as well as the prevalence, causes, diagnosis, the profile of Grade 6 learners with dyscalculia and intervention strategies for dyscalculia. I also discuss ICT and the potential use of ICTs during interventions in support of Grade 6 learners with dyscalculia. I also provide and explain the conceptual framework in detail.

Chapter 3: Research methodology

In Chapter 3 I discuss the selected paradigm, the research design and the methodological strategies I utilised during the study. I justify and explain the sampling procedures, data collection and documentation techniques, as well as data analysis strategies. I describe the validity and reliability of the study and explain how I adhered to ethical guidelines in undertaking this quantitative study.

Chapter 4: Analysis and interpretation of the data

In Chapter 4 I present the results of the study. I summarise the results in graphic and tabular format, based on the statistics I obtained. In this discussion, I indicate correlations and highlight the effect of the ICT intervention on the performance of the respondents in mathematics.

Chapter 5: Conclusions and recommendations

In this final chapter of the dissertation, I provide a brief overview of the preceding chapters and then focus on the results, relating them to the research questions and coming to conclusions in terms of the hypotheses that I set out to test. I also make recommendations based on the results of the study.

1.12 CONCLUSION

In this chapter, I introduced the research topic and provided some background to my study. I explained the rationale and purpose of the study and formulated research questions. I also stated the hypotheses I set out to test. In addition to introducing the paradigmatic choices I made briefly, I mentioned the selected research methodology, sampling procedures, and data collection and analysis strategies. I also referred to ethical principles, validity and reliability measures.

In the next chapter, I present literature that relates to the topic under investigation. I discuss dyscalculia and possible intervention strategies for dyscalculia, and then explore ICT and its use as a possible intervention strategy in cases of learning difficulties in the field of mathematics. I conclude the chapter with an explanation of the conceptual framework that informed and guided my research.

CHAPTER 2 - LITERATURE REVIEW

2.1 INTRODUCTION

In the previous chapter, I introduced the topic of this study and presented the rationale for and purpose of the study. I stated the paradigmatic perspectives, as well as the methodological approach and research design I selected. Furthermore, I formulated research questions and stated hypotheses. I briefly described the data collection and documentation, as well as the data analysis and ethical considerations of my research.

In Chapter 2 I explore existing literature on dyscalculia in terms of the concept of numbers, development of numerical abilities, factors influencing learners' performance in mathematics, dyscalculia as a phenomenon and the profile of learners with dyscalculia. I discuss ICT and potential intervention strategies for learners experiencing mathematical difficulties, more specifically, those who show tendencies for dyscalculia.

2.2 DYSCALCULIA AS PHENOMENON

Scholars working in the field generally agree that dyscalculia can be regarded as a specific learning disability that affects the acquisition of arithmetical skills. In this context, Kuhn (2015) regards developmental dyscalculia as a specific learning disability that affects mathematical abilities such as necessary number processing, calculation or the retrieval of mathematical facts and procedures.

2.2.1 Conceptualising dyscalculia

The term *dyscalculia* is often used to describe disabilities in learning mathematics (Braunn, 2017; Butterworth, 1999, 2011; Butterworth & Laurillard, 2010; Butterworth, Varma & Laurillard, 2011; Chinn & Ashcroft, 2017; Ganor-Stern, 2017; Kaufmann, 2008; Kaufmann et al., 2013; Rapin, 2016; Sudha & Shalini, 2014; Trott, 2009), with developmental dyscalculia being regarded as a possible developmental deficiency (Butterworth, 2008; Kaufmann et al., 2013; Kuhn, 2015; Landerl, Bevan & Butterworth, 2004; Rubinsten, 2015a; Shalev, 2007; Shalev & Gross-Tsur, 2001; Szűcs & Goswami, 2013; Wilson & Dehaene, 2007). Closely related, Ostad (1997) refers to mathematically disabled children, with the term *mathematical learning disability* being widely used (Chinn, 2011; Dehaene, 2011; Desoete, 2015; Geary, 2010; Geary & Hoard, 2001; Mazzocco & Myers, 2003; Mazzocco & Thompson, 2005). According to Szűcs and Goswami (2013, p. 34) scholars in the field use different terminology when defining dyscalculia. Terminologies frequently used are Dyscalculia, Developmental Dyscalculia (DD), Arithmetic-related Learning Disabilities (AD), Arithmetical Disability (ARITHD), Arithmetic Learning Disability (ALD), Mathematical Disability (MD), Mathematics Learning Disability (MLD) and Mathematical Learning Difficulty (MLD).

Kosc (1974, p. 165) classifies dyscalculia as a learning disability, based on developmental dyscalculia defined as follows:

> *A structural disorder of mathematical abilities which has its origin in a genetic or congenital disorder of those parts of the brain that are direct anatomico-physiological substrates of the maturation of the mathematical abilities adequate to age, without a simultaneous disorder of general mental functions.*

Closely related, Shalev (2004 p. 766) describes developmental dyscalculia as "a specific learning disability affecting the normal acquisition of arithmetic skills in spite of normal intelligence, emotional stability, scholastic opportunity and motivation". According to Butterworth (2008), people with developmental dyscalculia will thus experience specific problems in understanding basic numerical concepts, especially the concept of numerosity. As such, they present with an impairment in their capacity to learn arithmetic.

Mathematics disability is furthermore described as children's poor mathematics achievement relative to their peers of the same age and grade-level in similar educational environments (Mazzocco & Myers, 2003; Szűcs, 2016). Accordingly, people with dyscalculia generally experience an inability to understand basic number concepts (Butterworth, 2008; Dehaene, 2011), have difficulty with number relationships and recognising symbols, and may experience difficulty to comprehend spatial and quantitative information (Butterworth & Kovas, 2013). They may also find it hard to remember basic number concepts and facts, understand place value, imagine a number line, and find the larger of two numbers. People with dyscalculia may, as a result, count on their fingers when solving arithmetic problems (Butterworth, 2003; Pirani & Sasikumar, 2013).

Numerosity is innate and leads to numeracy, which in turn leads to the acquisition of mathematical skills (Zerafa, 2015). Learners with dyscalculia may experience impairment in numerosity (Zhou & Cheng, 2015). Not all of them will, however, experience difficulty with all the concepts of mathematics, such as geometry, for example. Pirani and Sasikumar (2013) regard dyscalculia as a computational disorder, where the learner with dyscalculia experiences difficulty with simple adding, subtraction, multiplication and division problems, and also as a reasoning disorder, where the learner with dyscalculia experiences difficulty with abstract concepts of time and direction because of an inability to do mathematical reasoning and problem-solving. These mathematical barriers to learning can be inherited (Butterworth, 2011; Butterworth & Laurillard, 2010; Butterworth, Varma & Laurillard, 2011; Kaufmann, 2008).

According to Geary (1994), children with developmental dyscalculia often rely on immature problem-solving strategies. They will, for example, calculate easy sums such as 2 + 3 or 5 x 2 by counting rather than retrieving the fact from memory, which implies delayed development, rather than abnormal development (Geary, 2004, 2010; Geary & Hoard, 2001). However, Butterworth (2008) believes that these learners are not merely delayed, but rather think in a different way about numbers than other people. Developmental dyscalculia is also regarded as a possible impairment of a single cognitive representation, possibly resulting from a weakness in a constellation of multiple representations (Rubinsten, 2015b).

Kaufmann (2008) views dyscalculia as an umbrella term, which includes mathematical weaknesses of isolated and variable purposeful backgrounds. She defines developmental dyscalculia as a mathematical learning disorder that is rooted in insufficiency of numerical skills. Primary developmental dyscalculia can appear as a diverse disorder caused by individual deficits in numerical functioning, whereas the term *secondary developmental dyscalculia* is used when numerical dysfunctions are caused by non-numerical impairments, such as attention disorders (Kaufmann et al., 2013). Similarly, Sharma (2015) states that dyscalculia entails a disorder in the ability to do or learn mathematics. Children with dyscalculia will as a result, experience difficulty in number conceptualisation, and will have difficulty in understanding number relationships, as well as with learning and applying algorithms (Lambert, & Moeller, 2019; Sharma, 2015).

Macaruso, Harley and McCloskey (1992) suggest three components of the adult arithmetical system, highlighting the idea that a deficiency in any of these may lead to different ways in which mathematical difficulties will manifest. How numbers are perceived, understood and produced entails the number processing system. Awareness of number facts is related, which includes one's knowledge of tables, Arabic and numerical procedures, as well as the meaning of signs. The third system entails procedural knowledge, which includes the procedures for addition, subtraction, division, multiplication and more complicated calculations (Lambert, & Moeller, 2019; Temple, 1997).

It seems clear that most researchers, therefore, regard the inability to remember number facts and perform calculation procedures as important characteristics of dyscalculia (Geary, 2010; Landerl et al., 2004; Olsson, Östergren & Träff, 2016; Price & Ansari, 2013; Shalev & Gross-Tsur, 2001; Zhou & Cheng, 2015), even though some people with dyscalculia can still perform procedural methods accurately, without an underlying understanding of these (Temple, 1997).

I decided to use the terms *dyscalculia* and *developmental dyscalculia* in my research as an overall concept to emphasise the mathematical disability affecting learners' acquisition, representation and use of numerical symbols, concepts and procedures, as viewed by scholars such as Butterworth (2008), Geary (2004), Price and Ansari (2013), Kaufmann (2008), Kucian, Loenneker, Dietrich, Dosch, Martin, and Von Aster (2006), Shalev (2004), Von Aster and Shalev (2007), and Wedderburn (2016).

2.2.2 Prevalence of dyscalculia

Dyscalculia, a specific learning disability in mathematics, has been found to be the origin of mathematical difficulties of 6% to 7% of the population that experiences mathematics as difficult (Butterworth, 2003). This finding corresponds with studies conducted in the United States, Europe and Israel, which put the prevalence of developmental dyscalculia in the range of 3% to 6,5% for the population in these countries (Shalev & Gross-Tsur, 2001). In this regard, researchers (Beygi, Padakannaya & Gowramma, 2010; Zerafa, 2015) report that 5% to 8% of school-aged children do not grasp mathematical concepts and procedures, and will experience some form of mathematical disabilities.

The prevalence of dyscalculia as defined in the DSM-IV revised, is between 3,4% and 10% (Butterworth, 2003), indicating that this percentage of people experience mathematical difficulties. The Diagnostic and Statistical Manual of Mental Disorders (DSM–V) does not name dyscalculia, but classifies mathematical difficulties as a specific learning disorder with impairment in mathematics (American Psychiatric Association, 2013). According to the DSM-V, the prevalence of "specific learning disorders across the academic domains of reading, writing and mathematics is 5% to 15% among school-age children" (American Psychiatric Association, 2013, p. 70).

2.2.3 Causes of dyscalculia

Various views exist on the core of dyscalculia and mathematical difficulties. In terms of mathematics, a specialised network in the parietal lobes of the brain will respond when comparing numbers and to the number of objects displayed (Butterworth, 2002; Butterworth & Laurillard, 2016; Dehaene, 2011). As toddlers can identify small quantities and can distinguish between small and large quantities, babies are taken to be born with some inherent pre-disposition for numeracy (Dehaene, 2011; Price, Holloway, Räsänen, Vesterinen & Ansari, 2007; Shalev & Gross-Tsur, 2001). In a study comparing the neural correlates of basic numerical processing by learners with development dyscalculia to those without developmental dyscalculia, it was found that the brain-level impairment of learners with developmental dyscalculia and related impairment in necessary numerical capacity provides the foundation on which higher-level arithmetical skills are built (Ashkenazi & Henik, 2010b; Price et al., 2007).

Neuroimaging is seen to be central to confirming the use of the intraparietal sulcus (IPS) in simple number tasks, such as magnitude comparison, and also the role of the left angular gyrus in calculations and the retrieval of arithmetic facts (Butterworth, 2011; Butterworth et al., 2011; Dehaene, Molko, Cohen & Wilson, 2004; Kaufmann, 2008; Landerl et al., 2004; Price et al., 2007; Rapin, 2016). To this end, functional magnetic resonance imaging (fMRI) may be used to demonstrate that the IPS of individuals with dyscalculia is more inactive than the IPS of those without dyscalculia and that learners with dyscalculia generally have reduced brain matter (Butterworth, 2011; Butterworth & Laurillard, 2016; Kaufmann, 2008; Price et al., 2007; Ranpura et al., 2013). Closely related, a study using numerical magnitude processing, symbolic number comparisons and mental arithmetic, suggests that learners with dyscalculia have atypical brain activation during basic numerical tasks (Price & Ansari, 2013). According to Price and Ansari (2013, p. 9), this finding provides a "clear link between the brain circuitry underlying numerical magnitude processing and arithmetic achievement".

To this end, Figure 2.1, borrowed from Butterworth, Varma and Laurillard (2011, p. 1051), captures how the brain of a young learner with dyscalculia differs from one without dyscalculia. In recent studies, reduced activation of the IPS is specifically noticeable in learners with dyscalculia when comparing numerosity, number symbols and when doing arithmetic. The left IPS, right IPS and bilateral IPS of learners with dyscalculia generally indicate reduced grey matter, implying that these brain areas will not develop as well as the brains of learners without dyscalculia (Butterworth, 2002; Butterworth & Laurillard, 2010; Butterworth et al., 2011).

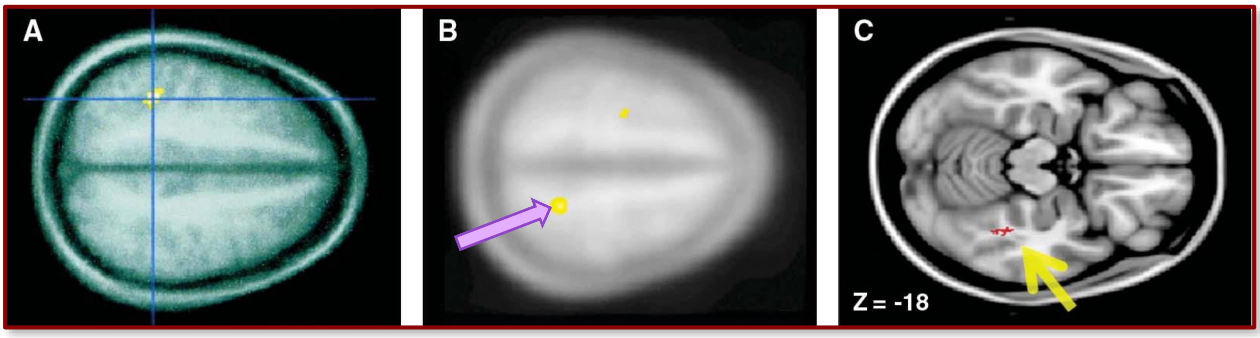


Figure 2.1: Structural abnormalities in young dyscalculic brains suggesting the critical role of the IPS

In Figure 2.1, image A shows a small region of reduced gray matter density in left IPS in an adolescent with dyscalculia. B shows right IPS reduced gray matter in the brain of a 9-year old with dyscalculia and C demonstrates the probability of connections from right fusiform gyrus to other parts of the brain (Butterworth et al., 2011, p. 1051).

It can, therefore, be concluded that a parietal dysfunctioning of the brain may cause developmental dyscalculia (Butterworth, 2002; 2008; Butterworth et al., 2011; Price et al., 2007). This implies that a learner with dyscalculia may have a dysfunction in the parietal lobes of the brain. Such a learner may be born with a predisposition to the dysfunctioning of certain parts of the brain, or it may be the result of underdevelopment caused by factors such as an injury, low socio-economic background, or limited educational stimulation (Ashkenazi, Mark-Zigdon & Henik, 2009a; Butterworth, 2011; Butterworth & Laurillard, 2016; Butterworth et al., 2011; De Visscher, Noël, Pesenti & Dormal, 2017; Dehaene, Piazza, Pinel & Cohen, 2003; Henik, Rubinsten & Ashkenazi, 2015; Iuculano, 2016; Jensen, 2010; Kucian & Von Aster, 2015; Kuhn, 2015).

According to Piazza et al. (2010) another view of the cause of dyscalculia is the result of an impairment in the ANS, which equips humans with the capacity quickly and instinctively to understand, estimate and manipulate non-symbolic quantities. Accordingly, problems to relate a symbol to its quantity is viewed as a better predictor of later difficulties experienced with mathematics than a weakness in the number module (Ansari & Dhital, 2006; Noël, Rousselle, & De Visscher, 2016). Keeler and Swanson (2001) as well as Bull, Espy and Wiebe (2008) relate dyscalculia to working memory functions, whereas Rourke and Conway (1997) ascribe dyscalculia to spatial processing difficulties.

As mathematics is a complex phenomenon the mathematics deficiency profiles of learners with developmental dyscalculia will differ, resulting in different possible causes for developmental dyscalculia (Skagerlund & Träff, 2014). Another view is the access deficit hypothesis, described by Rouselle and Noël (2007) as difficulty in accessing magnitude information from symbols, with individuals experiencing problems with numerals and number magnitude processing but not with performing non-symbolic tasks. In summary, learners experiencing general dyscalculia will probably have a deficiency in the ANS while learners with simple arithmetic fact retrieval (AFD) will probably suffer from an access deficit (Henik et al., 2015; Skagerlund & Träff, 2014).

Other scholars refer to disruptions in central executive functions as being at the core of dyscalculia (Blair & Razza, 2007; Hannula, Lepola & Lehtinen, 2010), with these executive processes driving the working memory system by coordinating and controlling information in the working memory, as such being central to mathematical computations that require continuous selection and manipulation of various items and processing steps (Fias, Menon & Szucs, 2013; Szucs, Devine, Soltesz, Nobes, &

Gabriel, 2013; Titz & Karbach, 2014; Wilson & Dehaene, 2007). In summary, Szücs (2016) posits that difficulty in acquiring mathematics skills involves three domains, namely space, language and executive functioning, where space refers to visual working memory, language to verbal working memory and executive functioning to organising activities and switching between tasks.

It seems that more than one type of dyscalculia is identified, one that is more about a deficiency in number sense and one that involves working memory and executive function (Ashkenazi & Henik, 2010b; Fias et al., 2013; Träff, Olsson, Östergren & Skagerlund, 2017). According to Wilson and Dehaene (2007), if an individual experiences a single core deficit that results in dyscalculia, it will probably entail one of the following:

- Number sense and nonsymbolic representation of numbers.
- Impaired connections between symbolic and nonsymbolic representations.
- A deficit in verbal, symbolic representation.
- A deficit in executive functioning.

Developmental dyscalculia can therefore be regarded as a disorder related to impairment in brain function, even though the type of function and region in the brain of the impairment may differ.

2.2.4 Diagnosis of dyscalculia

The diagnosis of dyscalculia is negatively affected by the fact that not all learners who experience mathematical learning difficulties have dyscalculia. Poor mathematics performance may, for example, be ascribed to several other causes, such as poor teaching, low socio-economic background, language deficiencies, low attention span, or other factors that can be corrected with remedial intervention (Haberstroh & Schulte-Körne, 2019). As dyscalculia is a diverse phenomenon, not all learners will furthermore display the same characteristics, once again making the diagnosis process difficult (Butterworth, 2003; Butterworth & Laurillard, 2010, 2016; Chinn, 2011; Chinn & Ashcroft, 2017; Emerson, 2015; Henik et al., 2015; Kaufmann & Von Aster, 2012; Moeller, Fischer, Cress & Nuerk, 2012).

The American Psychiatric Association describes disabilities in learning mathematics in the DSM-IV (1994) as evident when one's mathematical ability is substantially less than what is expected for one's age, education level and intelligence, and thus hinders one's achievement or daily living (American Psychiatric Association, 1994). The DSM-V (American Psychiatric Association, 2013) defines dyscalculia as a specific learning disorder with impairment in mathematics, characterised by four diagnostic criteria. Firstly, the individual must experience difficulty to master number sense, number facts or calculations, implying a poor understanding of numbers, their magnitude and relationships among them, as well as poor retrieval of mathematical facts and procedures. As a result, accurate and fluent calculations and mathematical reasoning is problematic. Secondly, mathematical skills are significantly below those that are expected of an individual's chronological age and as a result, interfere with academic or occupational performance or with life activities. Thirdly, these difficulties had to have been evident at a young age, before or during the school years and finally, other disabilities such as intellectual disabilities, or visual or auditory impairment may not have caused the mathematics learning disability (American Psychiatric Association, 2013). The DSM-V does not give specific diagnostic methods, but the methods used must enable the researcher to meet the four criteria characterised above for specific learning disorders with impairment in mathematics.

Shalev (2004) indicates that dyscalculia can only be diagnosed in cases of at least a two-year discrepancy between a learner's chronological grade in school and his or her mathematical skills, involving number concepts, number facts and/or arithmetic procedures. According to Wedderburn (2016), the principal of Unicornmaths[8], it is always important to distinguish between learners whose mathematical difficulties are due to neurodiversities such as dyslexia, those where difficulties are a result of other factors such as absence from school or poor teaching, and those whose problems with mathematics are a result of dyscalculia. Wedderburn (2016) recommends five steps of assessment when diagnosing dyscalculia. The author includes an initial screening test for dyscalculia using the *Dynamo Maths Profiler* (6 to 9 years old) (Dynamo Maths,

[8]Unicornmaths is a foundation in the United Kingdom founded by Sarah Wedderburn that specialises in the development of numeracy and the remediation of mathematics difficulties and dyscalculia.

n. d.) or *Dyscalculia Screener* (6 to 14 years old) (GL Assessment, n. d.), followed by a full assessment of cognitive non-verbal and verbal abilities and comparing these to age expectation. Thirdly, a learner's personal history needs to be assessed. Furthermore, a standardised test of mathematical ability is included and compared to age expectations. Finally, the Wide Range Intelligence Test (WRIT) forms part of the recommended assessment.

The *Dyscalculia Screener* (GL Assessment, n. d.), developed by Butterworth (2003), provides standardised software that can be used to determine dyscalculia tendencies through four computer-controlled tasks. The screener uses the speed at which a response is provided to determine a person's level of proficiency. As such a learner with slow reaction time but normal mathematical abilities may perform poor in using this instrument. As a result, Test 1 screens simple reaction time, with the time of the other tests subsequently being adjusted according to a learner’s reaction time. In Test 2 (dot enumeration), the person being tested must compare the number of dots (visual array of up to nine dots) with the numeral in the other half of the screen. Test 3 (number comparison) requires of the person being tested to select the larger (not taller) of two numbers, for example **4** and **2.** In Test 4, a sum, for example, 4 + 8 = 11 is given, requiring of the person being tested to indicate whether or not the sum is correct. According to Butterworth (2003), a learner who scores low on the first two tests will have a tendency to dyscalculia. If a learner scores low on the fourth test, but not on Tests 2 or 3, the learner’s poor mathematical abilities may rather be a result of poor instruction learning and learning (Butterworth, 2003). However, this test screens for dyscalculic tendencies only and does not diagnose dyscalculia.

Another test that may be used to detect dyscalculia is the Number knowledge test that was developed as part of the Number Worlds program, developed by Griffin (2004a) to teach specific math concepts, enhance number sense, computational fluency, mathematical reasoning and communication. The test was developed to measure a learner’s conceptual knowledge of numbers, thus number sense, at ages 4, 6, 8 and 10 years. The test is an oral test and determines whether or not a learner is functioning at, below or above age/grade level in number knowledge. It is furthermore used to determine which number concepts a learner has mastered, to assess a learner’s progress over a certain period and to help pinpoint on which level of the Number

Worlds program a learner can start (Griffin, 2004b, 2005).

Another way to diagnose dyscalculia is to assess a learner's arithmetic skills and check for a possible discrepancy between the intellectual potential of a learner and his/her arithmetic achievement, or to look for a discrepancy of at least two years between chronological grade and the achievement level (Shalev & Gross-Tsur, 2001). In this regard, Raven's Standardised Progressive Matrices Test (Raven, 2008) is frequently used to determine non-verbal reasoning. This test consists of a series of visual pattern designs with a piece missing. The correct piece must be selected to complete the design (Landerl et al., 2004; Skagerlund & Träff, 2016a).

As such, different ways are seemingly used to diagnose learners with dyscalculia, for example, Gross-Tsur, Manor and Shalev (1996) look at mathematical achievement in the 20th percentile and two grade years behind, for at least a year. Ostad (1997), on the other hand, selects learners that have been registered for long term help, while Mazzocco and Myers (2003) focus learners below the 17th percentile in a mathematics test that have experienced difficulties in mathematics for at least two years. Finally, Desoete, Ceulemans, De Weerdt, & Pieters (2012) look at two standard deviations below the norm in a mathematics test, assessed by a teacher, for MLD, and one standard deviation below the norm for mathematics learning problems.

2.3 DEVELOPMENT OF NUMERICAL ABILITIES

The Swiss psychologist, Jean Piaget, believed that all ideas and concept formation are derived from sensory experiences. All cognitive development occurs through stages and each stage forms the platform for the next stage so that no stage can be skipped (Ojose, 2008; Piaget, 1964), thus the importance of understanding the development of numerical abilities during infancy. Abstract ideas are created through particular experiences that are generalised. Piaget's theory on the cognitive development of children provided important information to educators about how children acquire concepts and ideas (Ojose, 2008). According to Piaget (1952)[9], understanding symbols and abstract concepts occur only after experiencing the ideas and concepts on a concrete level. Therefore, children are not able to comprehend

[9] I acknowledge that this is an old source, but I wanted to use the primary source.

numerical concepts before they can handle objects, separate one group from another, analyse objects and remember the results of their experiences (Piaget, 1952). This is possible around age two or three (Butterworth, 1999).

According to Piaget, concepts of sets, objects or calculation are absent during infancy. As a result, a child will not possess a constant representation of the number before the age of six or seven (Piaget, 1952). Von Aster and Shalev (2007) also proposed a model of number acquisition for the securing of numerical abilities in children, in which the achieving of number representations from infancy to schooling are defined by four steps. The steps are, firstly, the developing of a basic number sense that is based on a fundamental system representation of magnitude, thus the quantity of a specific number. The second step is the acquisition of number words during preschool, followed by the third step, which is learning Arabic symbols in primary school, and the fourth step, the developing of the mature mental number line. According to Dehaene (2011) who developed the concept of the mental number line, numbers are manipulated and represented mentally in three different codes, Arabic, verbal, and analogic code. The analogic code is the abstract and amodal (a frame, semantic network used for understanding words and concepts) internal representation of the magnitude of non-symbolic magnitudes, which is necessary to succeed in developing a mental number line (Lafay, St-Pierre & Macoir, 2017; Linsen, Verschaffel, Reynvoet & De Smedt, 2015; Sasanguie, De Smedt & Reynvoet, 2017; Siegler, 2016). A further look into the stages of intellectual development provides more insight into the mathematical abilities of learners.

2.3.1 The infancy stage

Piaget's theory of cognitive development consists of four stages. During the first stage, the sensorimotor stage, the child's functioning changes from a reflex level to a level where the child can perform practical actions. This sensorimotor stage (infancy) which is from birth to about 24 months, consists of six sub-stages. During the first substage, birth to approximately one month, the various reflexes that determine the infant's interactions with the world are the core of the infant's cognitive life, and form the basis of schemas that will develop. From one to four months, the second substage, the innate reflexes develop to acquired behaviours or habits, in which the infant shows primary circular reactions (repeated behaviours) and the infant begins to coordinate separate actions into single integrated activities. During the third substage, four to eight months (coordinating of secondary schemas), the child starts using external objects in his or her behaviour and develops schemas for handling external objects. Also, in this substage of secondary circular reactions, concepts of classification and forming of relations between objects and actions start to develop, thus the infant begins to act on the outside world. In the fourth substage (coordination of secondary circular reactions), from eight to 12 months, the infant combines and coordinates schemas to adapt to external objects and to generate a single act. During substage 5, the tertiary circular reactions stage (12 to 18 months) the infant develops the deliberate variation of actions that bring desirable consequences. The infant does not just repeat enjoyable activities, but seems to carry out miniature experiments to observe the consequences. In substage 6 (18 to 24 months) the internalisation of schemas develops. It is characterised by the capacity for mental representation or symbolic thought, although it is only on a concrete level. Infants develop the use of primitive symbols and use these symbols to think about the world and interpret it in their own way, thus infants shift to symbolic thinking (Lourenço, 2016; Ojose, 2008; Piaget, 1952).

Piaget's view of infants' limited numerical understanding is conservative (Siegler, 2016) and their levels of development may differ severely, as the development is determined by many factors, for example experience, culture, maturity and ability (Ojose, 2008). Many of the experiments conducted by researchers conclude that humans, and even animals, are born with a basic sense of and innate understanding of numerosity (Butterworth, 1999; Butterworth, Gallistel & Vallortigara, 2018; Butterworth & Kovas, 2013; Butterworth & Varma, 2013; Geary, 1994; Hyde & Spelke, 2011; Izard, Sann, Spelke & Streri, 2009; Starkey & Cooper, 1980; Strauss & Curtis, 1981; Xu, 2003; Xu & Arriaga, 2007; Xu & Spelke, 2000; Xu, Spelke & Goddard, 2005). Three issues can be observed when considering the numerical capabilities of infants (Strauss & Curtis, 1981). Firstly, the infant's understanding of numerosity means that the infant has the ability to discriminate between arrays of objects on the basis of the number of objects in the array. According to Starkey and Cooper (1980), it is possible for infants to discriminate, represent and remember small numbers of items. The capacity to do this is probably underlined by a perceptual enumeration process, namely subitising. Subitising is the ability to tell numerosity at a glance, without counting, thus to know there are three or four objects at just a glance, without having to count them (Ashkenazi, Mark-Zigdon & Henik, 2013; Butterworth, 1999). According to Butterworth (1999), the newborn infant can use subitising to distinguish between the numbers of objects, up to 4, in an array, showing there is some form of number capacity present in children before verbal counting (Starkey & Cooper, 1980). Secondly, infants have an awareness of ordinality. This means they are aware of the fact that three comes after two, and two after one, without it being taught to them (Starkey & Cooper, 1980; Strauss & Curtis, 1981). Thirdly, infants have the ability to add and subtract. Even babies as young as 5 months old can add and subtract small quantities (Wynn, 1992a). According to Wynn, the infants do not just notice that there is a change in numerosity, but they seem to be aware of the fact that 2-1 = 1 and 1+1 = 2 (Wynn, 1992a).

Early arithmetic is needed to transform verbal and numerical knowledge into math equations and algorithms, to understand mathematical concepts and operations, and to select appropriate strategies for computation and problem-solving (Desoete, 2015). As infants have some understanding of numbers and counting, as well as the capability to link numbers to objects in this stage, they should be provided with activities that include counting, to enrich their conceptual development of number (Ojose, 2008; Starkey & Cooper, 1980; Strauss & Curtis, 1981; Wynn, 1992b; Xu, 2003; Xu et al., 2005)

2.3.2 Pre-school development

The second stage of Piaget's theory of intellectual development, which is from 2 to 7 years (toddler and early childhood), is the stage of pre-operational thinking when the child's understanding of the world shows a noticeable improvement (Piaget, 1952). During this stage, there is an increase of language ability and symbolic functions, thus thought and representation are developed, but there is no conservation and therefore no reversible operations (Piaget, 1964). This stage is divided into two substages, the preconceptual thinking stage (2 to 4 years) and the intuitive thinking stage (4 to 7 years) (Piaget, 1952).

In the preconceptual thinking substage the child has an incomplete understanding of the properties of classes, although he develops the ability to have a mental representation of objects and to identify objects because of their affiliation to a specific class. The child also develops transductive reasoning that is not always logical, so that he makes conclusions from one specific to another, and thus sometimes makes correct deductions, but not always. During the intuitive thinking substage, the child makes assumptions and deductions using his perceptions of life. This substage is also characterised by egocentrism, which is the incapability to accept the opinions of other persons (Piaget, 1952; 1964). Memory and imagination are developed throughout the second stage. According to Ojose (2008), children in this stage should participate in problem-solving tasks with available materials, such as sand, water, blocks, and engaging in discussions about characterising objects (Ojose, 2008).

At the age of 2 to 3, children begin learning to count, although they may only understand the cardinal meanings of the counting words from 4 to 5 years of age. Children must acquire their culture's number words by rote, knowing the sequencing of numbers, the meaning of number words and how these words relate to number concepts (Geary, 1994; Gebuis & Reynvoet, 2015; Gelman & Butterworth, 2005; Wagner, Kimura, Cheung & Barner, 2015; Wynn, 1990; 1992b). During this stage, children start mapping number words onto the specific representations for the quantities (Geary, 1994), which usually include tagging (assigning a number word to each counted object) and partitioning (breaking collections of items to be counted into the counted group and the not yet counted group) (Chu & Geary, 2015; Gelman, 2006; Marmasse, Bletsas & Marti, 2000; Wynn, 1990; 1992b). Children also come to the understanding of cardinality (the number of the last counted object symbolises the number of objects counted) and ordinality (that sequential number words points to successively more substantial quantities, e.g. 6 is more than 5) during the pre-school stage (Chu & Geary, 2015; Geary, 1994; Wynn, 1992b); concepts develop gradually and are not always established in this stage, even at the age of 7 (Dehaene, 2011; Geary, 1994). Simple addition and subtraction also develop in this stage, from 4 to 5 years, but generally by using counting strategies (Piaget, 1952).

2.3.3 Primary school and early adolescence

Piaget's third stage (elementary and early adolescence), is the concrete operational stage (7 to 11 years), where rules such as reversibility, identity and compensation manage the learner's logic. The learner develops the ability to describe objects by terms of classes, numbers and series (Geary, 1994; Piaget, 1952). Operations of classification, ordering in series, construction of the idea of number, spatial operations and elementary mathematics develop (Piaget, 1964).

The learner uses his senses to attain knowledge and can consider two or three dimensions simultaneously and not just successively. Real experiences, to make abstract ideas concrete must be provided to assist the learners in making connections between concrete activities and mathematical concepts (Ghazi, Ullah, & Jan, 2016; Ojose, 2008). The learner develops mathematical ideas, tools and procedures for solving problems (Ojose, 2008; Piaget, 1952). According to Varol and Farran (2006) learners from 3 to 6 years must receive high quality and challenging mathematics education to ensure measurable growth, as a sound mathematics foundation set in this early years is necessary for mathematics performance in following years.

In this third stage, learners develop the ability to order objects in series by using factors like increasing and decreasing length, volume and weight. They also develop the ability to use common characteristics to group objects (Ojose, 2008). Learners also develop knowledge of fractions, decimals and rational numbers from Grade 4 to Grade 6, which is necessary for their mathematical development in following years (Hansen et al., 2015; Siegler, 2016; Siegler & Braithwaite, 2017).

Von Aster and Shalev (2007) describe a 4-step development of numerical cognition, in which the acquisition of number sense abilities and basic mathematical strategies over time and the capacity of the working memory are the variables (Figure 2.2) that will mostly be completed in this stage.

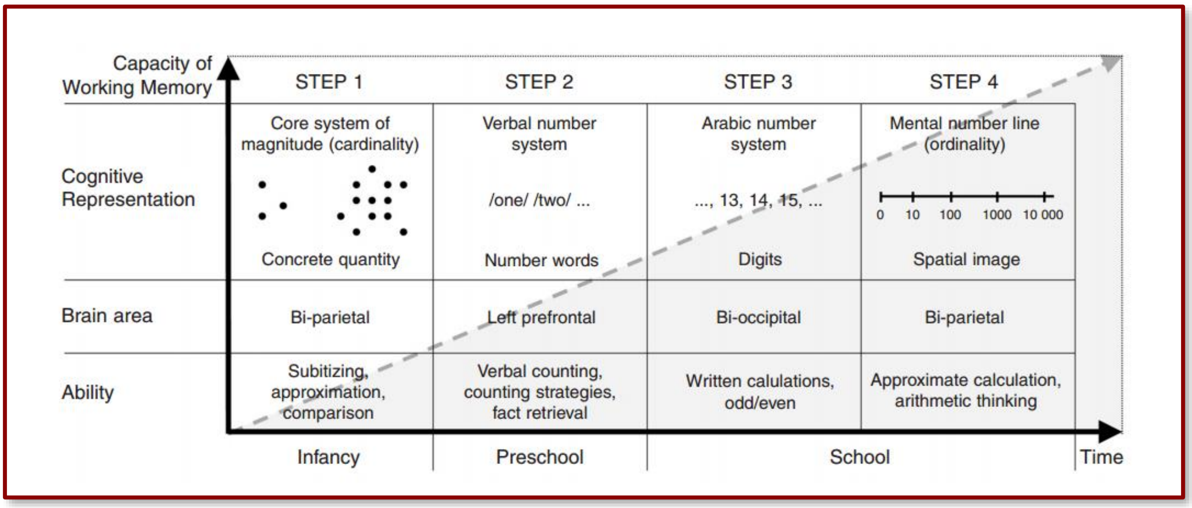


Figure 2.2: Four-step development model of numerical cognition, adapted from Von Aster and Shalev (2007 p. 870)

Each step in this 4-step model is a pre-condition for the next step. Thus, during infancy, the basic core system of magnitude must be developed, so that the infant is capable of subitising. Approximation and comparison before the pre-school stage, where the verbal number system is developed, will lead to verbal counting and counting strategies. This, together with the increase of working memory, will improve fact retrieval, which is necessary in mastering mathematical skills. The next two steps occur during the school years. During step 3 the Arabic number system that will enable the learner to do written calculations and become aware of other number characteristics, such as odd and even numbers, develops. Finally, during step 4, the mental number line develops, enabling the learning of approximate calculations and arithmetic thinking. In Figure 2.2, the grey area beneath the dotted line shows the increasing working memory over time (Von Aster & Shalev, 2007). Developing the mental number line is an ongoing process while expanding the knowledge of whole numbers to fractions, decimals and rational numbers (Lafay et al., 2017; Merkley & Ansari, 2016; Siegler, 2016).

2.3.4 Adolescence and beyond

Adolescence and early adulthood is the stage of formal operations and occur after 11 and 12 years. In this stage, intelligence is shown by logically using symbols related to abstract concepts. Children develop abstract thought, can converse and think logically. Propositional thinking, which deals with hypotheticals, is developed, so that learners can reason on hypotheses and not only on objects (Geary, 1994; Ojose, 2008; Piaget, 1952; 1964). The numerical development of the early years is the platform for the math equations, algorithms, mathematical concepts and operations, and utilising appropriate strategies for computation and problem solving needed in high school mathematics (Desoete, 2015; Merkley & Ansari, 2016; Siegler & Braithwaite, 2017; Watts et al., 2015; Watts, Duncan Siegler & Davis-Kean, 2014; Young, Levine & Mix, 2018).

All this research indicates that most children are supposed to be able to do mathematics up to at least an average level, as they are born with an innate numerosity ability. Even if they are not cognitively inspired in their home environment, when they go to pre-school and school they ought to be able to master a certain level of mathematics (Purpura & Logan, 2015).

2.4 UNDERSTANDING THE CONCEPT OF NUMBERS AND NUMBER SENSE

Numbers are used by all daily, when spending money, buying and selling, counting, practising sports like football, rugby, gymnastics and tennis, to mention but a few examples. In addition to daily living, theories of physical nature like Newton's law of motion, Einstein's $E = mc^2$ alternatively, and the numerically ordered periodic table of elements are based on numbers. Attributes such as intelligence, reading age and degree of introversion are also qualified by using numbers. Therefore, numbers are taken as "something about us, an intrinsic part of human nature, like the ability to see colours" (Butterworth, 1999, p. 4).

2.4.1 Understanding number sense

According to Butterworth (1999), an understanding of numbers and the difference between e.g. 5 and 4 implies an understanding of the abstract. As cultures without words for numbers also count, calculate and trade, the concept of numbers is taken as universal (Butterworth, 1999).

Number sense is a complex entity. According to Berch (2005), who reviewed existing literature and compiled a list of characteristics of number sense, this concept implies a variety of skills and abilities. It shows the ability to observe any small collection and distinguish any change in the collection, e.g. when an object is removed from or added to the collection without seeing it happen. Furthermore, number sense is also about the ability to approximate or estimate and to have a primordial, inborn and non-verbal capacity to process approximate numerosities (Berch, 2005; Butterworth, 1999; Butterworth et al., 2018; Hannagan, Nieder, Viswanathan & Dehaene, 2018; Piazza et al., 2010).

Having a good number sense also indicates having fundamental abilities and intuitions about numbers and arithmetic, thus having a non-algorithmic sense for numbers. This could lead to an excellent structured conceptual framework for working with numbers, which may support the relationship between numbers and operations and the understanding of number meanings and the multiple relationships between numbers (Berch, 2005; Butterworth, 1999; Butterworth et al., 2018; Dehaene, 2011). This framework integrates the many links between mathematical principles, relationships and procedures (Butterworth et al., 2018; Skagerlund & Träff, 2016b; Tosto et al., 2017). According to Berch (2005), a good number sense enables a good understanding of numbers that is needed to measure things in the actual world, as well as help moving without effort between the physical world of quantities and the mathematical world of numbers and numerical expressions.

The ability to use numbers in various ways, e.g. to compose and decompose numbers naturally, to compare numerical magnitudes, to develop strategies for solving complex problems and to "use numbers and quantitative methods to communicate, process, and interpret information" (Berch, 2005 p. 344), is a result of a good number sense (Dehaene, 2011; Hannagan et al., 2018; Tosto et al., 2017; Van Hoof, Verschaffel & Van Dooren, 2017). With a good number sense it may be possible to recognise whether a number belongs to a certain group or pattern of numbers and to identify gross numerical errors (Berch, 2005; Butterworth & Varma, 2013; Dehaene, 2011). It is unlikely to have knowledge of the effects of operations on numbers and to be confident and flexible working with numbers without having a good sense of number. Furthermore, to use the relationships between arithmetic operations to understand the base-10 number system, as well as to have a mental number line that can be used to represent and manipulate numerical quantities in the brain are likely with a good number sense (Berch, 2005; Butterworth, 1999, 2018; Dehaene, 2011; Lafay et al., 2017; Sousa, 2015).

Having a good number sense enables the representation of similar numbers in several ways determined by the context and purpose of the representation. Thus, a good number sense is about having a proficiency or type of knowledge about numbers. Number sense is not static and develops and matures during childhood with experience and knowledge (Geary, Berch & Koepke, 2014; Gebuis & Reynvoet, 2015; Griffin, 2004b; İvrendi, 2016; Lafay et al., 2017; Purpura & Logan, 2015; Tosto et al., 2017; Vandervert, 2017; Wong, Ho & Tang, 2017).

Berch's (2005) summary demonstrates that number sense as a whole consists of multiple forms of number senses that progress through development and education, and are integrated in the subsequent sense of number of an individual (Butterworth et al., 2018; Butterworth & Varma, 2013; Dehaene, 2011; Feigenson, Dehaene & Spelke, 2004; Gebuis & Reynvoet, 2015; İvrendi, 2016).

2.4.2 Understanding the number module

Dehaene (2011) hypothesised in his book, *The Number Sense* that there is a brain mechanism that he called The Accumulator, which interprets numbers as approximate quantities, so that different numbers are represented by different levels. Butterworth (1999) also identified a brain mechanism that identifies numerosities, which he called the Number Module. According to Butterworth (1999, p. 8) the *Number Module is the innate core of our numerical abilities* – *a numerical 'start-up kit'. It categorises the world in terms of numerosities, up to 4 or 5. To get beyond 5 we need to build onto the Number Module, using the conceptual tools provided by our culture*.

Butterworth (1999) divides these tools into four categories, namely body part representation (toes, fingers), linguistic representation (counting words), numerals (written symbols) and external representations (calculators, tallies, etc.). These tools are regarded as prerequisites to work with numbers and are normally acquired from other people (Butterworth, 1999).

The number module entails two central parts. The first, the parallel individuation system, used to subitise small numbers, refers to the identification of small sets of numbers by merely looking at them, without counting (Piazza, 2011). According to Butterworth, individuals can usually accurately subitise up to sets of five (Butterworth, 1999). The second system is the approximate number system (ANS), which entails a cognitive system that allows one to estimate the magnitude of a group of numbers, more significant than four, without relying on language or symbols. This is already used in early infancy (Feigenson et al., 2004; Izard et al., 2009; Mazzocco, Feigenson & Halberda, 2011a; 2011b; Piazza, 2011).

The ANS, which is an inherent system used when representing, comparing and combining the magnitudes of collection of objects (De Smedt et al., 2013; Feigenson et al., 2004; Geary et al., 2014; Halberda & Feigenson, 2008), matures through childhood and plays an essential part in the development of other numerical abilities. Several scholars believe that the ANS of a child can predict the success of mathematical achievement in school (Halberda, Mazzocco, & Feigenson, 2008; Jang & Cho, 2018; Mazzocco et al., 2011a, 2011b; Mazzocco & Thompson, 2005; Piazza, 2011; Piazza et al., 2010), yet other studies indicate that mathematical competencies are independent of ANS acuity. Individual differences in mathematics achievement may thus rather be related to the fluency of processing symbolic numerical and arithmetical information (Bugden & Ansari, 2016; De Smedt et al., 2013; Rousselle & Noël, 2007).

In support of the first group of scholars' view, Fazio, Bailey, Thompson and Siegler (2014) also found that ANS acuity and symbolic number knowledge individually contributed to the fifth graders' mathematics achievement involved in their study. In confirmation, Libertus and colleagues found that "the precision of 5- to 7-year-old children's mapping between the approximate number system and exact number words correlated with their math abilities" (Libertus, Odic, Feigenson & Halberda, 2016, p. 222). These scholars conclude that additional cognitive processes existing beyond ANS precision will play an important role in mathematics performance.

2.5 FACTORS INFLUENCING PERFORMANCE IN MATHEMATICS

Researchers across the globe agree that learners of all ages may experience barriers to learning mathematics (Butterworth, 2003; Dehaene, 2011). This often results in adults not possessing the numeracy skills required for everyday living (Cragg & Gilmore, 2014). Early acquisition of mathematical skills can predict academic success in life, in areas such as reading, mathematics and science (Engel, Claessens & Finch, 2013). Mathematics at school level is like a "house of cards" (Butterworth, 1999, p. 298). It is crucial to ensure that each layer is securely and precisely constructed, to serve as a steady and robust foundation for the layers directly above, keeping them from tumbling down (Butterworth, 1999). If a learner is absent or not giving attention, and missed out at a particular stage (stage A) of a concept in the mathematics curriculum, it will be hard for him or her to master the next stage (stage A+1) of that concept fully. As a result, the following stage (stage A+2), and all other stages and concepts based on the previous stages will not be fully mastered, causing the learner to have difficulty with that concept and other concepts based on it (Dowker, 2005). Therefore the gap between the learner's understanding and what is being taught in class will get wider and wider, resulting in severe difficulties in mastering the mathematics curriculum (Butterworth, 1999; 2002; Geary, 1994).

A challenge for many educators is to teach Mathematics to able children who are unable to learn arithmetic (Butterworth & Laurillard, 2010). Learners aged 11 are nearing the end of Piaget's concrete operational stage and should have mastered basic numeracy skills to proceed to the formal operational stage, learning formal mathematics, yet 5% of the participants in a study in the United Kingdom failed to obtain the numeracy skills that a 7-year-old should possess and 21% of the 11-year-olds did not reach the expected mathematical skill levels (Cragg & Gilmore, 2014). Many learners thus face difficulty with mathematics.

Difficulties in learning mathematics can differ in both nature and intensity (Katmada, Mavridis & Tsiatsos, 2014). According to Drigas and Ioannidou (2013), several factors can cause difficulties with mathematics, such as problems with concentration (Drigas, Ioannidou, Kokkalia & Lytras, 2014; Drigas & Kostas, 2014; Fernández-Alonso, Suárez-Álvarez & Muñiz, 2015; Howie, 2003; Kokkalia & Drigas, 2015), resulting in learners missing necessary steps (Butterworth, 1999, 2002; Drigas et al., 2014; Drigas & Kostas, 2014). Missing vital steps in the founding of mathematical concepts will result in gaps in their knowledge base, resulting in poor performance in mathematics (Bailey, Siegler & Geary, 2014; Dowker, 2005; 2013; Drigas & Kostas, 2014). Learners may also experience cognitive risk factors like auditory- and cognitive-processing difficulties that may hinder the mathematics learning process. Therefore, the learners may be unable to interpret what they see or hear (Arcara et al., 2017; Bartelet, Ansari, Vaessen & Blomert, 2014; Moll, Göbel, Gooch, Landerl & Snowling, 2016).

Metacognitive deficiencies, not to be able to think about thinking, being aware of one's awareness, knowing about knowing − thus, higher order thinking skills − may hinder learners in applying and adapting learning strategies in mastering mathematics (Bartelet et al., 2014; Desoete, 2009; 2015; Lai, Zhu, Chen & Li, 2015). An important factor influencing performance in mathematics and causing learners not to remember steps and to mix up steps is memory problems (Bull et al., 2008; Drigas, Kokkalia & Lytras, 2015; Passolunghi & Siegel, 2001), more specifically short-term memory, visual memory and working memory (Baddeley, 1992), labelled executive functioning by scholars in the field (Askenazi & Henik, 2010b; Ashkenazi & Henik, 2012; Ashkenazi, Rubinsten & Henik, 2009b; Fias et al., 2013; Henik et al., 2015; Shalev, 1997; Szucs et al., 2013; Szűcs, Devine, Soltesz, Nobes & Gabriel, 2014; Wilson &

Dehaene, 2007). Anxiety, and specifically mathematics anxiety, which can be described as an individual's negative affection for any situations involving numbers, calculations and mathematics, may lead to poor performance in mathematics. Failure in mathematical tasks in the early years, as early as first and second grade may be at the root of mathematics anxiety, consequently ending in a vicious circle of failure-because-of-anxiety followed by anxiety-because-of-failure (Drigas & Kostas, 2014; Geary, 2010; Rubinsten & Tannock, 2010; Skagerlund, Östergren Västfjäll & Träff, 2019).

Learners who experience difficulty with mathematics because of factors that are not a result of low intelligence, poor teaching, being absent, or other external factors hindering them in the learning process, may have a condition called dyscalculia, developmental dyscalculia or mathematics learning disability (Baddeley, 1992; Butterworth, 1999; 2008; Chinn, 2011; Dehaene, 2011; Geary, 2004). People use technologies such as computers, phablets, tablets and smartphones in today's world to help them process mathematical and numerical data. According to Price and Ansari (2013), all people need numerical and computational skills to use such technologies and to interpret, for example, financial and medical statements. It remains important to study dyscalculia and how it can be addressed by interventions as numbers will always be part of our world.

2.6 PROFILE OF GRADE 6 LEARNERS WITH DYSCALCULIA

The heterogeneity of dyscalculia must be taken into account when looking at the characteristics of learners with dyscalculia. Learners with developmental dyscalculia will, for example, count all the symbols on playing cards to say which one of 4 and 6 is the larger or to place the cards in sequence from small to large. They may have strange counting strategies, like counting 1 to 10, then 1 to 9, then 1 to 8, to count down from 10 to 1, or when counting up from 60 in tens will probably count 60, 70, 80, 90, 100, 200, 300 (Butterworth et al., 2011). According to Shalev and Gross-Tsur (2001), children of different ages and different age groups will present with different characteristics for developmental dyscalculia. "First graders with developmental dyscalculia present with problems in the retrieval of basic arithmetic facts and in the computation of arithmetic exercises, phenomena that presumably reflect their immature counting skills" (Shalev & Gross-Tsur, 2001 p. 338).

Learners in Grade 6 have already presumably mastered these skills, some by rote learning, and the retrieval of overlearned facts characterises developmental dyscalculia. They will use inefficient strategies to solve problems, like 4 x 8 or 12 – 9 because of experiencing difficulty in solving arithmetic problems (Shalev & Gross-Tsur, 2001). Errors these learners commonly make will be, for example, inattention to arithmetic signs, forgetting to "carry over" when adding, unable to "borrow" when subtracting, unable to multiply and divide correctly (Shalev & Gross-Tsur, 2001). Temple (1997) reports that learners with developmental dyscalculia show a detachment between arithmetic fact abilities and procedural skills. Butterworth (2008) and Geary (2010) view poor memory for arithmetical facts, reliance on immature strategies, and poor grasp of arithmetical procedures and laws as characteristics of developmental dyscalculia. According to Landerl et al. (2004, p. 101) it "may be easier for a child to memorise one or two meaningless procedures than the multitude of arithmetic facts (from simple number bonds to multiplication tables)", without necessarily understanding cardinality.

Grade 6 learners with developmental dyscalculia may also show wrong or inappropriate application of calculating strategies, may have difficulty generalising learnt content and also little or no automatic transfer of learnt content to other tasks or areas. Procedures are performed automatically without understanding the concepts behind them (Bugden & Ansari, 2016; Kaufmann & Von Aster, 2012). These learners experience an aversion to mathematics and calculations and suffer from anxiety when forced to be involved in such tasks (Jansen et al., 2013; Skagerlund et al., 2019).

Just like younger learners with developmental dyscalculia, some of the Grade 6 learners with dyscalculia have no *feeling* for numbers and relative quantities. Scholars who studied dyscalculia agree that different learners with developmental dyscalculia will show different characteristics, (Bugden & Ansari, 2016; Butterworth, 2008; Butterworth et al., 2011; Geary, 2010; Kaufmann & Von Aster, 2012; Kucian & Von Aster, 2015; Kuhn, 2015; Landerl et al., 2004; Pirani & Sasikumar, 2013; Shalev & Gross-Tsur, 2001; Sharma, 2015; Zerafa, 2015). Just like younger learners with developmental dyscalculia, some of the Grade 6 learners with dyscalculia may have no *feeling* for numbers or relative quantities, which will result in difficulty with subitising and the inability to understand the size of numbers, e.g. 5 is bigger than 4 (Butterworth

& Laurillard, 2010). They may have difficulty with sequencing and may experience a tendency not to recognise and understand number patterns. Some of these Grade 6 learners may still count on their fingers, even to do simple addition and subtraction, and experience an inability to count backwards reliably (Butterworth & Laurillard, 2010; Marmasse et al., 2000; Rousselle & Noël, 2007; Wedderburn, 2012).

Learners experiencing dyscalculia may, as a result of their poor number sense, find it difficult to estimate so that they will not know whether their answers are reasonable. They may also fail to read the value of multi-digit numbers correctly because they have difficulty with place value and value, as well as the orders and spacing of the numbers (Kucian & Von Aster, 2015; Von Aster & Shalev, 2007). Another characteristic emphasised by scholars of dyscalculia, is the inability to correctly add and subtract. This may be the result of multiple factors, such as that learners order and space numbers inaccurately in addition, multiplication, subtraction and division. They fail to carry over and borrow correctly and grouping and regrouping mistakes. Some may even misplace digits in multi-digit numbers or misalign digits in vertical numbers. They may even disregard decimals or start calculations from the wrong place, reaching unreasonable answers and not recognising it (Kucian & Von Aster, 2015; Kuhn, 2015; Wedderburn, 2016).

Other characteristics of learners with developmental dyscalculia may be a result of poor working memory and executive function, and poor visual-spatial orientation. The learners may not be able to remember number words or digits and experience difficulty in recalling number facts automatically. They may also experience difficulty with multi-step mathematics problems and may have weaknesses in short-term, long-term or visual memory (Von Aster & Shalev, 2007; Wedderburn, 2016; Young et al., 2018). These learners with developmental dyscalculia may also have a slow reaction time and slow processing speeds when engaged in mathematics activities so that they take a long time to complete calculations.

Another possible characteristic of learners with dyscalculia is the difficulty they experience with time. Not only do they show an inability or marked delay in learning how to tell the time on an analogue clock, they also show an inability to manage time in their daily lives. Some of them also seem not to be able to understand money and may experience difficulty with all aspects of money (Butterworth, 2003; Callaway, 2013; Trott, 2011; Zerafa, 2015).

Difficulty in learning mathematics may also be a result of not developing a mental number line (Ashkenazi & Henik, 2010a; Berch, 2005; Dehaene, 2011), and therefore some of the learners with developmental dyscalculia will not have a mental number line, resulting in having difficulties with fractions, rational numbers and decimals (Henik, Rubinsten, & Ashkenazi, 2011; Lafay et al., 2017; Trott, 2011; Van Hoof et al., 2017). The profile of a Grade 6 learner with developmental dyscalculia may include a wide variety of characteristics and will be different for different learners, as discussed above; therefore these learners need specialised intervention strategies enabling them to cope with the numerical and mathematical challenges in their environment.

2.7 INTERVENTION STRATEGIES FOR LEARNERS WITH DYSCALCULIA

Intervention strategies must always be aligned with learners' specific barriers to learning (Callaway, 2013; Monei & Pedro, 2017; Pirani & Sasikumar, 2013). As such, remedial programs and interventions for learners with dyscalculia may include pedagogical skills, presentation techniques and test provisions, to mention but a few (Haberstroh & Schulte-Körne, 2019). It is essential that intervention program for dyscalculia not only focus on the understanding that things have a precise quantity but also on the principle that quantity will increase and decrease if things are added or taken away (Butterworth, 2003; Callaway, 2013). As such, number sense is a central focus of interventions for learners with dyscalculia (Butterworth, 2003; 2018).

It is important that the intervention for developmental dyscalculia specifically strengthen the meaning of numbers and number words, to enhance number sense, but also to relate mathematical facts to the implication of the mathematical concepts and their components (Butterworth, 2003; 2011; Monei & Pedro, 2017; Shalev, 2004). According to Kucian and Von Aster (2015) and Shalev (2004), intervention strategies may include drill exercises that will help learners transcribe numbers into the corresponding value, to strengthen their concept of value and place value. They must understand, for example, that in the number 7 856, the value of the digit 7 in that number, is seven thousand, but the place value of the digit 7 is thousand.

Intervention strategies addressing dyscalculia and other difficulties affecting the learning of mathematics must be specialised (Butterworth, 2011). While addressing the multiple aspects of developmental dyscalculia, educational treatment must be provided to improve the learners' attitude towards mathematics and also their understanding of it (Shalev, 2004). Therefore, it is important that intervention include the improvement of automatic recall of number facts by way of repetition and rote learning, and address the mathematics information gap as a result of dyscalculia (Monei & Pedro, 2017).

As an intervention strategy, Griffin (2004a) developed number games that are often used in the classroom by teachers with Grade 1 or 2 learners, leaving room for learners with dyscalculia or other deficits in terms of numerical development to be supported to rectify their impairments (Griffin, 2004b), but the number games can also be used for any age individual experiencing the same difficulties, thus also for Grade 6 learners with impairments in numerical development. Games such as these use Concrete Representative Abstract methods (CRA), with the solid-phase focusing on hands-on methods and concrete instruments. In the second phase of CRA, graphic displays and mental images are included that may lead to abstract reasoning and the use of numerical symbols in the third phase of such CRAs (Beygi et al., 2010; Griffin, 2005; Butterworth, Varma & Laurillard, 2011). In line with such classroom-based games that may provide support, parents can help their children through games, such as snakes and ladders or board games where counting is involved, dominoes, the use of concrete items to represent numbers, also by manipulating these items to reach answers, and rote learning, when a child displays a better understanding of the value of numbers (Benavides-Varela, Butterworth, Burgio, Arcara, Lucangeli & Semenza, 2016; Butterworth, 1999; Wedderburn, 2016).

Teachers who provide informational feedback may furthermore support learners to become intrinsically motivated, which is important for successful interventions. Games used explicitly by special needs teachers include *Cuisenaire rods*, *Number tracks*, or playing cards (Butterworth, Varma & Laurillard, 2011). However, in order to be successful for intervention, such games must be used daily by specially trained teachers, with single learners or a small group of learners (Butterworth, Varma &

Laurillard, 2011). This kind of intervention is also time-consuming and difficult to implement during school hours.

Computers, computer software and other applications, such as mobile phone applications [Apps] can be used after school hours, when and where a learner is able to use these (Butterworth & Laurillard, 2010; Katmada et al., 2014; Khaddage, Müller & Flintoff, 2016). As such, the development of software based on research in neuroscience can provide learners with dyscalculia with the opportunity to receive remedial support in their own time, as often as possible and on the level where required (Butterworth, Varma & Laurillard, 2011).

As a result, researchers are continually attempting to develop games that incorporate neuroscience with the educational needs of learners with dyscalculia (Butterworth, Varma & Laurillard, 2011). Games that have been developed include *the Number Game, Math Muncher, Math Lines, Pacman, Counting Games* (Primary Games, n. d.). *The Number Race* (Wilson & Dehaene, 2004), *Dynamo Maths* (Dynamo Maths*,* n. d.; *JellyJames*, n. d.), *Calcularis* (Dybuster AG*,* n. d.), *Sheppard Software* (Sheppard & Chapgar, n. d), *IXL Maths* (IXL Learning, 2020) and many others. However, some games, such as *Number Worlds* (Number Worlds, 2015) focus more on primary dyscalculia, thus number sense primarily, and do not address high level mathematical skills. If an intervention is implemented with an adolescent or adult with dyscalculia, number sense still needs to be addressed, for which such program may be used. After that, other software programs can support a learner to reach the appropriate level. Examples of such software program include *IXL Maths (*IXL Learning, 2020*)*, *Learning Upgrade* (*Learning Upgrade*, 2017) or when working with Afrikaans and English learners, a bilingual program such as *The Rockseries* (*RockSeries Educational Software,* 2017). A limitation of such software and games is that these are typically presented on a computer or tablet, implying additional effort for parents and teachers to incorporate concrete experiences of numbers, the adding and subtracting thereof, as well as other types of intervention strategies (Butterworth & Laurillard, 2010).

In developing the intervention I implemented, I studied various available games for their potential use. I studied different games on different devices. Some of the games were available only on the App store, thus only available for Apple users, and others were available on the App store, Google Play, and for computers working with different operating systems. I studied *IXL Maths*, *the Number Race*, *Calcularis*, *Dynamo Maths*, *Sheppard Software*, *Learning Upgrade*, *The Rockseries*, *Dexteria Dots* and *Dexteria Dots 2* (Binary Labs, n. d), *Squeebles App Bundle* (Keystagefun, n. d.), *Thinking Blocks Bundle* (Math Playground, n. d.), *Super Bundle* and *Hungry Guppy* (Motion Math, 2020), *Mathsframe Number Games* (Mathsframe, 2020), *Math vs. Zombies* (TapToLearn, n. d.), *Monster school bus* (Math Snacks, n. d.), *Shuttle Mission Visual Algebra* (Math Playground, n. d), DoodleMaths (*DoodleMaths*, n. d.), and *Todo Math* and *Number Matrix* (Todo Math, 2018). The details of the games I chose follow in Chapter 3.

2.8 THE POTENTIAL USE OF ICT IN LEARNING SUPPORT

Information and Communication Technology (ICT) is used to define all the technologies and software used and summarises the “ways in which microchip technology has permeated many aspects of everyday life” (Drigas & Kostas, 2014, p. 46). ICT (Information and Communication Technology) is a growing industry, and remedial teachers and researchers must remain on the lookout for new software developments for computers and Apps for mobile telephones and tablets that can be used for interventions with learners with special needs (Drigas & Kostas, 2014).

2.8.1 Conceptualising ICT

The term *ICT* describes all technologies, like desktop computers, laptops, tablets, mobile telephones, other telecommunication devices, as well as software, thus the programs they are working with, and any application software, enabling individuals to access, manipulate, store and share information (Novotná & Jančařík, 2018). It is a convergence of audio-visual systems, telephone and cell phone networks, computer networks, television and other broadcasting networks, internet services and any other digital technologies concerning communication of information (De Witte & Rogge, 2014; Department of Basic Education, 2004; Drigas & Kostas, 2014; Drigas, Pappas & Lytras, 2016; Kaufman, 2015; Pappas & Drigas, 2015; Sarkar, 2012). Thus, all the digital devices and software in our schools, e.g. interactive whiteboards, computers, tablets, mobile phones, text-to-speech programs and digital games, to name a few, are ICTs. Consequently, ICT with its rapid developing and evolving devices, faster and more available internet and increasing applications, results in utilising these technologies becoming part of individuals' lives in school, workplace, home and their social world (Grant et al., 2015; Kaufman, 2015; Zaranis, 2016; Zhang, Trussell Gallegos & Asam, 2015).

2.8.2 Using ICT in schools

The rapid evolving of ICT in this electronic age makes the use of ICT in schools necessary and inevitable (Cullingford & Haq, 2016; Genlott & Grönlund, 2016). Schools must incorporate ICT and must lead in this change to a digital world, by using it as an asset in developing new learning material, expanding curricula, providing more and new resources, as well as another way of communication between teachers and learners (Bulman & Fairlie, 2016; Cullingford & Haq, 2016). Unfortunately, the change to e-education is slow, and the use of ICT in schools is frequently not comprehensive (Blackwell, Lauricella & Wartella, 2014).

The Department of Basic Education describes e-Education in White paper 7 (2004, p. 14) as the ability to do the following:

- ❖ *Apply ICT skills to access, analyse, evaluate, integrate, present and communicate information;*
- ❖ *create knowledge and new information by adapting, applying, designing, inventing and authoring information; and*
- ❖ *function in a knowledge society by using appropriate technology and mastering communication and collaboration skills.*

As ICT can improve the quality of education, as studies by Dell, Newton and Petroff (2016), Miller, Naidoo and Van Belle (2006) and Papadakis, Kalogiannakis and Zaranis (2018) have shown, and the learners grow up in a digital age, it is important to promote the use of ICT in schools. Ghavifekr and Rosdy (2015) show in their study that instruction and learning incorporating ICT is more effective than only using traditional teaching strategies. The use of ICT furthermore contributes to whole school enhancement, as it can be used for all aspects of school, like administration and management, increasing productivity, curriculum enhancement and integration, communication in school as well as with parents, the Department of Basic Education and outside world (Department of Basic Education, 2004).

Mobile technology as ICT includes any technology that is portable and therefore uses wireless technology, such as smartphones, tablets and laptops, to name a few (Park, 2011). Utilising mobile technologies for ICT in the school environment provides opportunities for learning, more specific m-learning, as described in Park (2011). M-learning has many advantages, for example, context-sensitivity so that real or simulated data may be gathered (Aluko, 2017). The use of mobile technologies as ICT in schools is also interactive, enabling learners and teachers to interact with technology, the learning environment and one another (Churchill, Fox & King, 2016; Dell et al., 2016).

Other advantages of mobile technologies include their portability, enabling learners and teachers to use them at different locations and individuality, because a device can be used by one individual at a time, which makes it promising for usage with scaffolding tasks (Domingo & Garganté, 2016; Looi et al., 2010). The feature of connectivity that is typical of mobile devices enables the individual to connect to other devices, a network and the internet, which may lead to successful learning experiences (Bulman & Fairlie, 2016; Churchill et al., 2016; Domingo & Garganté, 2016; Lim & Churchill, 2016). Zhang et al. (2015) regard the use of social media in the learning process as another advantage of the use of mobile learning, therefore of ICT, as the learners and teachers can create and exchange user-generated content in the learning process. The use of mobile learning as part of ICT in schools also promotes collaborative learning and peer collaboration, as well as provides the learners with the opportunity to share their learning experiences and the world (Domingo & Garganté, 2016; Jahnke & Kumar, 2014).

Incorporating ICT in schools is important, ensuring that learners will be part of the knowledge and digital society and ready for the 21st century when they leave school after Grade 12 (Ghavifekr et al., 2014). Therefore it is vital to devise successful integration of ICT in the school environment and thus be aware of possible challenges regarding policies, the school, teachers, learners, available technologies and type of project (Groff, McCall, Darvasi & Gilbert, 2016; Groff & Mouza, 2008).

2.8.3 Value of ICT for learning support

Using ICT in schools for the support of learners with learning disabilities is one possible intervention strategy (Adam & Tatnall, 2017; Butterworth & Laurillard, 2010; Hasselbring & Glaser, 2000). Learning disabilities include a variety of barriers to learning, which can be partly overcome by using ICT (Hasselbring & Glaser, 2000, Lidström & Hemmingsson, 2014; Mohd Syah, Hamzaid, Murphy, & Lim, 2016). Learners who are blind or partially sighted may utilise braille keyboards, or keyboards with large and/or colourful keys, as well as speech-to-text programs, like *Dragon NaturallySpeaking* (Nuance*,* 2020), to type on digital devices like computers, tablets or mobile phones, as well as text-to-speech programs and screen readers, e.g. *JAWS* (Job Access With Speech) (Freedom Scientific, n. d.), or the open-source software *nvda* (NV Access*,* 2020), to read their documents and assist them in handling their digital devices, enabling them to be part of the education system. A large number of assistive devices and software to help them learn have been developed for the visually impaired (Drigas & Ioannidou, 2013). Extensive ICT to assist them in learning and include them in education have been developed for the motor impaired learner; examples are trackballs, touch screens, specialised mouse and keyboard substitutions, eye-tracking devices, to name a few (Drigas & Ioannidou, 2013). According to Bruhn, Waller and Hasselbring (2016) learners with attention difficulties and who need self-regulation to keep at tasks may use devices like timers or mobile devices with software, or even tweets on Twitter to stay at the tasks on hand and keep concentrating.

There are many specific learning disabilities, other than physical that impede learners' learning processes so that they fail in reaching their potential. With the current ICT developing explosion, a vast quantity of software is developed for devices like computers, tablets and mobile cell phones to assist individuals with specific learning disabilities, like difficulty with reading and writing, dyslexia, memory difficulties as well as mathematics learning difficulty and dyscalculia (Adam & Tatnall, 2017; Drigas & Ioannidou, 2013; Drigas et al., 2016; Durkin, Boyle, Hunter & Conti-Ramsden, 2015). Utilising ICT in the intervention process lets the learner engage in the activities on his level and in his own time, repeating activities as many times as necessary, which improves learner involvement in the intervention process, reduces anxiety levels, and provides motivation, which may lead to improving the learning process (Bjekić, Obradović, Vučetić & Bojović, 2014; Drigas et al., 2014; Drigas & Ioannidou, 2013; Drigas et al., 2015; Durkin et al., 2015; Hasselbring, Goin, & Bransford, 1988; Rabah, 2015).

2.8.4 The potential use of ICT for learners with dyscalculia

Computer assisted instruction (CAI), where computer software is used by learners to practise mathematical skills as often and frequently as necessary, presents many possibilities for intervention for the learner with dyscalculia (Bakker, Van den Heuvel-Panhuizen & Robitzsch, 2016; Butterworth & Laurillard, 2010). Computer games are currently popular computer software and learners probably see intervention utilising computer games as "play" and not as "work", which will reduce anxiety and improve learning experiences (Butterworth & Laurillard, 2010; Katmada et al., 2014). Katmada et al. (2014) refer to this type of intervention, where digital game-based activities and educational content are combined, as Digital Game-Based Learning (DGBL). Games divert attention away from the tyranny of the right answer, which creates an anxiety-free environment for intervention to take place.

Digital intervention programs have significant benefits for the learners (Bakker et al., 2016; Butterworth & Laurillard, 2010; Mavridis, Katmada, & Tsiatsos, 2017), which may help reduce anxiety as games offer no threat to learners. Using ICT, learners may repeatedly practise a concept through playing games on a computer, tablet or mobile phone, anytime or any place when it is convenient. An older learner with developmental dyscalculia, already in Grade 6, or older, has the opportunity to improve a number sense and catch up with basic mathematical skills by using programs and Apps to play games concerning these concepts (Jupri, Drijvers, & Van den Heuvel-Panhuizen, 2015). Such software has typically a competitive part, where the learner earns points for correct responses and the game may automatically adjust to a next level after a certain number of points has been reached. This serves as motivation to keep on playing and practising, to reach the highest level (Katmada, Mavridis & Tsiatsos, 2013; Ke, 2013; Mavridis et al., 2017). Therefore, without realising, the learner repeatedly practises the concept. Using the *Dots2Track* and the *Dots2Digit* games (Hassan, 2020), Butterworth and Laurillard (2010) find that the learners repeat the digital games more than other games, and their attention is be more focused in a digital game environment.

Zhang et al. (2015) state that using mathematic applications may be beneficial to learners struggling with mathematics, as such programs allow learners to work at their own pace, give immediate feedback and divide complex processes into small steps, making such mathematics applications valuable instruments for intervention. Using ICT, such as computer programs assists learners in understanding number recognition, shape recognition, counting and may also improve the understanding of mathematical concepts and procedural knowledge (Domingo & Garganté, 2016; Doorman, Drijvers, Gravemeijer, Boon & Reed, 2013). It can also support learners in forming and training a mental number line (Moeller, Fischer, Nuerk, & Cress, 2015).

According to Papadakis et al. (2018), learners are attracted to mathematical games on computers or other electronic devices, also because of animations. Using ICT may assist learners in reaching higher levels of thinking and support them in developing mathematical skills, such as numbering and identification of numbers. Mobile technologies like tablets and mobile phones have touch screens that are intuitive and reduce the spatial demands required to manipulate the mouse and keys on the keyboard of a computer or laptop, therefore making it easier for the learners to use (Grant et al., 2015; Papadakis, Kalogiannakis & Zaranis, 2016).

Butterworth and Laurillard (2010) hypothesise that digital intervention programs provide multiple benefits to teachers and learners. According to these scholars, benefits for learners include the following:

- Providing the opportunity for repeated practice when and where they want.
- Usability for any age.
- Ease to manipulate digital objects using the mouse or touch screen.
- Virtual environments can link the abstract to the physical world, for example, zoom into a number line.
- Digital programs provide feedback to the learner in a separate way without involving other people. They offer no threat and can be repeated as many times as the learner needs.

By using digital intervention programs, teachers may customise tasks to suit specific learners with specific mathematical difficulties, generating follow-up tasks according to the learners' current performance. The teachers may also share their experiences and tasks with other teachers, resulting in not feeling isolated. Utilising digital intervention strategies may personalise the intervention process for the learners with mathematical difficulties, enabling the teacher to give attention to other learners in the class. The teacher may use digital programs as motivation for the learners and may use interactive and adaptive programs, which the struggling learner can use at home instead of doing pen and paper homework (Bjekić et al., 2014; Butterworth & Laurillard, 2010). Other scholars in the field also suggest that digital representations are flexible, manageable, free of distracting features, extensible, are easier and faster to use and provide immediate feedback (Chang, Evans, Kim, Norton, & Samur, 2015; Clements & Sarama, 2014).

Computer-supported instruction (CSI) adopts different ways to present information and provide learners with developmental dyscalculia the opportunity to develop their mathematical skills and to maintain a high self-esteem (Kumar & Raja, 2010). In a study conducted by Kumar and Raja (2010), their experimental group did significantly better in a post-test than their control group, after the experimental group received CSI as an intervention. Kadosh, Dowker, Heine, Kaufmann and Kucian (2013) point out that learners with developmental dyscalculia improved their spatial number representations as well as their numerical abilities after intervention with a computer game, *Rescue Calcularis* (Dybuster AG, n. d.), they developed.

Kiili, Moeller and Ninaus (2018) found that game-based training in conceptual rational numbers with Grade 4 learners had a positive effect on the learners' conceptual rational number knowledge. They used their games on number line estimation, magnitude comparison and magnitude ordering tasks, developed by their research engine, *Semideus*. Likewise, Kolovou, Van den Heuvel-Panhuizen, and Köller (2013) found computer games an appropriate instrument for teaching early algebra to Grade 6 learners, as a study with their online archery game provided positive results. Wilson et al. (2006b) also proved the positive effect of computer games on the performance in mathematics of learners with developmental dyscalculia, using the game *The Number Race,* developed by Wilson and Dehaene (2004). Similarly, Räsänen, Salminen, Wilson, Aunio and Dehaene (2009) proved significant improvement in numbers compared with *Graphogame-Math,* which is an example of computer assisted intervention (CAI). According to Räsänen et al. (2009, p. 466), "using computer software, it is possible to present very tightly controlled stimuli in an entertaining game-like format that provides enough repetitions for learning". Other scholars that experienced a positive effect of digital game-based intervention strategies on the performance of learners struggling with mathematics are Adebisi, Liman and Longpoe (2015), Ariffin et al. (2017), Carter and Dean (2006), Dell et al. (2016), Drigas et al. (2016), Laurillard (2016), Mutlu and Akgun (2018), Sánchez-Pérez et al. (2018) and Van der Ven, Segers, Takashima, and Verhoeven (2017), to name a few.

The use of ICT in intervention strategies for developmental dyscalculia to change the role of the teacher in the intervention process is a positive outcome of game based learning. Papadakis et al. (2018) state that the healthy didactic relationship of teacher, learner and mathematics may change to a didactic tetrahedron, by including technologies in the relationship. Teachers and schools are using ICT more frequently, as it is becoming more and more affordable and available, making it an essential part of the learning experience and intervention process (Iuculano, 2016).

2.9 CONCEPTUAL FRAMEWORK

In compiling a conceptual framework for my study, I integrated the number sense theory of Butterworth (2003; 2011) and the working memory and executive function theories of Dehaene (2011) and Geary (2010) with elements of the use of adaptive digital interventions as proposed by Butterworth and Laurillard (2010), as well as Wedderburn’s (2016) theory of vertical acceleration in learning mathematical skills.

According to Butterworth's (1999) theory of dyscalculia, the intraparietal sulcus (IPS) maintains the representation of the magnitude of symbolic numbers. Almost all calculations and mathematical processes imply the use of the parietal lobes, specifically the IPS. This suggests that the parietal lobes, specifically the IPS where number sense is centred, play a critical part in all mathematical processes (Butterworth, Varma & Laurillard, 2011). In this context, Butterworth, Varma and Laurillard (2011, p. 1050) state that "if parietal areas, especially the IPS, fails to develop normally, there will be an impairment at the cognitive level in numerosity representation, which may cause barriers to learning in terms of mathematics".

Butterworth and Laurillard (2010) rely on pedagogical principles and good teaching practice to encourage the use of adaptive digital interventions designed to strengthen number sense. They propose number sense games such as *Dots2Track*, *Dots2Digits*, and *Numberbonds* (Hassan, 2020) to stimulate activity in the parietal lobes of the brain and assist learners with dyscalculia to acquire some level of number sense. When following this approach, learners may experience the computer environment as less threatening than a classroom situation, being more focused in the digital gaming environment. To this end, Butterworth and Laurillard (2010, p. 5) believe that "virtual environments can link the physical to the abstract in ways that are not possible in the physical world".

Geary (2004; 2010) recognises three subtypes of dyscalculia. The first subtype experiences a procedural memory dysfunction due to executive dysfunction. This may result in a deficiency in the acquisition of counting and counting procedures so that the learner experiences difficulty in solving simple arithmetic problems. A second subtype recognised by Geary (2004; 2010) is as a result of a deficiency in semantic memory, which may be characterised by verbal memory dysfunction. This may lead to errors in the retrieval of arithmetic facts. A third subtype suggested by Geary (2004; 2010) is visuospatial dysfunction where the learner with developmental dyscalculia experiences difficulty in processing visual stimuli to comprehend spatial relationships between objects and to visualise different images, resulting in difficulty forming a mental number line. Despite initial reservations Geary (2010) recognises number sense deficiency as part of dyscalculia following ongoing research in this field.

Closely related, Dehaene (2011) proposes the existence of more than one type of dyscalculia. He firstly recognises a deficit in number sense, which may be seen as a deficiency in the symbolic representation of a number. The learner with developmental dyscalculia may experience an impaired understanding of the meaning of numbers and may be unable to compare numbers correctly or to subitise, as well as experience difficulty with addition, subtraction resulting in a delay in all aspects of mathematics. According to Dehaene (2011), the second type of developmental dyscalculia includes a deficiency in verbal, symbolic representation, resulting in a defective semantic memory, so that the learner experiences difficulty in learning and retrieving mathematical facts. The third type of developmental dyscalculia recognised by Dehaene (2011) is when the learner experiences a deficiency in executive function. This may lead to a deficiency in fact retrieval and procedural knowledge, but may also result in difficulty with planning, organising, setting priorities and decision making. The fourth type of deficiency in learners with developmental dyscalculia recognised by Dehaene (2011) is spatial attention deficiency, resulting in difficulties with subitising, manipulation of quantities and the perception of nonsymbolic quantities.

Wedderburn recognises developmental dyscalculia as a heterogenic deficiency that may be the result of any or all the above theories (Wedderburn, 2016). In terms of Wedderburn's (2016) tree of obtaining mathematical skills, numerosity, as the root system of mathematical skills, can be supported by including a software application such as *Number Sense* games for intervention (Butterworth & Laurillard, 2010). After that, another software application, such as *The Rockseries (*RockSeries Educational Software*,* 2017)., can be used as an intervention for mathematical skills, in the order shown in Wedderburn's tree, starting with place value and then addition, following a learner's pace. Wedderburn (2016) proposes the acquiring of mathematics as the building of a wall, with different mathematical concepts as building bricks, resulting in the collapsing of the wall if one brick is not there or is defective.

Figure 2.3 provides an overview of the conceptual framework that guided the investigation. I incorporated the dyscalculia theories of Butterworth (1999; 2008), Geary (2010) and Dehaene (2011), thereby recognising the heterogenic nature of developmental dyscalculia. I combined this with digital intervention strategies proposed by Butterworth and Laurillard (2010), Wilson and Dehaene (2007) and the theory of Wedderburn (2012), stating that the roots of the mathematical tree must be strong, and flows over into intervention strategies to form strong building bricks in the mathematical wall. In Figure 2.3 the concepts below the red line point to the foundation, which must be reliable, enabling other mathematical concepts to be built onto it. When intervening with a learner with developmental dyscalculia, intervention strategies must be planned to secure the concepts in the block with the blue dotted line, before attending to other concepts.

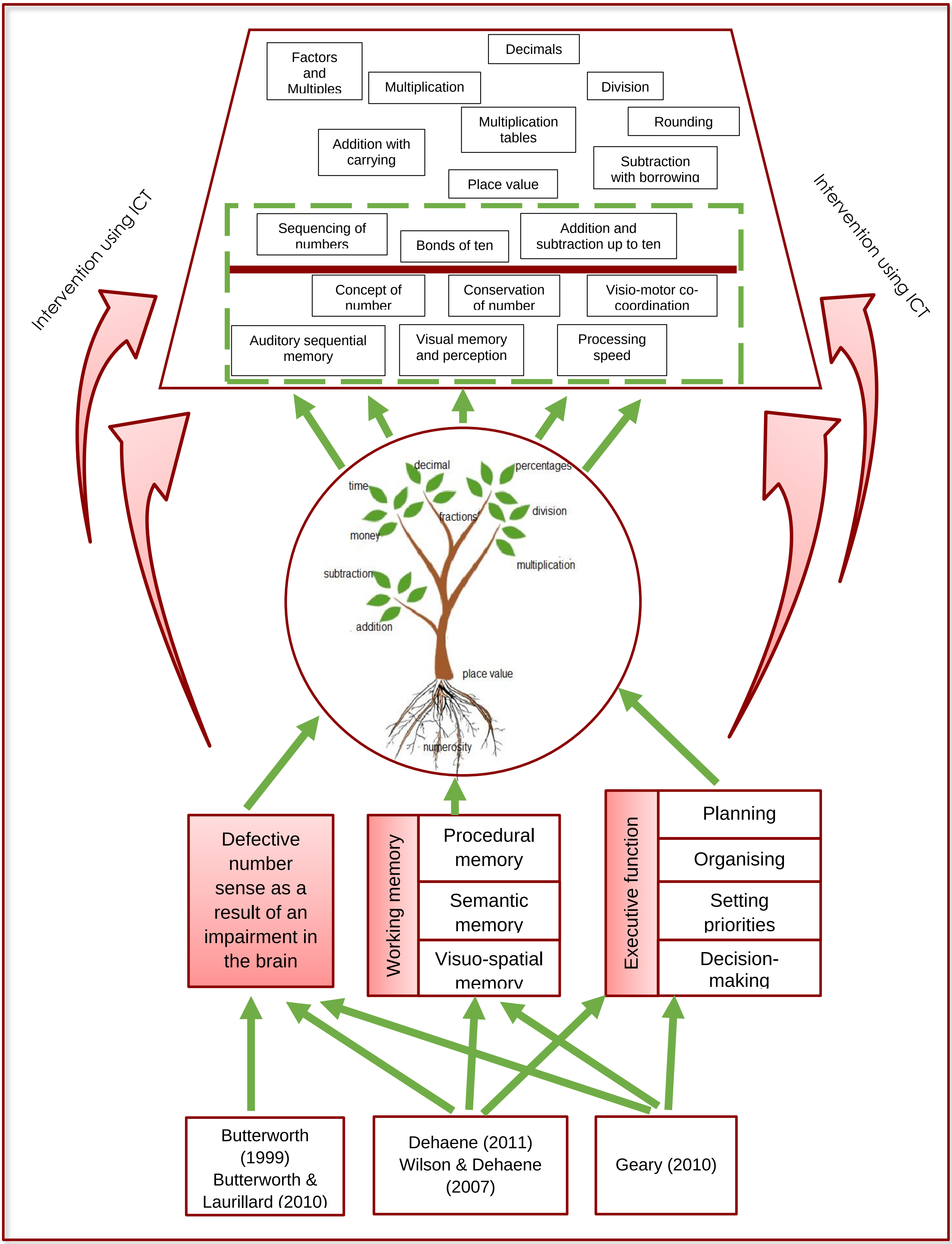


Figure 2.3: Conceptual framework of the study

2.10 CONCLUSION

In this chapter, I discussed the existing literature underlying my study. I explored dyscalculia and the terms and definitions used to clarify this heterogeneous concept. I specifically discussed the characteristics, causes, diagnosis of and intervention for dyscalculia. I then explored ICT and its potential use for interventions with learners with special needs. I concluded the chapter by explaining the conceptual framework that guided my study.

In the following chapter, I discuss the empirical choices I made. I explain the paradigm, the research approach, the research design, sampling procedures, data collection, data documentation and data analysis strategies. I also attend to validity and reliability as well the ethical principles I adhered to in undertaking this investigation.

CHAPTER 3 - RESEARCH METHODOLOGY

3.1 INTRODUCTION

In Chapter 2, I reviewed the literature relevant to this study. I explained that dyscalculia, as a complex concept, can be defined in various ways and has several characteristics. I explored interventions that utilise ICT and then discussed the conceptual framework.

In this chapter, I discuss the paradigmatic choices, the research design and the research methodology I utilised. The chapter focuses on the sampling procedures as well as the data collection and analysis strategies. Validity and reliability issues as well as the ethical principles of this study are discussed.

3.2 PARADIGMATIC PERSPECTIVES

Research aims to understand the world and reality. The way in which researchers look at the world influences their understanding of it (Flick, 2015; Maree, 2016; Mertens, 2015). Ontology can be viewed as the beginning of research and thus of understanding the world (Sefotho, 2015). Research is conducted through investigating and questioning phenomena that researchers have become aware of. In this investigation, I collected, analysed and interpreted data from my worldview, looking at the world through my own lenses coloured by philosophical views and values (Mertens, 2015; Mouton, 2001) as discussed in the subsequent sections.

Social research aims to find patterns in social life and seeks to generate measurable data that can be tested (Cohen et al., 2011; Flick, 2015; Mouton, 2001). Researchers do such research from their perspectives on the world, and thus from a specific epistemological paradigm, following the philosophical assumptions associated with the paradigm (Ferreira, 2012; Flick, 2015; Gitchel & Mpofu, 2012). Whereas ontology is about the expectations researchers have of the nature of reality and understanding of the world, epistemology relates to ways to learn about the social world, thus to the study of knowledge and how to find knowledge of reality (Maree, 2016). Creswell (2014) explain that epistemological assumptions guide methodological considerations, directing how a researcher conducts a study stating the strategies chosen by the researcher to do the research. It is crucial to contextualise the epistemological foundation and methodological considerations of this study. These choices influenced the type of data I collected, and how the data was analysed and how it was interpreted (Mouton, 2001).

3.2.1 Epistemological paradigm: Positivism

Cohen et al. (2011, p. 7) state that positivism claims that "science provides us with the clearest possible ideal of knowledge". Positivists use logical analysis and empirical observations to explain procedures (Flick, 2015; Henderson, 2011). Truth and evidence, and thus objectivity are important premises of the positivist philosophy (Bryman, 2016; Maree, 2016). Accordingly, the researcher and respondents are independent in positivist studies, with the researcher remaining objective, not influencing the respondents or being biased (Cohen et al., 2011; Mertens, 2015). Findings from positivist studies can, as a result, be generalised (Flick, 2015; Mouton, 2001).

Bryman (2016) summarises a few assumptions of positivism, namely phenomenalism, deductivism, inductivism and objectivism. Firstly, phenomenalism refers to phenomena that can only be seen as knowledge if validated by the senses. Another assumption of positivism is deductivism, referring to the generating of hypotheses based on theories. These hypotheses "can be tested and allow explanations of laws to be assessed" (Flick, 2015, p. 22). Additionally, objectivism refers to the objectivity of science, when conducted without being influenced by values. Inductivism furthermore implies the collecting of facts that are the basis of laws, consequently creating knowledge. The aim of positivism is, therefore, to develop objective scientific statements and renounce normative statements (Bryman, 2016; Maree, 2016).

My choice of the positivist paradigm enabled me objectively to reveal the effect of an ICT intervention on the performance of Grade 6 learners with dyscalculia in mathematics. To be able to do this, I remained objective and provided only technical support to the respondents for the use of computers and computer programs − software − during the intervention. As such, I did not influence the intervention process. Even though I acknowledge that the mere presence of a researcher (myself) may influence respondents, my presence applied to everyone who participated; I provided a controlled situation. The outcome was measured by a test and not by myself to avoid any researcher bias and the possible effect of personal values.

Positivist researchers typically work with quantitative data and use experiments, questionnaires and statistics to test hypotheses (Anderson & Arsenault, (1998; Mertens, 2015), which may then be generalised to a defined population (Mouton, 2001). The researcher formulates hypotheses, which indicate variables that guide the research (Ary, Jacobs, Irvine, & Walker, 2018; Cohen et al., 2011). The outcome of hypotheses testing, in turn, guides the researcher to make deductions about the outcome of the ICT intervention followed by the respondents (Creswell, 2014; Mouton, 2001). It is important that all deductions are scientifically valid, and that the process is standardised as far as possible to promote neutral observations, control and objectivity (Cohen et al., 2011). Hypotheses should, as a result, represent statements about the relations between variables, indicate clear implications for testing the relations between variables, reveal compatibility with current knowledge and be expressed as economically as possible (Cohen et al., 2011).

An advantage of using positivism for this study was the possibility of the findings leading to new knowledge about Grade 6 learners with dyscalculia and how they may be supported through an ICT intervention. I did not actively take part in the intervention, yet remained an objective observer; the outcome may be regarded as truthful and can thus generate new knowledge about respondents with dyscalculia. One point of criticism against positivism is that it is reductionist in nature. However, this study was intentionally reductionist, as it viewed the mathematics performance of the respondents only and not as holistic human beings.

Another potential challenge of utilising a positivist paradigm is that respondents are often human (as in the current study) with many factors potentially playing a role, such as anxiety, attitude towards the researcher and experiment, to name a few, as not all human behaviour can be controlled (Cohen et al., 2011; Flick, 2015). I created good rapport with the respondents in an attempt to limit anxiety and any potential negative attitudes, as these factors tend to have a negative influence on mathematics performance (Katmada et al., 2014). The intervention itself may have been helpful during this experiment, as it is new and modern, and should appeal to Grade 6 learners in general. ICT was, perhaps, also regarded as gaming rather than as work by the respondents, which may have further reduced anxiety and any potential negative attitudes (Katmada et al., 2014).

3.2.2 Methodological paradigm: Quantitative research

As a positivist, I followed a nomothetic approach in studying a phenomenon by using a representative sample, numerical data and statistical analysis that may be generalised to the population, staying objective while also being structured. I thus followed a quantitative approach as a methodological paradigm, which is typically objective, formalised and systematic (Ary et al., 2018; Cohen et al., 2011; Gitchel & Mpofu, 2012). As such, a quantitative approach allowed me to remain unbiased and neutral (objective nature) and implement procedures and methods that are designed to discover general laws (nomothetic nature) (Cohen et al., 2011; Hoy & Adams, 2015). Besides, this approach is formalised because it is ceremonious and systematic as it is orderly, methodological and logical (Ary et al., 2018; Cohen et al., 2011; Gitchel & Mpofu, 2012). When following a quantitative research approach, the research process and data collection are standardised to meet the criteria of reliability, validity and objectivity (Flick, 2015; Hartas, 2015), which support findings to have truth and value and be generalisable.

My reasons for choosing a quantitative approach firstly relate to this approach allowing me to create a situation in which some variables could be controlled to exclude their potential influence on the outcome of the research (Cohen et al., 2011), thus proving the validity of the outcome. Secondly, a quantitative approach aims to generalise results (Ary et al., 2018; Cohen et al., 2011; Flick, 2015), thereby allowing one to generalise the findings I obtained about the ICT intervention on the performance in mathematics of the sample group of Grade 6 respondents with dyscalculia to the population of Grade 6 respondents with dyscalculia. Thirdly, when following a quantitative approach, measures are generally repeatable (Flick, 2015). In other words, it should be possible to get the same results if the experiment is repeated, using the same methods and under the same conditions (Ary et al., 2018; Flick, 2015; Morgan & Sklar, 2012b), thereby allowing other researchers to confirm the outcome. I thus viewed a quantitative approach as suitable for my research, as my interest did not lie in the causes of dyscalculia, but in the possibility to support Grade 6 learners to achieve in mathematics by using ICT during a support intervention.

A quantitative researcher may, however, face challenges related to sampling, validity and reliability (Flick, 2015). An inadequate sample size may, for example, limit the accuracy of the findings (Osborne, 2010), yet sample size depends on various factors, such as the type of test, the level of accuracy anticipated and the type and group size of the population being researched (Ary et al., 2018; Bryman, 2016). As only 3% to 8% of school-aged children display severe difficulty in acquiring mathematical skills (Geary, 2010; Griffin, 2004b) I could not obtain a sample size of 30 or more at the two schools that formed part of the research project. As such, I acknowledge that the small sample size may have affected the validity and reliability of the current study.

A quantitative researcher typically attempts to analyse data in a way that is credible, objective and reliable, despite a variety of challenges associated with this possibility (Ary et al., 2018; Creswell, 2014). Content validity refers to the relevance and representation of the test instruments (De Bekker-Grob, Donkers, Jonker & Stolk, 2015; Denscombe, 2014; Osborne, 2010). In this study I used the same test instruments that are valid for all the respondents during the pre- and post-intervention phases. For time validity (Osborne, 2010), which implies that conclusions will be valid overtime, I controlled the time spent on the intervention process. Next, environmental validity may influence the validity of findings, as respondents may learn something from the environment, for example, a normal class that may have a positive effect, or a negative environmental issue such as feeling sick or troubled (Osborne, 2010). In this regard I found it challenging to control environmental factors, as I could not control what the respondents learnt in class as part of their standard curriculum or what they did at home outside the intervention context.

Internal validity factors include measurement variations between dependent and independent variables that are not caused by other factors (Osborne, 2010). In this regard, I as researcher attempted to control the variables to ensure that the change in the dependent variable was the result of the intervention (Osborne, 2010; Pietersen & Maree, 2016c). More specifically, the independent variable in this study was the intervention utilising ICT, but other variables present that might have affected the outcome were the probability of other types of learning, time spent using software, anxiety issues and attitudes towards the research project and mathematics. All these factors might have influenced the dependent variable (Ary et al., 2018; Di Fabio &

Maree, 2012). However, I attempted to limit this potential challenge by implementing the following strategies:

- I spent the same amount of time on the intervention with all the respondents.
- I built good rapport with the respondents in attempting to lessen anxiety and promote motivation.
- I asked the respondents' teachers to continue with their regular classes in the usual way.
- I requested the respondents to refrain from doing additional work or playing extra mathematics games to appear better during the period of the intervention.
- I attempted to motivate the respondents to use their participation in the intervention as an opportunity to do better in mathematics.
- I started with low-level intervention activities so that respondents could succeed in assignments and gradually increase their scores and levels of play, which in return could serve as motivation.
- I acknowledged small achievements.
- I attempted to create the necessary background for the intervention to feel like play and not work.

3.3 RESEARCH DESIGN: QUASI-EXPERIMENTAL DESIGN

The research design refers to the methodical approach that guides the researcher in conducting a scientific study, integrating different components of the study clearly and rationally (Ary et al., 2018). The research design must be chosen to answer the research questions as unambiguously and effectively as possible through creating a well-planned design to collect, measure and analyse data (Flick, 2015). I chose a quantitative approach as a methodological paradigm (Consult Section 3.2.2), as a quantitative approach allowed me to state the hypotheses and test them with empirical data obtained from the investigation (Bryman, 2016; Johnson & Christensen, 2016). According to Haegele and Hodge (2015, p. 61), a " research hypothesis is the predicted outcome or the expected results from a study". In setting the hypotheses for the study (Consult Chapter 1), I set null hypotheses, which stated that there was no significant improvement after an ICT intervention for each hypothesis. In using null hypothesis testing, I applied deductive reasoning to ensure the assumptions were indisputable (Haegele & Hodge, 2015). To test these hypotheses, I collected relevant data and used statistical strategies to decide whether a hypothesis had to be rejected or provisionally accepted. According to Muijs (2010), the acceptance of a hypothesis is provisional, because new data that may emerge in future, may reject the hypothesis.

I collected the data to test the hypotheses utilising scientific strategies, such as experimental research to create a cause and effect relationship between variables. In experiments an independent variable is the causative strategy, which is manipulated by the researcher, leading to observing the dependent variable, which is the effect of the manipulation (Ary et al., 2018; Bryman, 2016; Pietersen & Maree, 2016b). In this research process, it is crucial to attempt keeping extraneous variables from influencing the experiment (Walker, 2005). The effect of the independent variable on the dependent variable is measured and analysed to determine the relationship between them (Ary et al., 2018; Johnson & Christensen, 2016; Kothari, 2009).

There must be at least two groups to have an experiment, one receiving the treatment (experimental group) and one not receiving treatment (control group) to observe the cause-effect relationship between the variables (Ary et al., 2018; Campbell & Stanley, 2015; Christensen, Johnson, & Turner, 2011). In utilising a control group, the researcher may exclude alternative explanations for the effect of the treatment on the dependent variable. In a true experiment, the researcher uses randomisation to assign respondents to experimental and control groups, ensuring each respondent has an equal opportunity to be assigned to any group, independent of the researcher's judgement and choice or the respondent's characteristics (Ary et al., 2018; Campbell & Stanley, 2015; Cohen et al., 2011). If random assignment to the groups is not possible, then a quasi-experimental design can be followed. The quasi-experimental design also tests causal hypotheses, but lacks random assignment to the experimental and control groups, although it is essential to create a control group as similar as possible to the experimental group (Mertens, 2015; White & Sabarwal, 2014). Consequently, because the researcher does not have full control over all experimental factors, one must be aware of threats to internal as well as external validity when interpreting the results of a quasi-experimental study (Ary et al., 2018; Christensen et al., 2011).

I implemented a quasi-experimental design, as this type of design allowed me to "control and manipulate one or more variables, to determine the cause-and-effect relationship between the variables" (Seabi, 2012, p. 84). I was thus able to observe the effect of the independent variable on the dependent variable (Cohen et al., 2011), with the independent variable being the intervention program. I used a nonrandomised control group pre-test post-test design.

I utilised a quasi-experimental design because it was not possible for me to carry out a true experiment (Cohen et al., 2011; White & Sabarwal, 2014). The quasi-experimental design thus allowed me to test causal hypotheses, like a true experiment, however not randomly assigning respondents to the experimental and control groups as in the case of experimental designs (Becker et al., 2017; Cohen et al., 2011; White & Sabarwal, 2014). The respondents were namely arranged according to merit from the lowest to the highest marks in the pre-test. After that, they were randomly assigned to the experimental or control group, as explained in more detail in the following section. Some, however, did not want to be part of the experimental group and as a result were swopped with other respondents in the control group. However, I aimed for the control group and experimental group to be as similar as possible. Figure 3.1 shows the path followed in the research design:

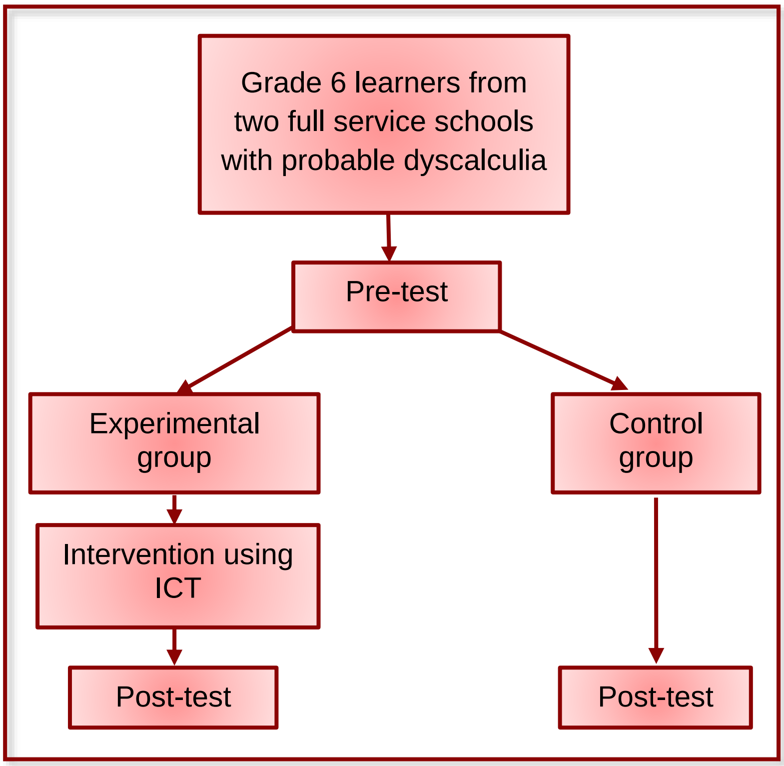


Figure 3.1: Nonrandomised control group pre-test post-test design

The strength and advantage of experimental research is the control over the variables and external factors, so that deductions may be made about cause and effect (Muijs, 2010). This emphasises the need for using standardised procedures to exclude systematic bias and incorrect conclusions (Walker, 2005). Another advantage of the quasi-experimental design is that one may be confident that if the intervention program is successful in the study, it probably will be successful in real-life situations like the classroom and home (Haegele & Hodge, 2015).

Challenges of the quasi-experimental design are the instrument used to test the hypotheses, the time frame and the conditions under which it was administered (Ary et al., 2018; Haegele & Hodge, 2015; Walker, 2005). The sample size must also be as large as possible because respondents were not randomly allocated to the two groups (Mertens & McLaughlin, 2004). I tried to keep the test conditions similar for all respondents to limit the influence of test conditions on the outcome of the study. The biggest challenge I had to deal with, was the sample size, as only less than 20% of learners present with developmental dyscalculia, minimising the population that could be used for sampling. Another challenge contributing to the small sample size was that only two full service schools out of the possible eight were prepared to participate in the study. According to Gribbons and Herman (1996), if the groups perform similarly in the pre-test and one group performs better in the post-test than the other group, initial differences may be ruled out.

I designed a pre-test that was administered to the learners in the afternoon after school. All the learners from the same school wrote it in one session. The post-test, which I designed to be similar to the pre-test, was administered to the experimental and control groups simultaneously five days after the last intervention session, in the afternoon after school. Internal validity may not be as high with quasi-experimental design as with experimental design because the experimental and control groups were not the same. In Section 3.4 I discuss validity in more detail. There were also external factors challenging the quasi-experimental study, such as the distance I had to drive to the schools after school, the respondents were tired after school, four learners left the study after the pre-test, and difficulty with the internet connection resulting in longer hours to finish the intervention. I minimised most challenges to limit their influence on the outcome of the study.

3.3.1 Sampling and respondents

It is important to define clearly the target population of the study, thus all the possible subjects of our research, sharing a common characteristic at the core of the study (Etikan, Musa & Alkassim, 2016; Lohr, 2019; Taherdoost, 2016). The population in this study was Grade 6 learners with dyscalculia in South Africa. As it was impossible to include all Grade 6 learners with dyscalculia from all schools in South Africa in my study, a sample unit of Grade 6 learners with dyscalculia was taken from full service schools in the Bojanala district in North West Province. As I am working at a school that is a resource centre in this specific district, I reached out to full-service schools in the area, thereby fulfilling the requirements for resource centres as stipulated in Education White Paper 6 on Special Needs Education (Department of Basic Education, 2001).

I sent letters of invitation to eight full service primary schools that were not more than an hour away from my home, inviting them to participate in the research. These specific schools were thus conveniently selected due to their accessibility for the researcher and because as full service schools, they were expected to support learners in need, such as learners experiencing difficulty in attaining mathematical skills. Convenience sampling is a non-probability sampling method widely used, because it is quick, inexpensive and convenient, as the researcher selects respondents that are nearby, available and accessible (Ary et al., 2018; Cohen et al., 2011; Elfil & Negida, 2017; Etikan et al., 2016; Taherdoost, 2016). As such, I conveniently sampled two schools, based on easy access, vicinity, and my work requirements. Implementing convenience sampling, therefore, allowed for the selection of population elements due to their availability and accessibility (Etikan et al., 2016; Maree & Pietersen, 2016b; Taherdoost, 2016). Only three schools responded, one declined due to difficulty for their learners to stay after school, with two accepting the invitation.

To identify and sample Grade 6 learners with developmental dyscalculia in these schools, I utilised non-probability sampling and purposive sampling. Probability sampling extracts randomly from the target population so that all members of the population have the same opportunity to be included in the sample, which allows the researcher to make generalisations to the population (Ary et al., 2018; Bryman, 2016;

Cohen et al., 2011; Denscombe, 2014). The advantage of using probability sampling − random sampling − is that the sampling is bias-free and therefore representative of the whole population; but it may take much time, money and energy (Ary et al., 2018; Flick, 2015; Taherdoost, 2016). Non-probability sampling results in the sample being selected using a non-systematic process, thus not randomly, so that respondents from the population do not have equal opportunity to be selected to the sample (Elfil & Negida, 2017; Maree & Pietersen, 2016b). The main disadvantage of non-probability sampling is that it may not be representative of the population and therefore may not be generalised to the population (Ary et al., 2018; Cohen et al., 2011; Elfil & Negida, 2017). The main advantages are convenience and budget (Taherdoost, 2016). The researcher may consider using non-probability sampling methods when the timeframe in which research much be completed is limited, funds are limited, it is difficult to get full access to the population, the measurement needs to be tested and preliminary studies must be done in developing an instrument (Maree & Pietersen, 2016b).

Purposive sampling is a type of non-probability sampling that is used when the sampling is done with specific characteristics of the respondents and the objective of the study in mind (Cohen et al., 2011; Flick, 2015; Maree & Pietersen, 2016b).I utilised a non-probability purposive sampling method to identify the sample unit. This method supports the positivist paradigm and quantitative approach followed in this study. I used non-probability and not random sampling, as I relied on test scores to select the initial sample, which was thus not random (Flick, 2015; Lohr, 2019; Maree & Pietersen, 2016b; Mertens, 2015). For this purpose, I obtained all the marks of the Grade 6 learners as entered into SAMS for the end of their Grade 5 year in 2017, as well as their first term marks for 2018 from the two schools. As the two schools were in the same district, they used the same ATP (annual teaching plan). I used the first term marks to make my selection to ensure that everybody was in school.

Next, I used several methods to ensure that I selected respondents who might display dyscalculic tendencies. I relied on the four criteria of the DSM-V (American Psychiatric Association, 2013) as first criteria for selection, looking at the mastering of number sense, number facts or calculation, and severe difficulty in applying mathematical concepts, facts and procedures, as reflected in low scores in Mathematics. Secondly, I looked at affected academic skills; in this case, mathematics performance, with the stipulation it being substantially and quantifiably below what is expected for the specific individual's chronological age (thus below peers), and may, as a result, cause significant interference with academic performance. Thirdly, I ensured that the learning difficulty started during the school years, and fourthly I checked for all the respondents that the difficulty had not been caused by an intellectual disability, mental or neurological disorder.

The specific type of non-probability sampling that I used was purposive sampling, as it was essential to select learners with a probable tendency towards dyscalculia (Denscombe, 2014; Flick, 2015; Maree & Pietersen, 2016b). For this purpose, I first asked the teachers to remove the names of learners that had failed more than once, probably due to an intellectual disability. They also removed names of learners that had been diagnosed with other learning disabilities like dyslexia, as these could have caused the dyscalculic tendencies, resulting in mathematical difficulties and potentially influencing the reliability and validity of the results of my study.

In selecting the respondents, I entered the first term 2018 scores for the learners for all subjects into an Excel spreadsheet and determined the average of all subjects for each learner that was not older than 13 years of age, so that the sample included only 12- and 13-year-old learners in Grade 6. I used codes for the sake of anonymity. I then determined the average of the subjects, excluding Mathematics, to see whether or not the average without Mathematics was significantly higher than the average including Mathematics. If no significant difference existed between the average with Mathematics and the average excluding Mathematics, I concluded that these learners most probably might have experienced other difficulties that influenced all their subjects, and not Mathematics only. I also compared their Mathematics scores to their language of learning and teaching (Lolt) scores, to determine whether a language problem could perhaps have caused learners' difficulty with Mathematics.

I imported all scores into the Statistical Package for the Social Sciences (SPSS 25) and then used the analysis software to identify potential respondents in the lowest quartile of the Grade 6 learners at their school in terms of their Mathematics scores. I used SPSS also to determine the standard deviation (SD) of the Mathematics scores and then used Excel to calculate 1 SD below the average of all the Mathematics scores. I then applied SPSS to all the learners to identify learners whose Mathematics scores were one or more SDs below the mean. I compared the two lists to ensure that all learners with Mathematic scores more than 1 SD below the average for Mathematics were included in the list in the 25th percentile (lowest quartile). I then showed the list, with the names, to the Mathematics teachers and asked them if they agreed to the identified learners and whether there were any other learners, they would like to add. The teachers approved the lists and did not add any learners. They agreed that the identified learners were the ones in their classes with probable dyscalculic tendencies.

In undertaking this procedure, I used a wide margin not to exclude anyone who might probably be dyscalculic, but narrow enough so that everyone in the group displayed severe difficulties with mathematics. At the one school, with a total of 62 Grade 6 learners, 10 learners (16,1%) were included in the initial sample, while at the school with 141 Grade 6 learners, 24 (17,0%) were included in the sample. Parent meetings and meetings with these learners were then scheduled and the study explained to them. Informed consent was obtained from the parents who agreed for their children to be part of the study, and informed assent from the learners. As not all the parents attended the meetings and gave consent, eight learners from the first school participated and 19 learners from the second school.

All respondents with tendencies towards dyscalculia, i.e. the initial sample, then completed a pre-test to determine the level of the dependent variable. Scores were arranged from low to high, and the respondents were randomly assigned to two groups. The two groups were then labelled the experimental group (14 respondents) and control group (13 respondents) by flipping a coin. This was done to ensure that the two groups were as similar as possible and that differences between them after the intervention would not have occurred as a result of the differences between the two groups. Some respondents in the experimental group asked to be in the control group as they did not want to stay behind after school for the intervention at that stage but wanted to remain part of the study. I made the requested changes, which had a small effect on the averages of the pre-tests of the two groups. After the pre-test and assigning to the two groups, three respondents of the control group decided to leave the study, leaving the control group having 10 respondents.

Choosing Grade 6 learners ensured that all respondents were of approximately the same age, had received more or less the same level of mathematics teaching and were at the end of the Intermediate Phase in school. Thus, the sample unit of learners with dyscalculia was more homogeneous than it would have been if a random sample unit from the whole school had been taken. This ensured that other factors such as age, different grade level and different content teaching did not interfere with the study. A challenge of using this method was that the sample was small and came from only one grade from two schools. It was thus not a representative sample of Grade 6 learners with dyscalculia in South Africa, and the findings may as a result not be generalised to all dyscalculic Grade 6 learners, but may still show the effect of an intervention using ICT. This may lead to further research with more significant and representative samples, allowing for generalisability.

The learners in the two subunits of the sample formed a homogeneous sample of the unit and thus led to informed deductions about the best feasible way to intervene when teaching learners with developmental dyscalculia. Furthermore, these methods of sampling suited the quasi-experimental design I implemented for this study.

3.3.2 Development of the intervention

I chose to use ICT for the intervention program because I wanted to see if there would be any improvement in the respondents' mathematics achievement, their number sense and their mathematic skills if ICT was used. I wanted to use intervention programs that are readily available and that learners can follow at home in their own time without having to rely on other individuals for practising additional mathematics. Using ICT has many advantages, such as the following:

- It is cheaper than one-on-one and even group mathematics intervention classes and not time restricted.
- Mobile phones, tablets and laptops are readily available and are widely used.
- ICT can be used any time of the day, any day of the week so that finding time to use it for mathematics is not as difficult to fit in extra classes in the learners' schedule.
- Teachers can use ICT like tablets or laptops in class or computers in computer centres at school to have group intervention sessions.

The intervention programs I selected are freely available on the internet or will be cheap for parents to obtain. The reasons for the choices relate to the possibility of the respondents being able to continue on their own with the intervention after the completion of the study. It was also important to choose programs that were enjoyable for Grade 6 learners and could retain their attention.

The programs I selected were *The Number Race* (Wilson & Dehaene, 2004) and various games on the *Sheppard Software* site (Sheppard & Chapgar n. d.) for mathematics, for example, *Math Lines, Math Man* and *Balloon Pop* as explained in Table 3.1. I used these games to intervene in their mental number line, subitising, place value and basic addition, subtraction and multiplication. I also used *The Rockseries* (RockSeries Educational Software, 2017), which is a South African developed program in Afrikaans and English, to allow them to catch up with basic mathematical skills as their number sense improved. The dependent variable was the respondents' possible improvement in mathematics performance. Control variables (covariates) were the grade level, time spent on intervention and gender.

Table 3.1: Programs used for intervention strategies

Name of the program	Website	Reason for inclusion	Focus
The Number Race	http://www.thenumberrace.com/nr/home.php	The Number Race is a fun computer game that teaches basic concepts of numbers and arithmetic. The game was designed to address developmental dyscalculia and to strengthen the brain circuits representing and manipulating numbers.	It uses concrete sets, digits, number words to practise counting with numbers 1 to 40, addition and subtraction in the range 1 to 10.
Math Lines	http://www.sheppardsoftware.com/math.htm	The shooting of the correct ball with a numbered ball, quickly moving through levels will keep the respondents' focus and encourage them to try over and over for a higher score and level.	❖ Addition to 10, to 20 and to 30 (respondent's own tempo) ❖ Multiplication of numbers up to 10 with each other.

Name of the program	Website	Reason for inclusion	Focus
Math Man	http://www.sheppardsoftware.com/math.htm	The learner solves mathematics problems, catches and avoids ghosts and sharpens the mathematics skills all at the same time. The game is like an arcade game and the respondents have to try moving to the next level, getting as high score as possible and entering their scores in the high score table, keeping them interested, even when doing elementary mathematics.	❖ Addition to 20. ❖ Multiplication to 10 and 12. ❖ Place value expanded form. ❖ Place value and value of digits. ❖ Rounding of hundreds and thousands.
Balloon Pop	http://www.sheppardsoftware.com/math.htm	The learner answers mathematic questions by popping the balloons containing the correct answer, or in the correct sequence. It is also an arcade type game, with levels, scores and a high score table, motivating the respondents to get as high a score as possible.	❖ Count and order objects in balloons. ❖ Greater and lesser than, with two or three balloons. ❖ Order numbers 1 to 10; 1 to 100 ❖ Skip counting ❖ Number patterns.
The Rockseries	https://rockseries.co.za/Math.htm	A fun, interactive multimedia learning kit with lessons, worksheets and tests. Respondents can see and listen to lessons about mathematics, and I chose the program because the respondents could listen to lessons in work they had fallen behind with.	The respondents used this program to focus on their time tables, place values and values, addition with carrying over and subtraction with borrowing.

3.3.2.1 The Number Race

The Number Race was originally developed by Wilson and Dehaene (2004) and it has been scientifically tested (Wilson et al., 2006b). The objectives of the game are to strengthen the brain mechanisms of number processing, to help forming a mental number line, to teach counting and re-enforce the concept, to encourage fluency, to teach early addition and subtraction and re-enforce the concepts, and to support individuals with dyscalculia. The players have to compare the dots and digits on the left with those on the right and click on the extra one. Then they drag the dots to the number line. All the respondents started as beginners with a number line up to ten.

They followed at their own pace and some ended with number lines at 12, still at the beginner level, some at 20 and some at 40 at intermediate level. All instructions are also verbal and the respondents use earphones to listen to the commands. Figure 3.2 below shows a beginner level comparing the dots and digits, before putting the dots on the number line.

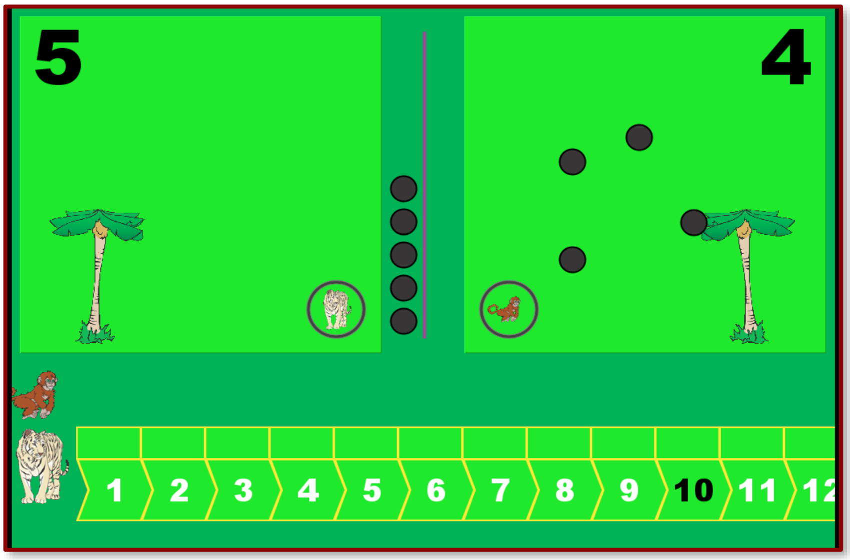


Figure 3.2: Comparing the dots in the Number Race

Figure 3.3 below shows a higher level of the game, where players have to add numbers on one or both sides, compare the sides and click on the side having the majority of dots, after which the characters have to be placed on the correct places on the number line by first putting the dots on the line.

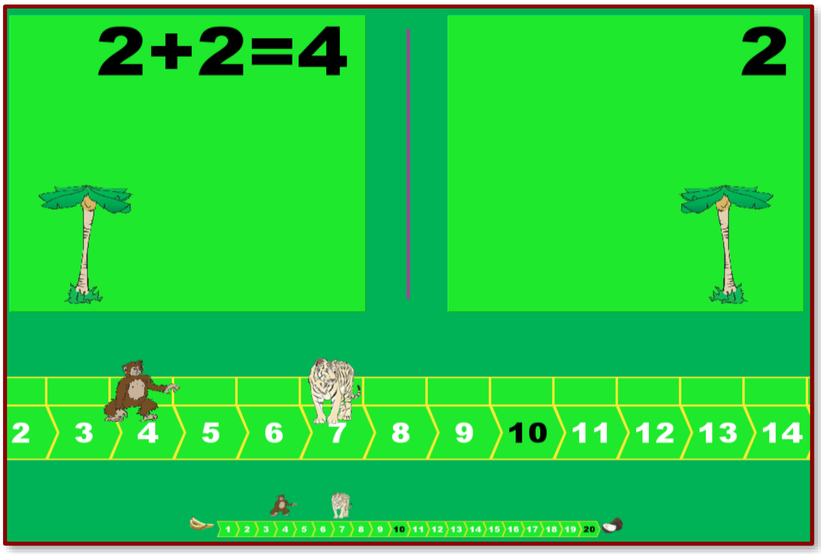


Figure 3.3: Putting the characters on the number line in the Number Race

The Number Race is open source software and can be downloaded for free from the website. More advanced learners can use *the Number Catcher*, which is available on Google Play and the App Store.

3.3.2.2 Sheppard Software

Sheppard Software (Sheppard & Chapgar, n. d.) creates educational content and games. The aim is to design games with many difficulty levels so that players experience challenges. The developers provide games challenging players' brains and they add sound and visual effects to the games to make it fun and unforgettable to learn. They have hundreds of free online mathematics games that can be used to let individuals practise mathematics while having fun, with many levels per game and for a wide range of ages and abilities. The reasons I decided to use *Sheppard Software* was because the player can practise a wide variety of skills on different levels. Given the amount of animated games, the player would probably look forward to the intervention sessions and would stay interested in the intervention. Figure 3.4 shows a few of the mathematics games available on *Sheppard Software*.

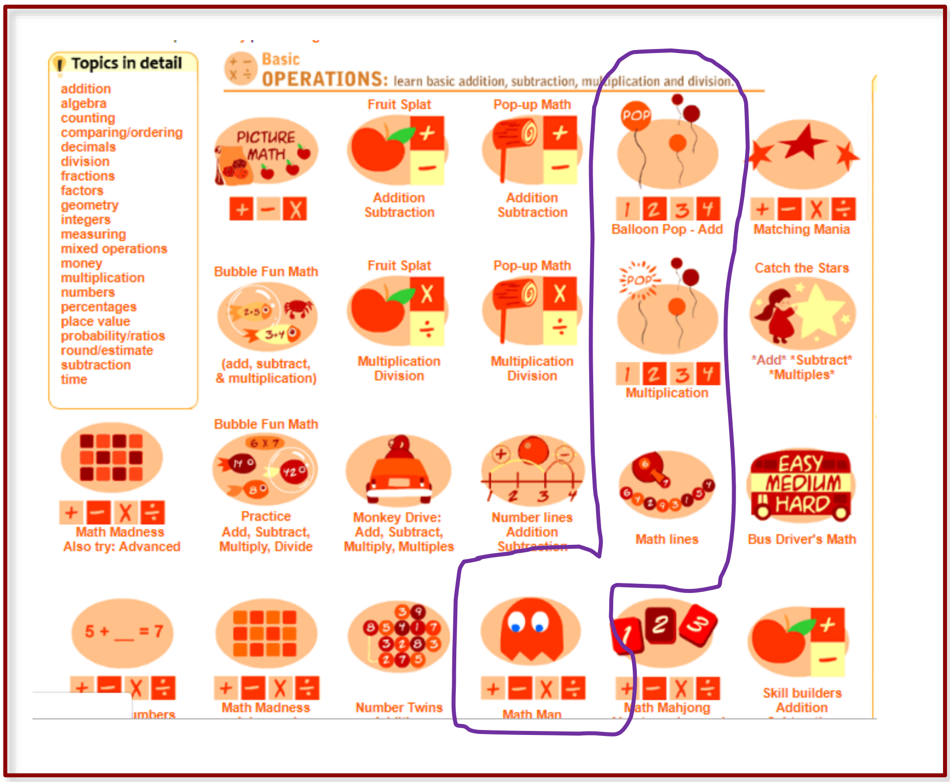


Figure 3.4: A few games in Sheppard Software

The respondents used *Pop the Balloon* to count and order numbers, as shown in Figure 3.5.

Figure 3.5: Counting and ordering numbers

In the game shown in Figure 3.6 the respondents had to add the number in each balloon, and then pop the balloons from the smallest to the largest number with the needle.

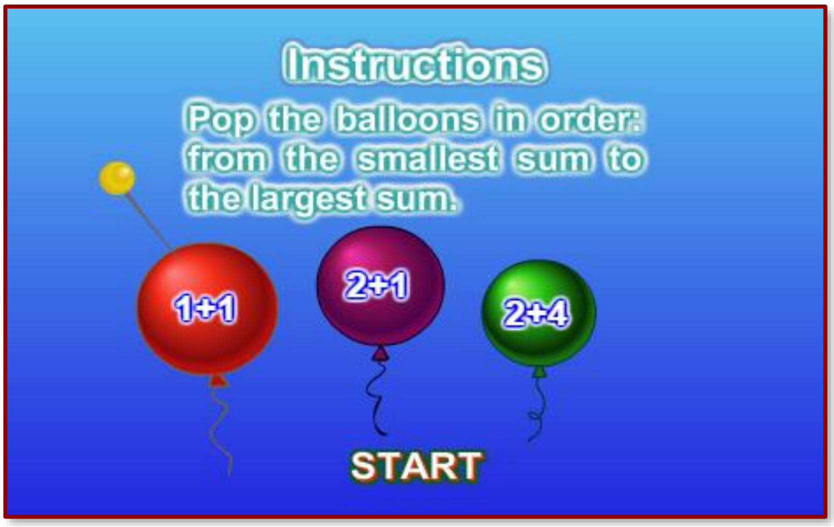


Figure 3.6: Adding and ordering game

The next game the respondents played was *The Math Line,* which is a type of number line shooter. The player has to shoot the ball to its pair, for example, if playing add to 10, a number 3 ball will be shot in the direction of a number 7 ball, because 3 + 7 = 10. They both then disappear, making the line of balls shorter, until there are no more balls and then the player moves to the next, more difficult and faster level. If there is no match for the ball, the player has to shoot it away from the other balls, otherwise it will connect to the line of balls, making it longer. Figure 3.7 shows an example of the instructions the player sees in *Math Lines.*

Figure 3.7: The instruction window for the Math Lines game

The game gets faster and more colourful at higher levels, as can be seen in Figure 3.8.

Figure 3.8: The Math Line game

Math Man is a game usable for many mathematics skills. A sum appears at the bottom, and the player must use the up, down, left and right keys on the keyboard to eat the ghost with the correct answer, making extra points as *Math Man* eats the little dots and fruits on the way to the correct answer, as can be seen in Figure 3. 9.

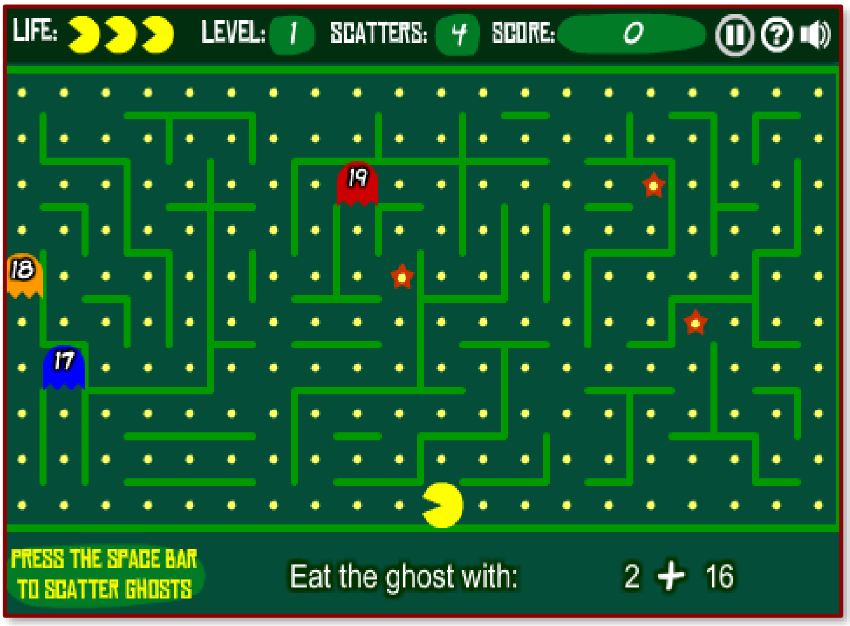


Figure 3.9: Using Math Man for adding up to 20

I used *Math Man* also for place value, expanded form, and for the value of digits in a number, as shown in Figure 3.10 and Figure 3.11.

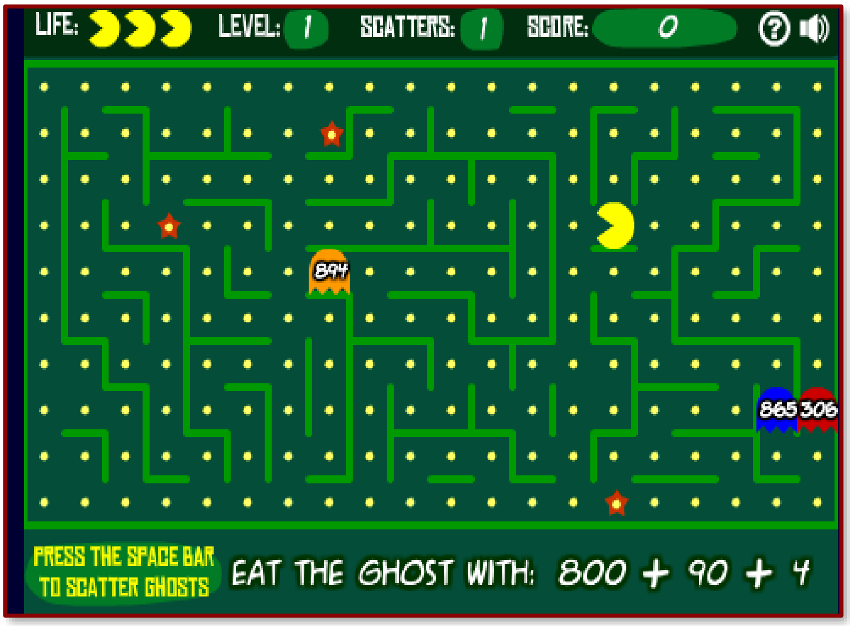


Figure 3.10: Place value in expanded form using Math Man

Figure 3.11: Using Math Man to practise the value of a digit in a number

I used Math Man to practise rounding up to 100 and up to 1000, as Figure 3.12 shows.

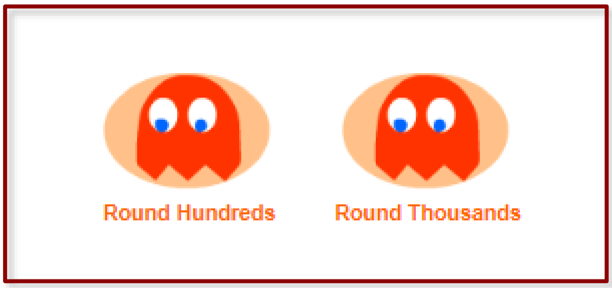


Figure 3.12: Math Man can also be used for rounding numbers

3.3.2.3 The Rockseries

The Rockseries or *Die Rotsreeks* in Afrikaans (RockSeries Educational Software, 2017), is a program developed in South Africa and is suitable for usage in a computer centre at school or on a computer at home. It is available on a CD and comes with a password to use, so no internet is needed. The program contains lessons, worksheets and tests and has audio files in Afrikaans and English. Figure 3.13 shows the window when a player, for example, wants to review fractions.

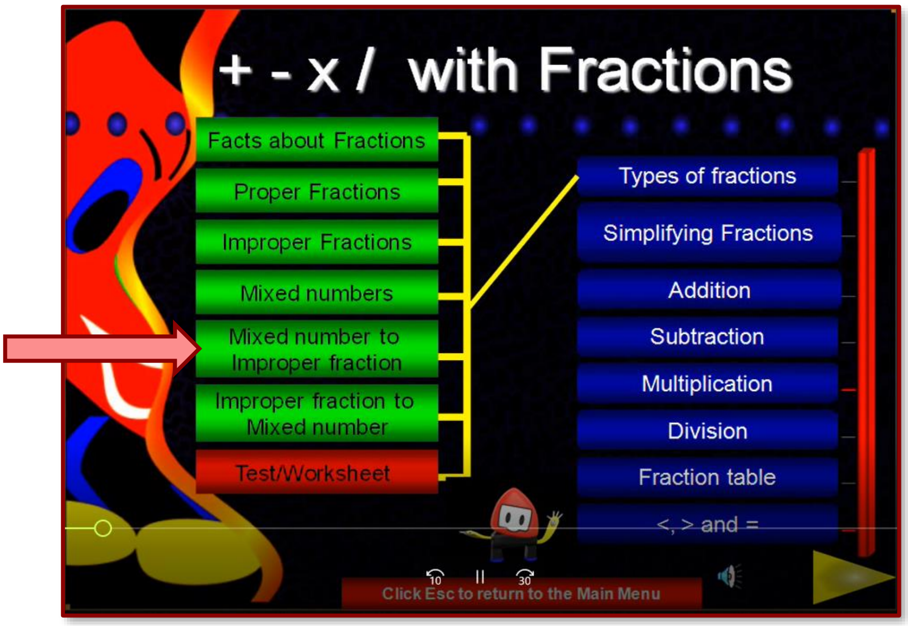


Figure 3.13: The Rockseries menu for reviewing fractions

In Figure 3.14 it can be seen how the program explains changing a mixed number into a fraction.

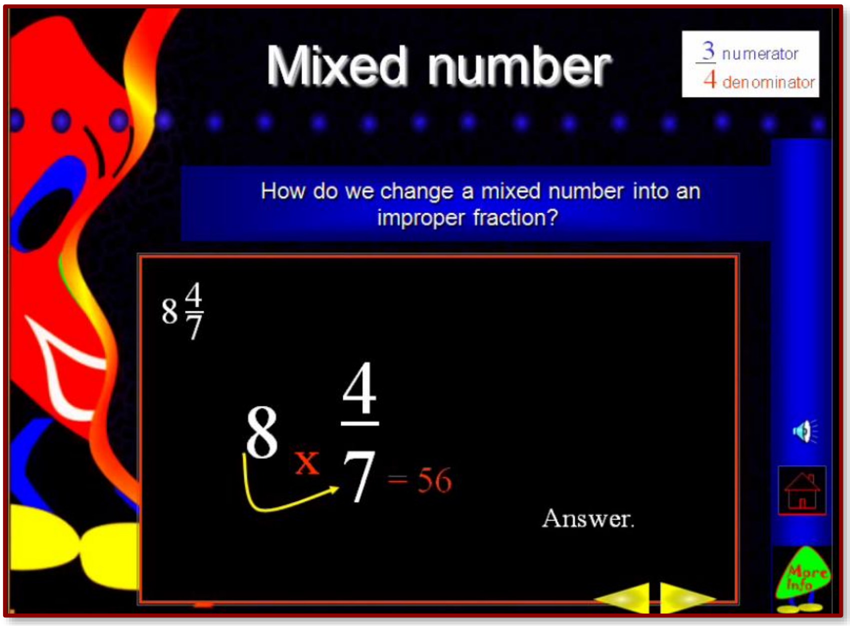


Figure 3.14: Example of the working screen of The Rockseries

I used these games and programs in combination with one another as intervention, thus using more than one game to practise the same concept. The respondents were allowed to stay at a lower level should they feel more comfortable doing more accessible work to receive higher scores. They could then proceed to more challenging work when they felt ready to do so. Other respondents proceeded to higher levels and more difficult sums whenever they wanted to.

Appendix H provides an analysis of the pre-test and indicates which game practises the concepts in the questions in more detail. Appendix I shows the course of the intervention. The respondents wrote the post-test that provided some of the data after 30 minutes twice a week for six weeks.

3.3.3 Data collection

A vital aspect of a research study is the collection of the data, as incorrect data may have an influence on the study and cause invalid results. Quantitative data collection methods must produce results that are easy to summarise, compare and generalise (Flick, 2015; Hoy & Adams, 2015). Therefore quantitative data collection includes methods that produce numerical values as data, expressing quantity, amount or range (Ary et al., 2018). Quantitative data may be used to look for cause and effect relationships and may be used to make predictions (Cohen et al., 2011; Hoy & Adams, 2015). Different types of data can be collected, for example, nominal and ordinal data, which is non-metric data, and interval and ratio data, which is metric data (Maree & Pietersen, 2016a). Data on the nominal scale consists of two or more categories and values are distinguished by different names, like male or female. Data on the ordinal scale is more or less the same as nominal data and has the same characteristics, except the categories can be arranged in a meaningful order, like disagree, neutral, agree, strongly agree. Data on the interval scale keeps the features of ordinal and nominal data of classification and order but also has an equal interval between each data point. This data is numeric, has quantity and differences in quantity or magnitude can be measured. Data on the ratio scale adopts the features of the previous three scales, namely classification, order and equal interval, but it also has a true zero, enabling the researcher to determine proportions, like three times more, twice as long, and so forth. (Cohen et al., 2011; Maree & Pietersen, 2016a). The type of data I collected with the quasi-experimental design was on the interval scale, thus metric data, enabling the use of statistical methods to describe and interpret the data.

In collecting the data for this study, I utilised three sets of data, namely the pre-test scores, the post-test scores and stanines for Butterworth's *Dyscalculia Screener* (GL

Assessment, n. d.). The respondents took the pre-test and were assigned to the experimental and control groups. Then, in the next week, both groups completed the *Dyscalculia Screener*. The experimental group received the intervention, which is the independent variable, for six weeks, and five days after the last intervention session both groups took the post-test. The following week all the respondents again completed the *Dyscalculia Screener*.

The scores obtained on the pre-test provided the first data collected for both the experimental group and the control group. The purpose of the pre-test was to obtain a base-line for some mathematical concepts for each learner. Specific performance in the test was not essential, as the importance lay in the improvement, or not, in the scores of each respondent and also in the average of the group following the intervention. The purpose of the post-test was to determine whether the intervention had a significant influence on the factors test by the pre-test. I utilised the *Dyscalculia Screener* to determine whether the respondents would be categorised as having a tendency towards dyscalculia as defined by Butterworth (2003), and also to have stanines for the five subparts of the screener, namely reaction time, dot enumeration, numerical stroop, addition and multiplication. I repeated the *Dyscalculia Screener* after the post-test to determine if there was any change in the tendencies towards dyscalculia and in the stanines for the subparts of the screener. I did not statistically analyse the data of the *Dyscalculia Screener* but described the possible changes in the results of the screener after the intervention, because I used the stanines of the screener and not the scores. The *Dyscalculia Screener* is standardised for the United Kingdom and not for South Africa, so it does not measure the achievement of Grade 6 learners in South Africa. Therefore the Dyscalculia Screener cannot be used to answer the research question. Moreover it probably should not be repeated as a diagnostic tool for dyscalculia in such a short time period.

I designed a pre-test and post-test to determine whether the ICT intervention as an independent variable had a significant influence on the mathematics performance of the respondents. As the respondents were halfway through their Grade 6 year and I wanted to test their mathematics performance, I did not use a standardised test that tests features of dyscalculia or their performance in Grade 6 mathematics. Instead, I designed a test using some types of sum in the Annual National Assessment of the

Department of Basic Education (2014; 2015a) for Grade 5, that did not seem to be too tricky and for which the same type of work had been done in Grade 6 before June 2018, according to the teachers' ATPs, as well as sums from a Grade 6 Mathematics textbook (Bowie, 2012). I designed the test in a manner to incorporate sums that have number sense at their core, for example, place value, as well as sums that are more about the learning of mathematical skills, like addition. This was done to provide the respondents with a test in which the questions appeared familiar and were not too difficult, to lessen their anxiety. It was not possible to test every detail of number sense and mathematical skill obtained in Grade 6. The idea was to test the respondents without making them more negative about mathematics and tests, so the tests were not supposed to be too long or too difficult, but if there were any improvement in number sense or mathematical skills, there had to be an improvement in the test scores. My aim was not to determine the level of achievement in mathematics reached by the respondents but to determine whether there was a significant improvement in the scores after the ICT intervention. I also did not want the total of the test to be more than 50, as a large total and a test that takes more than an hour to complete may also cause anxiety.

In designing the pre-test, I tried to incorporate questions about place value, sequencing, size of numbers, the concept of number and conservation of number to determine whether the respondents had a poor number sense to answer the research questions and test the set hypotheses. For the same reason, I included questions testing factors and multiples, rounding, addition with carrying, subtraction with borrowing and multiplication of three-digit numbers with two-digit numbers to determine the respondents' mathematical skills. I used the total scores of all these questions as a measure of the respondents' achievement in mathematics, as these questions covered some of the content in CAPS Grade 4 to 6 already done, for Grade 6 learners.

The post-test needed to measure the same factors on the same level that the pre-test did for comparison their results. Therefore, the pre- and post-tests had the same questions, but with different numbers. The order of the questions was also changed. The pre-test and post-test are available in Appendices E and F. To determine whether there was an overall improvement in the achievement in the mathematics of the respondents, the average of the total scores of the experimental group was compared to the average of the total scores of the control group for the pre-test and for the post-test; the average of the total scores of the pre-test of the experimental group was compared to the average of the total scores of the post-test of the experimental group, and likewise for the control group. Table 3.2 shows the breakdown of the questions in the pre-test and the post-test.

Table 3.2: Breakdown of the questions in the pre-test and the post-test

Variable	Concept	Question in pre-test	Question in post-test	CAPS Grade 4-6	Based on	Marks	Percent-age
Number sense	Place Value	1	5	1.1	Text book, ANA 2014, 2015	3	6
	Sequencing	6	6	2.1	ANA 2014, 2015	12	24
	Bigger/Smaller	2, 3, 4, 9	2, 3, 4, 7	1.1; 4.3	Text book, ANA 2014, 2015	8	16
	Concept of number	7, 8, 10	8, 9, 10	1.1	Text book, ANA 2014, 2015	6	12
	Conservation of number (Value)	5, 14	1, 12	1.1	Text book, ANA 2014, 2015	4	8
Mathematical skills	Factors and multiples	12, 13	13, 14	1.1	ANA 2014, 2015	2	4
	Rounding	11	11	1.1	Text book, ANA 2014, 2015	3	6
	Addition with carrying	15a, 15b	15a, 15b	1.1	Text book, ANA 2014, 2015	4	8
	Subtraction with borrowing	15c, 15d	15c, 15d	1.1	Text book, ANA 2014, 2015	4	8
	Multiplication: three-digit number with two-digit number	15e, 15f	15e, 15f	1.1	Text book, ANA 2014, 2015	4	8

All the respondents received their tests in the language of teaching (LOLT) at their school. The tests were read to all the learners so that good or bad reading skills would not influence the scores. It took the respondents approximately one hour to complete the test. The pre-tests were marked, and the total marks entered into an Excel spreadsheet. The marks for individual questions were also entered. Hereafter, the control group continued with regular teaching, while the experimental group participated in the intervention program that might have an effect on the level of the dependent variable (Cohen et al., 2011; Maree, 2016). The intervention program was followed for six weeks, two sessions of 30 minutes each week − thus 60 minutes per week.

The intervention was followed by a post-test for all respondents of both groups to measure any potential change in the dependent variable (Maree, 2016) and determine the success of the intervention (if any) on the dependent variable, being achievement in the post-test (Cohen et al., 2011). All the respondents in the experimental and control groups wrote the post-test so that the performance of the respondents in the experimental group could be compared to the control group. The scores could furthermore be compared to the average score of the whole group and the deviation from the average score compared to the pre-test. It is possible that other factors, such as sickness, anxiety, emotional problems, outside help such as extra classes, to name a few, might have influenced the scores, even though the respondents were requested to refrain from other intervention strategies while busy with the research project. They all received similar mathematical teaching during school hours, as all the schools in the district used the same annual teaching plan developed according to the national CAPS[10] curriculum, so the classroom teaching probably did not have a limited effect on the outcome of the study. The gender, age, race and home language of all respondents were documented to identify any factors that could probably have influenced the findings.

As explained previously, I used Butterworth's *Dyscalculia Screener* (GL Assessment, n. d.) before and after the intervention to see if there were any changes in the reaction time, numerical stroop and dot enumeration, which Butterworth relies on for making

[10] Curriculum and Assessment Policy Statement. This is a single, comprehesive, and concise policy document for all the subjects listed in the National Curriculum Statement Grades R – 12 in South Africa.

the diagnosis as probably dyscalculic. Thus, I had to determine whether the intervention had changed the respondents' diagnosis as possibly dyscalculic according to Butterworth's criteria. I also used the screener's achievement tests to see if there was an improvement besides and multiplication of numbers smaller than ten. The data collected using Butterworth's *Dyscalculia Screener* is described in Chapter 4 but was not used to answer the research questions or to test the hypotheses.

The *Dyscalculia Screener* is a computerised test that contains three computer-controlled tests that are timed per item. The speed of responses to the questions is used to determine whether an individual responds slowly to the question or is just a slow responder. A fourth test, simple reaction time, is the first test the respondents will see, and the computer program will adjust the respondents' reaction times as a function of this test. The second and third tests they see are the two tests of capacity, namely dot enumeration and numerical stroop (number comparison). The last test is an achievement test, which contains questions about simple addition. For older respondents there is a fifth subtest on multiplication. In all the tests, the respondents can see the question on the screen and listen to the audio. They must then press any one of a given set of left keys for left, and right keys for right. All the questions prompt the respondent to press left or right for a specific answer. When attempting the simple reaction time test, the respondent must press a left key as quickly as possible when seeing a black dot on the screen. In the dot enumeration test, the respondent compares the number of dots on half of the screen to the numeral on the other half of the screen and then presses a key indicating whether the numbers match or not. Some immediately see whether the given answer is correct, without counting, thus subitising, while others have to count the dots, resulting in slower reaction time. In the next test, numerical stroop, the respondents have to compare two numbers and select the larger of the two, thus testing whether the respondent can order numerosities by size and understand numerals. The last test is an arithmetic achievement test consisting of a subtest on addition for respondents younger than ten, and subtests on addition and multiplication for respondents aged 10 and older. As all my respondents were between 11 and 14, they all did addition and multiplication subtests. In this test, they saw a sum with an answer, for example, 4 + 5 = 9, and they had to decide as quickly as possible whether the answer was correct or not and press the corresponding key. All the answers were captured and scored by the computer program. The computer program automatically calculates the scores and gives the results as standardised scores in a printable form (Butterworth, 2003).

The test takes 15 to 30 minutes to complete, depending on the age and ability of the respondent. The respondents in this study, with the exception of two, were not used to computers, and most of them had never worked on a computer before the study, resulting in their being a little scared of the computers at first. It took the respondents in this study between 30 and 45 minutes to complete the test. I used two laptops and let two respondents complete the *Dyscalculia Screener* at a time. I explained to them what to do and they used earphones to listen to the instructions in the tests. All the tests had a practise round first, which the learner could repeat. I translated the instructions and questions in the practice rounds to the Afrikaans-speaking learners, but as they all understood English, they all caught on quickly and did not need any translations to complete the tests. Figure 3.15 explains what each test did, what it looked like, and what audio question the respondents heard.

The *Dyscalculia Screener* was standardised in February 2002, with 549 learners in 21 schools, including infants, primary, junior and secondary schools in the United Kingdom. As the screener was standardised for learners in the United Kingdom, it was not necessarily standardised for the learners in South Africa and was not used to answer the research questions or to test the hypotheses. However, the screener tests basic numerosity and basic arithmetic skills, which are also applicable to learners in South Africa, and the results of the *Dyscalculia Screener* may as such give valuable insight into possible changes in the scores after the ICT intervention. The *Dyscalculia Screener* cannot diagnose a student with dyscalculia but can screen learners to indicate a tendency to dyscalculia (Butterworth, 2003). If learners did not test as having dyscalculic tendencies, they might still have barriers to learning mathematics but it would probably not be because of an impaired number sense. These learners may be regarded as learners with developmental dyscalculia, with other causes, which also formed part of this study. The stanines of the dot enumeration, numerical stroop, addition and multiplication were recorded in an Excel spreadsheet.

Sub-test 1

Simple Reaction Time

Speed of response is the measure used in the assessment so a test of simple reaction time is shown first. The reaction times of the other sub-tests are adjusted to take this measure into account.

Example question:

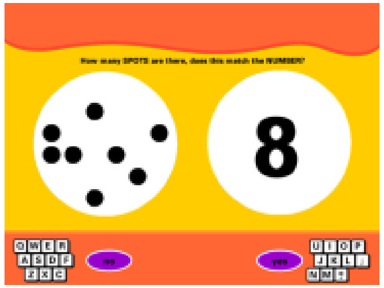
Audio: As soon as you see a black spot, press a left key with your LEFT hand.

Sub-test 2

Dot Enumeration

Asks the learner to compare the number of dots on half of the screen with the number on the other half of the screen, and to press a key to show whether the two numbers match.

Example question:



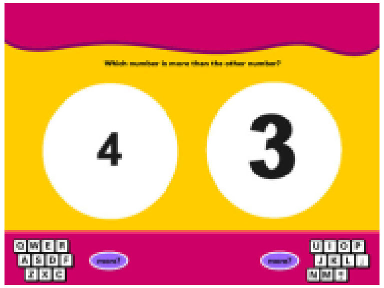
Audio: How many SPOTS are there, does this match the NUMBER?

Sub-test 3

Numerical Stroop

Asks the learner to select the larger of the two numbers shown on the screen.

Example question:



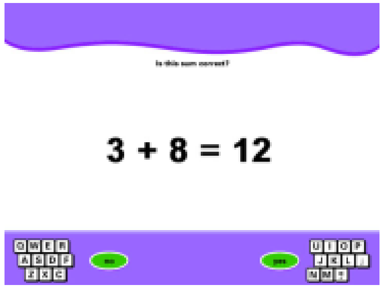
Audio: Which number is more than the other number?

Sub-test 4

Addition

A sum is shown on the screen with an answer. The learner has to judge as quickly as possible whether the answer shown is correct.

Example question:



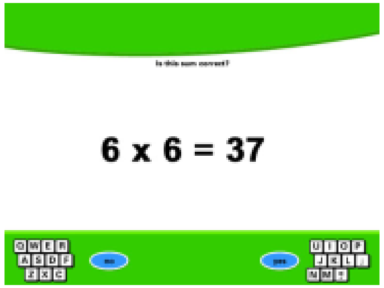
Audio: Is this sum correct?

Sub-test 5

Multiplication

A sum is shown on the screen with an answer. The learner has to judge as quickly as possible whether the answer shown is correct. Only those aged 10 or over will see the multiplication sub-test.

Example question:



Audio: Is this sum correct?

Figure 3.15: Explanation of the Dyscalculia Screener

3.3.4 Data documentation

The scores of the learners for the pre-test, the *Dyscalculia Screener* and post-test provided data on the interval scale because they were numeric and had quantity. Data was entered into an Excel spreadsheet based on the various mathematical and statistical functions offered, as well as the option of graphs that can be used to analyse data and indicate probable relationships between the data. The researcher is skilled in using spreadsheets and the documentation of data into the spreadsheet was double-checked for accuracy. When documenting the data, the learners' age, gender and race were also documented. The last column captured anything out of the ordinary that took place during the intervention process, such as sickness or anxiety.

3.3.5 Data analysis and interpretation

Data analysis was conducted after the raw data had been captured, organising and summarising it to make meaningful deductions and conclusions stemming from the data. I had to decide if parametric or non-parametric tests should be used to analyse the data. Parametric tests, such as the t-test, are used when it is known that the scores will show a normal distribution; the population and both groups' sample sizes were at least 30 (Cohen et al., 2011; Pietersen & Maree, 2016d); Hartas, 2015; Hoy & Adams, 2015). Non-parametric tests, on the other hand, do not make assumptions about the population and may be used for small sample sizes. In Table 3.3 I describe the statistical methods utilised in this study, which were completed by using the statistical analysis software program SPSS 25 at the University of Pretoria.

Table 3.3: Data analysis procedures

<table>
<tr><th>Item analysed</th><th>Type of analysis</th><th>Rationale</th></tr>
<tr><td>Pre-test scores</td><td>Cronbach's alpha of the scores in the pre-test was calculated using SPSS software.</td><td>Cronbach's alpha is a test of reliability. A high alpha score points to high reliability. If an item has a negative score or has a large negative impact on the alpha, it may be discarded from the test to obtain a higher alpha and thus more reliability. If the items in a test are correlated, the value of alpha is increased (Tavakol & Dennick, 2011; Vaske, Beaman & Sponarski, 2017).</td></tr>
<tr><td>The scores of the subtests for number sense of the pre-test.</td><td>The average of the subtests for number sense was calculated. The Spearman rank correlation coefficient was calculated for the subtests and the average of number sense.</td><td rowspan="2">The Spearman rank correlation coefficient was used to determine the relationship between the variables for number sense, and also between the variables for mathematical skills, to determine if the variables measured what they were supposed to measure.</td></tr>
<tr><td>The scores of subtests of mathematical skills of post-test.</td><td>The average of the subtests for mathematical skills was calculated. The Spearman rank correlation coefficient was calculated for the subtests and the average of mathematical skills.</td></tr>
<tr><td>Pre-test scores and post-test scores separately.</td><td>❖ Descriptive statistics were used to analyse the marks. These marks were used for the sample units, namely the experimental group and control group.
❖ Mean, quartiles, range, interquartile range, standard deviation and variance of the whole Grade 6 population, as well as the experimental group and control group were calculated.</td><td>❖ The mean entails the arithmetic average of marks (Cohen et al., 2011; Pietersen & Maree, 2016a). Calculating the mean of each group on the same test provided information about where the groups' averages were in accordance with one another, as well as where each respondent's mark was in his /her own group and in the Grade 6 group.</td></tr>
</table>

Item analysed	Type of analysis	Rationale
		❖ The range, interquartile range, variance and standard deviation of each group described the spread of the distribution of marks (Cohen et al., 2011; Pietersen & Maree, 2016a). The range of each group indicates the difference between the highest and lowest marks, where the interquartile range provides information about the range of the middle 50% of the marks (Cohen et al., 2011; Pietersen & Maree, 2016a). Furthermore, variance measures the level of spread of the data around the mean value, enabling the researcher to see whether the spread around the mean differs for the different groups. The standard deviation entails the square root of the variance and indicates the spread around the means for the different groups (Hoy & Adams, 2015). Furthermore, the standard deviation can be used to standardise each respondent's mark by calculating the standard score (z-score) so that it can be compared to marks in other groups and also to the marks of the post-test (Hartas, 2015). ❖ Graphical representations of the data are included in Chapter 4 to show the skewness and kurtosis (that

Item analysed	Type of analysis	Rationale
		is the flatness of the curve) of the distribution.
Dyscalculia screener scores collected before the intervention and after post-test.	Performance in the *Dyscalculia Screener* was analysed according to the manual of the screener. Respondents each received a standardised score on each of the subtests of the screener. The program indicates the ranking of each respondent on each of the tests in terms of stanines (distribution of scores divided into nine segments), and then composes a total score for all the subtests; it consists of the mean of the standardised scores of the subtests and a narrative interpretation based on this total score.	The rationale for using the analysis of the *Dyscalculia Screener* was to have a way to determine whether a respondent experiencing difficulty in learning mathematics has a tendency towards dyscalculia as defined by Butterworth. The test was repeated after the intervention for both groups and the results were described in comparison with the results of the screener test before the intervention.
Post-test marks in relation to pre-test marks.	❖ Hypotheses on the number sense of Grade 6 respondents with developmental dyscalculia were tested. ❖ Hypotheses on the mathematical skills of Grade 6 respondents with developmental dyscalculia were tested. ❖ The Mann-Whitney U test, which is the nonparametric test equivalent to the independent-sample t-test and compares two independent groups (Cohen et al., 2011), was utilised to compare the pre-test and post-test scores of the experimental group with the control group. ❖ The Wilcoxon matched-pairs signed-rank test, which is a non-parametric test similar to the t-test (Cohen et al., 2011; Pietersen & Maree, 2016d), was used to compare the marks of the pre- and post-tests for the experimental group. This test	❖ The hypotheses were accepted (Consult Chapter 4) and inference from sample to population was done. ❖ By using the Mann-Whitney U test, the experimental and control groups could be compared and deductions could be made about the effectivity of the intervention. ❖ The Wilcoxon matched-pairs signed-rank test rather than the parametric paired t-test was used because the sample size was smaller than 30. The Wilcoxon signed-rank test is appropriate for sample sizes of fewer than 30 (Cohen et al., 2011) and is used to examine a set of differences in one group. It was used to compare differences in

Item analysed	Type of analysis	Rationale
	tests the null hypothesis that states that the median of the difference score is equal to zero. If the null hypothesis is rejected, it can be assumed that the median of the differences is significantly different from zero (Cohen et al., 2011).	factors of number sense and mathematical skills between the pre-test and post-test in the experimental group.

3.3.5.1 The Spearman rank correlation coefficient

The Spearman rank-order correlation coefficient is the non-parametric equivalent of the Pearson product-moment correlation and evaluates the relationship between two variables (Cohen et al., 2011; Karros, 1997; Pietersen & Maree, 2016d; Puth, Neuhäuser, & Ruxton, 2015). It converts the data to ranks instead of using the actual values. The Spearman Rho ranges from -1 to +1. The Rho correlation will be -1 if the respondents' ranks on one variable are precisely the opposite of the other variable and +1 if the respondents have the same ranks on both variables. If the Spearman Rho is zero, there is no correlation between the variables (Altman & Krzywinski, 2015; Ary et al., 2018; Cohen et al., 2011). When using SPSS software, the output is a table giving the magnitude of the correlation, the direction of the correlation (positive or negative) and the significance level, which SPSS automatically calculates using the coefficient and the sample size (Cohen et al., 2011). The numerical value of the correlation coefficient indicates the strength of the relation. If the value is near zero, the relationship is weak; if the value is near 1, the relationship is strong. When interpreting the Spearman rank correlation coefficient, it is important to provide the level of statistical significance (Cohen et al., 2011; Pietersen & Maree, 2016d).

3.3.5.2 Hypotheses testing

A hypothesis is an important tool in the research procedure of quantitative research. The hypotheses give direction to the research and direct every aspect of the study; for example, the sampling, data collection, statistical analysis strategies and interpretation (Ary et al., 2018; Lazar, Feng, & Hochheiser, 2017). Therefore, the setting of a research hypothesis when the research process is started is essential and will influence every aspect of the study (Cohen et al., 2011; Haegele & Hodge, 2015). Hypotheses provide the researcher with a testable statement that can be confirmed or not confirmed and also a framework to report on the outcome of the study, thus on the findings and coming to conclusions (Ary et al., 2018; Pietersen & Maree, 2016b). The hypothesis must be a statement that can be tested and reflects the possible relationships between two variables. It must support existing knowledge and be precise and exact (Ary et al., 2018; Cohen et al., 2011). The hypothesis can be directional, thus states the kind of relationship between the variables, for example, better than, more than, less than, or it can be non-directional, thus only stating that there is a relationship, but not stating the kind of relationship (Cohen et al., 2011).

The researcher normally sets two kinds of hypotheses that can be tested, namely the null hypothesis (H_0) and the alternative hypothesis (H_1). The null hypothesis usually evaluates whether an apparent relationship between two variables really exists, or is likely there because of chance, whereas the alternative hypothesis confirms a relationship (Cohen et al., 2011; Lazar et al., 2017). The researcher aims to reject the null hypothesis, as the researcher wants to confirm the relationship (Ary et al., 2018). Thus, the researcher tested the null hypothesis against the alternative hypothesis, using the collected data, and if the null hypothesis was confirmed, the alternative hypothesis would be rejected and vice versa (Ary et al., 2018; Cohen et al., 2011; Pietersen & Maree, 2016b). It is important to state the level of significance used when testing the hypothesis.

3.3.5.3 The Mann-Whitney U test

The Mann-Whitney U test for two independent samples is the non-parametric equivalent of the independent-sample t-test. When working with a normal distribution and a sample size of at least 30 or more, researchers use the t-test as a different test for parametric data, which enables them to make inferences about the wider population. I used SPSS 25 to test for normality; the Kolmogorov-Smirnov statistic had a p-value (significance level) of 0.200, which is greater than 0.05, indicating that normality is assumed. When a sample size is less than 50, SPSS automatically calculates the Shapiro-Wilk value. Therefore with a sample size of 24 for all the respondents in the pre-test, the Shapiro-Wilk statistic was calculated. The p-value was

0.148, which is greater than 0.05, indicating possible normality. The value for skewness in the descriptive statistics was 0.726, which is a positive value indicating that the distribution of the values was more concentrated on the left. A perfect normal distribution will have a skewness value of zero (Cohen et al., 2011; Pietersen & Maree, 2016a). Because of the small sample size (14 for the experimental group and 10 for the control group), which was far less than the 30 per group required for parametric data (Cohen et al., 2011) and the fact that the data was skewed to the left, I decided to use non-parametric data, even though non-parametric data does not make assumptions about the population (Cohen et al., 2011).

The purpose of the Mann-Whitney U test is to compare to independent samples, namely the experimental group and the control group in this study. The parametric t-test uses the difference between two means, whereas the Mann-Whitney U test uses the difference between two medians (Allen & Seaman, 2007). Also, the Mann-Whitney U test is based on ranks; it compares how many times a score from one of the samples is ranked higher than a score from the other sample (Cohen et al., 2011; Singh et al., 2013). It is essential to state the level of statistically significant when reporting on the Mann-Whitney U test.

3.3.5.4 The Wilcoxon matched-pairs signed-rank test

The Wilcoxon signed-rank test is a non-parametric test that can be used to test two variables in one sample, thus to compare the pre-post and post-test of the same sample (Pietersen & Maree, 2016d; McCrum-Gardner, 2008; Singh et al., 2013). As my sample size was small and the distribution of the data was skewed to the left, I used the Wilcoxon signed-rank test to determine the relationship between test scores of the experimental group before and after the intervention. The Wilcoxon signed-rank test examines a set of differences of two paired samples, as it calculates the differences between the pre-test and post-test scores, and then orders the differences and assigned ranks to them, which results in the actual values of the differences not being used, but the ranks are used (Cohen et al., 2011; McCrum-Gardner, 2008; Pietersen & Maree, 2016d). Whereas the paired t-test tests a null hypothesis of the mean difference, the Wilcoxon signed-rank test assesses a null hypothesis that states that the median of the difference score is equal to zero (McCrum-Gardner, 2008;

Pietersen & Maree, 2016d). When reporting on the Wilcoxon signed-rank test, it is important to state the level of statistical significance (Pietersen & Maree, 2016d).

3.4 VALIDITY AND RELIABILITY

When researching phenomena, it is important to attend to specific issues that can validate the research and ensure a research project's reliability. More specifically, it is important to attend to sampling, data collection, data documentation and the analysis of data (Cohen et al., 2011; Flick, 2015; Mouton, 2001). The researcher must thus take the necessary steps to guarantee the validity and reliability of the research (Cohen et al., 2011; Pietersen & Maree, 2016c).

3.4.1 Validity

According to Cohen et al. (2011), research is valid when it measures what it is supposed to measure in a correct and ethical way. As I conducted a quantitative study, I attempted to improve validity by careful sampling, using appropriate instruments as well as applicable and proper statistical treatments of data during analysis (Cohen et al., 2011). I minimised the inbuilt standard error, which is inevitably part of quantitative studies (Cohen et al., 2011). As I utilised a positivist paradigm, I aimed to adhere to the positivist principles of controllability, predictability, replicability, context freedom, fragmentation and atomisation of research, derivation of laws and universal statements of behaviour, observability and randomisation of samples (Cohen et al., 2011). I attended to careful sampling to obtain as homogeneous units as possible, as this could improve validity.

I tried to obtain a high validity of the pre-test and post-test as the validity of the tests will influence the validity of the study (Cohen et al., 2011; Pietersen & Maree, 2016c). I considered criterion-related, content and construct validity. As no respondent obtained a high score for the pre-test, which was very easy, it correlated with the respondents' Mathematics marks at the school level, which was also low, resulting in them being chosen for this study, proving a high criterion-related validity. According to Ary et al. (2018), to determine the content validity of a test, experts in the subject or other teachers can examine the test to assess whether the test is appropriate for the content and objective for which it will be used. I asked an experienced Grade 6 teacher as well as an expert of the district Inclusive Education unit to evaluate the pre-test and the post-test. They both approved the test as valid for the content and the objective it intended to test. According to Cohen et al. (2011) construct validity can be achieved if results in a test correlate with other measures of the same concept. The pre-test and post-test were designed to test achievement in mathematics, to determine if there will be an improvement in achievement after an ICT intervention. Given that the respondents' scores in the pre-test were low, it correlated with their low scores for Mathematics at school, supporting construct validity. The post-test was similar to the pre-test. Therefore, I assumed the pre-test and post-test were valid instruments to use in this quasi-experimental study.

In experimental studies, internal and external validity may be threatened by various factors (Cohen et al., 2011). As a result, I attempted to obtain high internal and external validity, as this will determine the reliability of an experiment (Pietersen & Maree, 2016c). According to Creswell (2014), internal validity implies that the researcher has controlled the variables sufficiently. In this study, this implies the conclusion that any changes in the mathematical performance of the respondents might be attributed to the intervention (Pietersen & Maree, 2016c). Furthermore, external validity points to the degree to which the results of a study may be generalised to the population (Cohen et al., 2011; Pietersen & Maree, 2016c).

It is important to consider threats to internal as well as external validity. Internal validity occurs when extraneous variables do not influence the results of a study, allowing the researcher to be sure that the results are because of an intervention (Ary et al., 2018; Di Fabio & Maree, 2012). Internal factors in this study, for example, include selection bias (where systematic differences in respondents cause results), history (teaching in normal classrooms or additional classes or extra work at home that influences results), attrition (respondents drop out of study), the Hawthorne or placebo effect (respondents change behaviour due to their being part of a group, for example getting better marks as they believe they can do mathematics because of the computer programs) and instrumentation (pre- and post-tests may perhaps not be exactly the same standard) (Ary et al., 2018; Seabi, 2012). I tried to minimise these factors that could have influenced internal validity.

Next, external validity can be threatened by factors that may influence the generalisability of results. These factors include bias in sampling or not defining a population accurately (Ary et al., 2018; Morgan & Sklar, 2012a). In this study, the population was specialised and thus only a limited population could be used to make conclusions. It was essential to choose the respondents with care to obtain as true as possible a sample of the specific population, being Grade 6 learners with dyscalculia.

Table 3.4 provides a summary of the factors that may threaten internal and external validity (adapted from Di Fabio and Maree, 2012, Pietersen and Maree, 2016c, and Seabi, 2012), which I considered throughout my study.

Table 3.4: Internal and external validity

Variable	Factor	Description	Strategy used in this study to avoid the factor
Internal factors	Attrition	Systematic loss of respondents may influence the outcome.	I tried to make the intervention fun and adapted to times suiting the schools and respondents to prevent the respondents from leaving the study. Three respondents left the study at the beginning, resulting in the control group being four less than the experimental group.
	Historic	Factors may be present between pre- and post-tests and may influence the dependent variable yet cannot be foreseen.	I asked the teachers and the parents not to involve the respondents in any other mathematical activities and games except the lessons and activities that they should do according to the ATP.
	Instrumentation	Observers, unreliable instruments or the changing of instruments might influence the results.	• No observers were in the room when completing the tests. • An experienced Grade 6 teacher and the representative of the district Inclusive Education unit evaluated the pre-test and post-test and approved it as valid testing basic concepts important in Grade 6 Mathematics.

Variable	Factor	Description	Strategy used in this study to avoid the factor
Internal factors	Maturation	This indicates changes in the respondents themselves, for example boredom, tiredness, etc. that might influence the results.	I tried to keep the intervention interesting to avoid boredom, and the respondents had food and time to rest before the tests and the intervention program started after school.
	Mortality	This points to respondents who cannot continue with an experiment up to the end, due to sickness, moving, etc.	I explained beforehand the importance of all respondents staying in the study and not being absent. I could not foresee sickness, but fortunately all the respondents could attend all the sessions.
	Pre-testing	Just taking a pre-test may influence the findings, as some respondents may act differently than normal in test situations.	I tried to calm the respondents and built a relationship of trust before the pre-test for the respondents to experience the test as just answering some questions as they would normally do.
	Selection bias	When experimental and control groups are not similar, due to the assigning to groups not being randomly done.	The experimental and control groups were as similar as possible as explained in Section 3.3.1. I compared their average age as well as their means in the pre-test to prove similarity.
	Statistical regression	Some respondents with extremely high scores in a pre-test might do worse in the post-test.	I tried to keep the tests as reliable as possible to prevent statistical regression.
	Testing effect	A pre-test may have an effect on the outcome of a post-test, because learning through just taking a test may occur.	The period of six weeks between the pre-test and the post-test, and the numbers and order of questions that were changed in the post-test, reduced any testing effect that might occur. Both the groups wrote the same tests at the same time, resulting in all respondents being exposed to the same testing effects.
External factors	Reaction to experimental conditions (sensitisation)	A pre-test might influence the results of an experiment.	The respondents of the control group and experimental group both wrote the same pre-test. It was not possible to measure the influence

Variable	Factor	Description	Strategy used in this study to avoid the factor
External factors			of the experimental conditions on the respondents.
	Insufficient realism	This points to the realistic nature of the treatment, and how randomly respondents were selected.	I tried my best to include all the Grade 6 learners with probable developmental dyscalculia from the two schools and assigned them as randomly as possible to the two groups to keep the experiment as realistic as possible.
	Insufficient description of independent variables	It is difficult to replicate the research if the independent variables are not described unambiguously.	The independent variable is explained in Section 3.3.2.
	Hawthorne-effect	Respondents may act differently than normally and fake answers or become anxious when they know they are part of an experiment.	I maintained a good relationship with the respondents before administering the pre-test and starting the intervention in order to minimise the Hawthorne effect.
	Ecological validity	This includes research conditions, such as the physical environment, time of day and year, test sensitisation, presence of the presenter, gender of the presenter, etc.	The research conditions were kept as normal as possible. They wrote the tests and had the intervention in their own classes at their own schools that were familiar to them.
	Instrumentation	Unreliable instruments or changing the measuring instrument.	I tried to keep the pre-test and post-test as similar as possible, without compromising internal validity. I also measured Cronbach's alpha of the pre-test to prove the reliability of the testing instrument.
	Pygmalion effect	Respondents may cause certain results when they think that it is what the results should be.	The respondents were requested to do the best they could in both the pre-test and the post-test to minimise the Pygmalion effect.

Variable	Factor	Description	Strategy used in this study to avoid the factor
External factors	Experimental effect	The researcher may subconsciously cause achievement of expected results.	I refrained from assisting any respondents in completing the tests, and as the tests were on mathematics questions there was probably no experimental effect on the results caused by me.
	Placebo effect	Respondents attain improved results when they believe they are expected to improve.	I asked the respondents to do the best they could in the pre-test and post-test and kept all conditions for the two tests as similar as possible to minimise the placebo effect.
	John Henry effect	The respondents in a control group may try to prove that they can get better results than those in the experimental group that received the intervention (Pietersen & Maree, 2016c).	As all the respondents in the pre-test and the post-test were asked to do the best they could; they could not do better than their best, as was requested in this study, minimising the John Henry effect.

A quantitative researcher must do his/her best to minimise the effect of especially the external factors on the reliability of an experiment. Pietersen & Maree (2016c) warns against certain pitfalls that must be avoided by researchers as discussed in Table 3.4. I endeavoured to minimise the effect of the external factors that could influence the study.

3.4.2 Reliability

Reliability in quantitative research, according to Cohen et al. (2011) is the same as consistency, dependability and replicability over time, space and groups of respondents, implying that if the same research is done at another time and place with different respondents, similar results will be obtained (Flick, 2015; Oluwatayo, 2012). For reliability in this study, where a pre- and post-test were used, it was important to consider factors such as time between the tests, content and the difficulty of the tests (content and standard had to be similar), and whether some respondents had learnt more about the subject on their own because they wanted to look good or became interested or motivated by the process (Flick, 2015). According to Heale and Twycross

(2015), three types of reliability must be considered in quantitative research, namely equivalence, stability and internal consistency.

Equivalent reliability can be predicted utilising two parallel forms of an instrument assessing the same content with the same test specifications, the same number of items in the same format and with the same difficulty (Cohen et al., 2011; Oluwatayo, 2012). The pre-test and post-test in this study had exactly the same questions, only with different numbers and in a different order. In Chapter 4, I compare the means and standard deviations of the pre-test and the post-test of the control group, as they did not receive any intervention and their scores were not expected to change. It can also be tested by using statistical strategies such as the paired t-test (Ary, et al., 2018; Cohen et al., 2011; Flick, 2015) or in this study, utilising a non-parametric test as the Wilcoxon-signed rank test, to demonstrate a high correlation coefficient as well as similar means and standard deviation as I do in Chapter 4.

Reliability as stability is a measure of consistency over time, meaning that if a similar sample of respondents is tested with a similar test after some time, it will produce similar results (Cohen et al., 2011; Flick, 2015; Oluwatayo, 2012). In this study, the control group completed the pre-test and after six weeks they completed a similar post-test. In Chapter 4 I use descriptive statistics to compare the test results of the control group to prove stability as reliability.

Internal consistency assesses whether items in a test that measures the same concept produce similar scores. The most commonly used test to determine the internal consistency of items in a scale is Cronbach's alpha, ∝, referred to as alpha (Ary et al., 2018). Cronbach's alpha evaluates the proportions of variance that are consistent in a test, thus the correlation of an item with the sum of the other relevant items (Ary et al., 2018; Cohen et al., 2011; Vaske et al., 2017). Internal consistency indicates whether the relative position of each respondent in a group stayed the same or whether the respondent's position changed (Ary et al., 2018). In Chapter 4 I used Cronbach's alpha to measure internal consistency between the items of the pre-test as reliability. The alpha is a score between 0 and 1. A score of 0.7 and higher is considered as high reliability (Heale & Twycross, 2015), but even lower scores such as 0.67 and higher (Oluwatayo, 2012) are acceptable. Vaske et al. (2017) state that scores of 0.5 to 0.8

are adequate. The level of confidence should be reported with the alpha score (Bonett & Wright, 2015).

The internal consistency of tests can also be validated by using the split-half method, where the results of similar halves in the same unit must be similar to ensure the reliability of tests (Cohen et al., 2011; Flick, 2015). Reliability can furthermore be improved by excluding extreme results from respondents.

Another non-parametric test for determining reliability is the Spearman rank correlation coefficient (counterpart of the parametric Pearson correlation coefficient) (Karros, 1997). This test measures the strength of the relationship between two variables and produces a value r as a result. The value r = 1 indicates a perfect positive correlation and the value r = -1 a perfect negative correlation. When r = 0 there is no correlation (Altman & Krzywinski, 2015; Karros, 1997; Puth et al., 2015).

A factor influencing the reliability of a test is the length of the test. A more extended test with more items testing the same concept is more reliable (Ary et al., 2018). As the respondents were learners with difficulty in mathematics, I designed a test with 34 items and a total of 50, which took the respondents approximately 1 hour to complete. Although the number of items was probably insufficient, I did not want to make the test so long and challenging that the respondents became discouraged and anxious. A second factor that may influence the reliability of a test is the heterogeneity of the group. The more heterogeneous the group, the greater the reliability (Ary et al., 2018). I included male and female multi-racial respondents from two different schools in different towns, to attempt heterogeneity.

Thirdly, the ability level of a group may influence reliability, as a test that is too easy or difficult for the group may influence the reliability of the study (Ary et al., 2018). I attempted to take this factor into consideration by not making the test too long and difficult. A fourth factor influencing the reliability of a test is the objectivity of scoring (Ary et al., 2018). As the pre-test and post-test were mathematics tests with only one possible answer to each question, the scoring of the tests was very objective and did not influence reliability. I aimed to design the tests and conduct the research in a way not to compromise the reliability of the study.

3.5 ETHICAL CONSIDERATIONS

Cohen et al. (2011) explain the importance of ethical considerations in research. When doing research it is important that no harm is done (Bryman, 2016; Cohen et al., 2011; Elias & Theron, 2012; Flick, 2015; Maree, 2016). According to Flick (2015), it is important to consider all ethical principles when planning and designing a research project. Walliman (2017) states that two aspects of ethical issues exist in research, namely the values concerning honesty and frankness that the researcher personally endorses, and how the researcher treats other individuals forming part of the research involving informed consent, anonymity, confidentiality and consideration.

It is important to view ethics as not only procedural, but that it "concerns right and wrong, good and bad, and so procedural ethics is not enough; one has to consider how the research purpose, content, methods, reporting and outcomes abide by ethical principles and practices (Cohen et al., 2011, p. 76). According to Stutchbury and Fox (2009), Seedhouse (1998) provided a grid as a framework for understanding ethical issues and this framework is applicable to educational research. The framework consists of four layers of a square pyramid, with each layer representing an ethical aspect (Stutchbury & Fox, 2009). The bottom layer is the external layer and consists of all external issues, such as laws, code of practice, wishes of others, resources available, effectiveness and efficiency of actions, the responsibility to justify actions in terms of external evidence, degree of certainty on which action is taken and risk. The second layer is the consequential layer; thus in this layer, the researcher must foresee consequences for those involved in the study and the society; for example, the most beneficial outcome for society, a particular group, the respondents or the researcher self. The third layer, the deontological layer, is about doing one's duty, regardless of consequences and includes to tell the truth, to keep promises, to do positive good and to minimise harm (Brooks et al., 2014). The top layer is the individual and has to do with respecting individuals equally, creating autonomy, respecting autonomy and serving needs first (Cohen et al., 2011; Stutchbury & Fox, 2009). According to Stutchbury and Fox (2009), the grid provides a framework to think about ethical problems that may arise in research. I attended to all four layers of ethical issues in this study.

3.5.1 Permission to do research, informed consent and voluntary participation

Governments and institutions like universities have specific policies and codes for ethical issues in conducting research to protect society (Resnik, 2011). Therefore ethics committees ensure that ethical principles are maintained by assessing proposed research designs before involving humans in the research, and by evaluating whether the research project will bring a new perspective to existing knowledge (Flick, 2015). I obtained permission to conduct research from the Ethics Committee of the University of Pretoria (Consult Appendix A).

Informed consent is when individuals choose to be part of a research project, after being informed of all the facts regarding the study and how it may influence their lives (Cohen et al., 2011; Walliman, 2017). Three important factors of informed consent are that it should be based on sufficient knowledge of the project, the consent must be voluntary and individuals must feel free to decline and to withdraw from the study (Blaikie & Priest, 2019; Mertens & Ginsberg, 2009). The individual must be competent to decide consent (Brooks et al., 2014; Cohen et al., 2011). When informing individuals about the research, it is important to explain the purpose, content and procedures of the study, as well as any predictable risks and adverse outcomes, consequences or discomfort and how these will be handled (Brooks et al., 2014; Flick, 2015). The individuals must also be informed about how they will benefit from the study. They must be informed that participation is voluntary and they may withdraw at any stage should they no longer want to be part of the study (Blaikie & Priest, 2019; Cohen et al., 2011; Mertens & Ginsberg, 2009). It is also important to inform individuals about confidentiality and anonymity. The respondents must have the opportunity to ask questions and must sign contracts for participating in the research project (Brooks et al., 2014; Cohen et al., 2011; Denscombe, 2014; Walliman, 2017).

When the respondents are children, the researcher must be sensitive to their welfare and always keep their best interests in mind (Cohen et al., 2011). The respondents in this study participated voluntarily and they, their parents, the schools and the North West Education Department were adequately informed about the purpose, contents and the procedures of the research before obtaining permission for the study (Consult Appendices B and C) and informed consent/assent from the parents (Consult

Appendix D) and Appendix E). All relevant parties were informed about the potential benefits of the study (Cohen et al., 2011; Mouton, 2001). The learners and parents were informed that they could withdraw from the study should they wish to do so and that they did not have to be part of the study if they did not want to.

3.5.2 Anonymity and confidentiality

Respondents have a right to remain anonymous, and therefore no other person should be able to identify a respondent from any information or results provided by the study (Cohen et al., 2011; Mouton, 2001). To obtain anonymity, it is important not to use names or any other means of identification (Cohen et al., 2011). Confidentiality is to protect the respondents' right to privacy by not disclosing any information about the respondent that can lead to the identification or detecting of the respondent (Burgess, 2005; Cohen et al., 2011; Flick, 2015). Confidentiality and anonymity were respected throughout by not identifying the participating schools and by using codenames for the respondents instead of their names, so that they could not be identified. No photographss of the respondents were taken and no videos or recordings were made of the testing and intervention sessions. I also promised the respondents that I would not show their pre-tests and post-tests to their teachers or principal and that the marks for the tests were only meant for me and not for their assessment at school.

3.5.3 Protection from harm

Respondents must be protected from any harm in conducting the research as well as in reporting the findings (Blaikie & Priest, 2019; Cohen et al., 2011; Walliman, 2017). I informed the respondents that they were going to do mathematics after regular school hours, and they were going to write mathematics tests, which they might find as negative, as they had to make special arrangements for food and transport, and as they all experienced difficulty with mathematics, writing extra mathematics tests might increase anxiety levels. As a result of these factors the probability of becoming distraught arose, so that the respondents were debriefed afterwards and I was prepared to refer any respondent experiencing any emotional difficulty because of the study for professional support.

An ethical dilemma that might be present in this study was that there was a control group that would receive no intervention. All the respondents received their normal mathematical teaching at school, so nobody was harmed. As the study was about the success of the intervention, it was important to have a control group without intervention to compare the results. To rectify the possible ethical issue, the same intervention program was followed with the control group than had been followed with the experimental group after the conclusion of the study

3.5.4 Trust

Trust is an important part of the relationship between the respondent and the researcher (Flick, 2015; Mertens & Ginsberg, 2009). The researcher must not lie to the respondents and the respondents must not falsify answers to have a trusting relationship (Brooks et al., 2014; Mertens & Ginsberg, 2009). Failure to keep the promises made in the contract between researcher and respondent will destroy trust in the relationship, which may be harmful to the respondents, the researcher and the outcome of the study.

I was open and honest with the respondents about all factors, negative and positive, concerning the research project. I asked them to have fun and enjoy playing the mathematics games, and always to try their best. I reassured them that the marks obtained in the pre-test and post-test could not harm them in any way. They seemed positive and trustworthy throughout the study and were eager to try their best and not fake answers. The respondents did ask questions about the research and I tried to gain their trust by being open, truthful, respectful, calm, trustworthy and considerate.

The respondents, their parents, the schools and the North West Education Department are to receive proper feedback regarding the outcomes of the research (Mouton, 2001), following the completion of the study.

3.6 CONCLUSION

In this chapter, I discussed the paradigmatic choices I made and the research design guiding my study. I explained the research process, sampling procedures, as well as the data collection, documentation and analysis strategies. The chapter also focused on validity and reliability issues as well as ethical considerations that I considered.

In the next chapter, I present the results of the study, following data analysis with the aid of SPSS 25 software. I explain how I interpreted the results.

CHAPTER 4 - ANALYSIS AND INTERPRETATION OF THE DATA

4.1 INTRODUCTION

In Chapter 3, the methodology of the research was discussed, focusing on the methods used to answer the research questions. Sampling procedures, data collection and analysis strategies were discussed, as well as the validity and reliability considerations. In conclusion, ethical principles were outlined.

In this chapter, I present and discuss the results and their interpretation. I accept or reject the formulated hypotheses to answer the research questions.

The following primary research question guided the study:
How can an Information and Communication Technology (ICT) intervention support (or not) the achievement in mathematics of Grade 6 learners with dyscalculia?

For the purpose of addressing the primary research question, the research was guided by the following secondary research questions:

- ❖ How can software, including Applications (Apps) be utilised to support Grade 6 learners with dyscalculia in terms of number sense skills?
- ❖ How can software, including Applications (Apps) be utilised to support Grade 6 learners with dyscalculia in terms of basic mathematical skills?

The following hypothesis applied to the primary research question:

Hypothesis 1:

This hypothesis aimed to determine whether or not an ICT intervention improved the achievement in mathematics of Grade 6 learners with dyscalculia. The hypothesis was formulated as follows:

- H_0: The performance of Grade 6 learners with dyscalculia in mathematics will not improve following an ICT intervention.
- H_1: The performance of Grade 6 learners with dyscalculia in mathematics will improve following an ICT intervention.

The following hypotheses applied to the secondary research questions:

Hypothesis 2:

The second hypothesis aimed to determine whether or not an ICT intervention had a positive effect on the number sense of Grade 6 learners with dyscalculia. The hypothesis was formulated as follows:

- H_0: The number sense of Grade 6 learners with dyscalculia will not improve following an ICT intervention.
- H_1: The number sense of Grade 6 learners with dyscalculia will improve following an ICT intervention.

The following sub-hypotheses applied to the possible improvement of some aspects of number sense:

Hypothesis 2.1:

This sub-hypothesis aimed to determine whether or not an ICT intervention had a positive effect on the *place value* of Grade 6 learners with dyscalculia. The hypothesis was formulated as follows:

- H_0: Performance on place value questions by Grade 6 learners with dyscalculia will not improve following an ICT intervention.
- H_1: Performance on place value questions by Grade 6 learners with dyscalculia will improve following an ICT intervention.

Hypothesis 2.2:

The following sub-hypothesis aimed to determine whether or not an ICT intervention had a positive effect on the *ordering of numerosities according to size* of Grade 6 learners with dyscalculia:

- H_0: Grade 6 learners with dyscalculia's ability to order numerosities according to size will not improve following an ICT intervention.
- H_1: Grade 6 learners with dyscalculia's ability to order numerosities according to size will improve following an ICT intervention.

Hypothesis 2.3:

The following sub-hypothesis aimed to determine whether or not an ICT intervention had a positive effect on *conservation of number* skill of Grade 6 learners with dyscalculia:

- H_0: The conservation of number skill of Grade 6 learners with dyscalculia will not improve following an ICT intervention.
- H_1: The conservation of number skill of Grade 6 learners with dyscalculia will improve following an ICT intervention.

Hypothesis 2.4:

This sub-hypothesis aimed to determine whether or not an ICT intervention had a positive effect on the *sequencing of numbers* of Grade 6 learners with dyscalculia:

- H_0: Performance related to the sequencing of numbers of Grade 6 learners with dyscalculia will not improve following an ICT intervention.
- H_1: Performance related to the sequencing of numbers of Grade 6 learners with dyscalculia will improve following an ICT intervention.

Hypothesis 2.5:

The following sub-hypothesis aimed to determine whether or not an ICT intervention had a positive effect on the *number concept* of Grade 6 learners with dyscalculia:

- H_0: The number concept of Grade 6 learners with dyscalculia will not improve following an ICT intervention.
- H_1: The number concept of Grade 6 learners with dyscalculia will improve following an ICT intervention.

Hypothesis 3:

The third hypothesis aimed to determine whether or not an ICT intervention had a positive effect on the mathematical skills of Grade 6 learners with dyscalculia. The hypothesis was formulated as follows:

- H_0: The basic mathematical skills of Grade 6 learners with dyscalculia will not improve following an ICT intervention.
- H_1: The basic mathematical skills of Grade 6 learners with dyscalculia will improve following an ICT intervention

Some sub-hypotheses applied to the possible improvement of some subparts of the mathematical skills of Grade 6 learners with dyscalculia, as follows:

Hypothesis 3.1:

This sub-hypothesis aimed to determine whether or not an ICT intervention had a positive effect on the *rounding of numbers* of Grade 6 learners with dyscalculia:

- H_0: The rounding of numbers by Grade 6 learners with dyscalculia will not improve following an ICT intervention.
- H_1: The rounding of numbers by Grade 6 learners with dyscalculia will improve following an ICT intervention.

Hypothesis 3.2:

The following sub-hypothesis aimed to determine whether or not an ICT intervention had a positive effect on the *multiples and factors* of Grade 6 learners with dyscalculia:

- H_0: The performance in questions related to multiples and factors by Grade 6 learners with dyscalculia will not improve following an ICT intervention.
- H_1: The performance in questions related to multiples and factors by Grade 6 learners with dyscalculia will improve following an ICT intervention.

Hypothesis 3.3:

This sub-hypothesis aimed to determine whether or not an ICT intervention had a positive effect on the *addition with carrying skill* of Grade 6 learners with dyscalculia:

- H_0: The addition with carrying skill of Grade 6 learners with dyscalculia will not improve following an ICT intervention.
- H_1: The addition with carrying skill of Grade 6 learners with dyscalculia will improve following an ICT intervention.

Hypothesis 3.4:

The following sub-hypothesis aimed to determine whether or not an ICT intervention had a positive effect on the *subtraction with borrowing* skill of Grade 6 learners with dyscalculia:

- H_0: The subtraction with borrowing skill of Grade 6 learners with dyscalculia will not improve following an ICT intervention.
- H_1: The subtraction with borrowing skill of Grade 6 learners with dyscalculia will improve following an ICT intervention.

Hypothesis 3.5:

The following sub-hypothesis aimed to determine whether or not an ICT intervention had a positive effect on the *multiplication of 3-digit with 2-digit numbers* of Grade 6 learners with dyscalculia:

- H_0: The multiplication of 3-digit with 2-digit numbers skill of Grade 6 learners with dyscalculia will not improve following an ICT intervention.
- H_1: The multiplication of 3-digit with 2-digit numbers skill of Grade 6 learners with dyscalculia will improve following an ICT intervention.

4.2 RESULTS BEFORE THE ICT INTERVENTION

Initially, 34 out of 203 Grade 6 learners, accounting for 16,7% of the two schools that participated were identified as possibly dyscalculic and therefore as learners with a specific learning disorder in mathematics. This is slightly higher than the prevalence of 5% to 15% of specific learning disorders, as indicated by the DSM-V (American Psychiatric Association, 2013) and the prevalence of 3,4% to 10% of dyscalculia specifically, as indicated in the DSM-IV revised (American Psychiatric Association, 1994; Butterworth, 2003). This difference may be ascribed to the fact that I used a broader range of criteria for initial identification purposes, as discussed in Chapter 3, so that all learners who might possibly be diagnosed with dyscalculia in the two schools could be included in the research. After the initial sampling process 14 respondents formed the experimental group and ten respondents the control group. Both groups wrote the same pre-test prior to implementation of the ICT intervention with the experimental group.

For the purpose of my study I first had to determine whether the control and experimental groups were approximately the same in terms of the dependent variable at the beginning of the investigation with the dependant variable being the scores obtained in the test. Figure 4.1 indicates that the data is skewed to the left. As it was not possible to prove normality because of the small sample size, I decided to use non-parametric statistics.

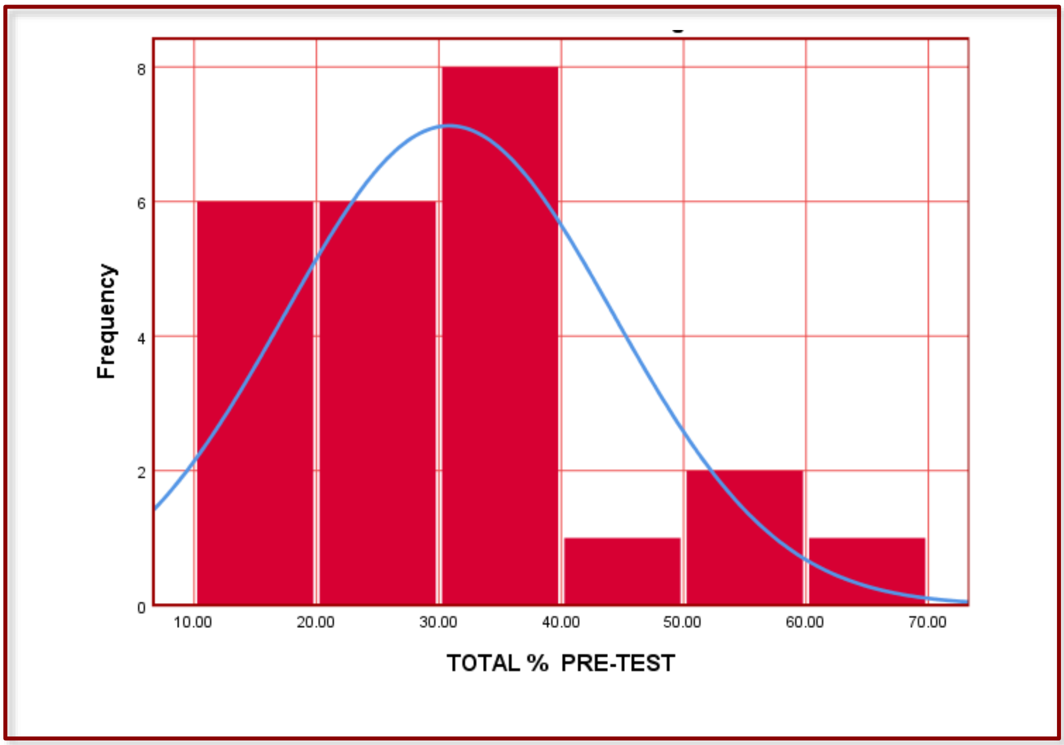


Figure 4.1: Graph representing the frequency of pre-test scores

4.2.1 Similarity of the experimental and control groups prior to the intervention

I conducted descriptive and inferential analysis of the scores of the pre-test, using SPSS to determine the similarity of the experimental group and the control group before the intervention. The means and standard deviations of the pre-test scores for the experimental and control groups are presented in Table 4.1, pointing to no apparent statistically significant difference between the two groups.

Table 4.1: Descriptive statistics of the pre-test of the experimental and control groups

Test	N	Minimum	Maximum	Mean	Std. Deviation
Experimental group: pre-test percentage	14	14.00	58.00	30.57	13.438
Control group: pre-test percentage	10	12.00	60.00	31.20	14.148

Next, the difference between the pre-test scores of the two groups was investigated more comprehensively. For this purpose the Mann-Whitney U test ($p = 0.05$) was used to determine whether there was a statistically significant difference between the scores of the pre-tests of the experimental group and the control group. The Mann-Whitney U test is a non-parametric test that compares two independent groups (experimental group versus control group) on a single variable (the test scores) and represents the non-parametric equivalent of the t-test for independent groups. In the Mann-Whitney U test, it is assumed that if all the scores are ranked according to their values, ignoring the groups they belong to, the ranks will be evenly distributed between the two groups if the two groups have equal medians. This test thus makes use of the ranks of the scores and not of the actual values (Cohen et al., 2011; Pietersen & Maree, 2016d). The test then uses both the sums and means of the ranks to compare the independent groups, resulting in extreme values not having a significant effect on the outcome. In Table 4.2 it can be seen that the mean rank for the test scores for the experimental group is the same as the mean rank of the control group (12.50), thereby indicating no difference between the two groups.

Table 4.2: Ranks of the pre-test scores

Group	N	Mean Rank	Sum of Ranks
Experimental group	14	12.50	175.00
Control group	10	12.50	125.00

The p-value (two-tailed) was used to determine whether there was a significant difference in the test scores of the two groups before the ICT intervention to determine whether any one of the two groups performed better in the pre-test. Table 4.3 captures the test statistics of the pre-test scores of the experimental and control groups according to the Mann-Whitney U Test.

Table 4.3: Test statistics for the pre-test scores of the experimental and control groups using the Mann-Whitney U Test

Variable	Total
Mann-Whitney U	70.000
Wilcoxon W	125.000
Z	0.000
Exact Sig. (two-tailed)	1.000

The critical value for the group sizes (experimental, n = 14; control, n = 10) was 36. According to the Mann-Whitney U test, there was no statistically significant difference between the experimental group and the control group before the ICT intervention according to the pre-test scores (U = 70; p = 1.00), as the p-value was greater than 0.05. This implies that both groups performed on similar level prior to the intervention being implemented with the experimental group.

4.2.2 Reliability of the pre-test and post-test

The pre-test (Consult Appendix F) and post-test (Consult Appendix G) consisted of various questions testing concepts that have to do with number sense and mathematical skills, such as place value, bigger and smaller numbers, conservation of number, sequencing, number concept, rounding, multiples and factors, adding with carrying, subtraction with borrowing, and multiplication of three-digit numbers with two-digit numbers. A question by question analysis of the pre-test can be viewed in Appendix H.

In terms of reliability, the Cronbach's alpha was used to measure the internal consistency of the pre-test. According to Cohen et al. (2011), an alpha coefficient of 0.70 and higher can be considered as reliable. I used SPSS to determine Cronbach's alpha, which had a value of 0.751 for the pre-test. This value indicates internal consistency of the test items and it can thus be assumed that the pre-test was reliable.

The post-test consisted of the same questions, with different numbers in the questions and a change of order of questions. Cronbach's alpha coefficient for the post-test was 0.789, which indicates reliability of the post-test.

4.3 RESULTS AFTER THE ICT INTERVENTION

The respondents in the experimental group participated in an intervention program that was implemented over six weeks, with sessions of 30 minutes each, twice per week. All the respondents wrote a post-test after the six weeks intervention. The post-test was similar to the pre-test, as the same type of questions were asked, but using different numbers and values. The order in which the questions were asked was also changed.

The ICT intervention consisted of mathematical games played on a computer, as explained in Chapter 3. Respondents played *The Number Race* (Wilson & Dehaene, 2004), *Math Line* (adding to ten, and later to 20), *Mathman* (adding, place value, expanded form, value of digits, rounding, multiplying by single digits), *Pop the Balloon* (counting, add, order and sequencing) (Sheppard & Chapgar n. d.), and lessons from *The Rockseries* (lessons about the basics concerning numbers, value, place value, adding and subtracting) (RockSeries Educational Software, 2017). The respondents in the control group did not participate in the intervention at the time and merely attended their regular classes at school, together with the experimental group.

In analysing the data, the overall scores of the pre-test of the two groups were compared to the scores of the post-test of the two groups to determine any differences between the pre-test and post-test scores of the two groups. Subsequently, the experimental group and control group were compared to each other to determine whether a significant difference existed between the scores of the two groups in the pre-test and post-test.

4.3.1 Comparison of the control and experimental groups using descriptive statistics

As already stated, I compared the pre-test scores of the experimental and control groups to the post-test scores of the experimental and control groups. In Figure 4.2 it can be seen that the pre-test scores of the groups were almost the same, whereas there was an increase in the experimental group on the post-test scores and a decrease in the control group's scores. To avoid errors such as regression to the mean I used an experimental group and a control group that wrote the same tests after the same period of time, while receiving the same education during school hours. Some possible explanations for the decrease in the mean of the control group include that the different numbers used in the post-test could have made the test more complicated, that the respondents might not have been as positive and motivated in writing the post-test as the experimental group, as they had not received the intervention, or that they might have experienced higher levels of anxiety than during the pre-test, or did not try their best.

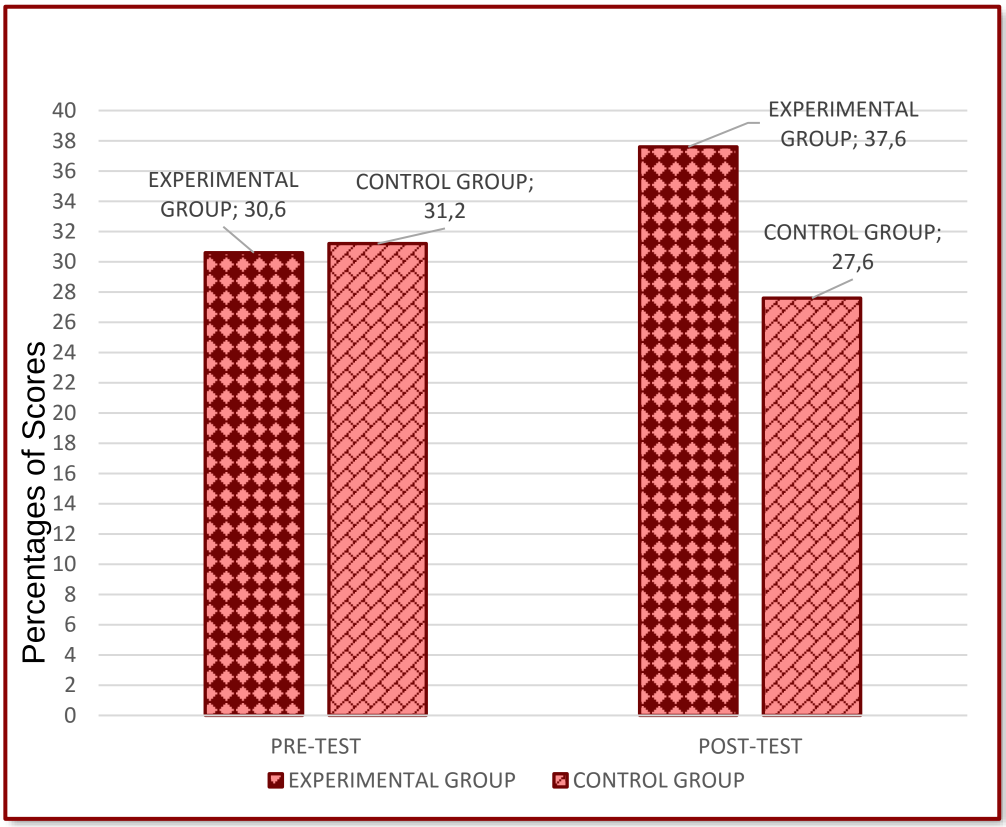


Figure 4.2: Graphical representation of the percentages in the pre-test and post-test of the experimental and control groups

Next, descriptive statistics using SPSS were utilised to explore the differences between the experimental and control groups. The results are captured in Table 4.4.

Table 4.4: Descriptive statistics of the pre-test and post-test scores of the experimental and control groups

Group		Number	Minimum	Maximum	Mean	Std. deviation	25th percentile	50th percentile	75th percentile	Inter-quartile range
Experimental group	Total percentage pre-test	14	14.00	58.00	30.57	13.44	18.00	33.00	38.00	20.00
	Total percentage post-test	14	14.00	70.00	37.57	15.54	21.50	38.00	48.00	26.50
Control group	Total percentage pre-test	10	12.00	60.00	31.20	14.15	22.50	28.00	40.50	18.00
	Total percentage post-test	10	14.00	54.00	27.60	13.50	17.00	23.00	40.50	3.50

In Table 4.4 it can be seen that the mean test score of the experimental group improved from 30.57 in the pre-test to 37.57 in the post-test, but with a more significant standard deviation (SD = 15.54 in the post-test while SD = 13.44 in the pre-test). Contrary to this, the mean test score of the control group that received no intervention but attended only regular classes together with the respondents of the experimental group, decreased from 31.20 in the pre-test to 27.60 in the post-test, with a smaller standard deviation (SD = 13.50 in the post-test and SD = 14.15 in the pre-test). Therefore, it seems as if there was an increase in mathematical performance after the intervention, whereas the group that did not participate in an intervention showed a decrease in mathematical performance.

Twenty-five per cent of the respondents in the experimental group obtained 18% or less in the pre-test, whereas 25% of the respondents obtained 21,5% or less in the post-test. This was different for the control group as 25% of the respondents obtained 22,5% or less in the pre-test yet in the post-test 25% obtained 17% or less. Furthermore, 50% of the respondents in the control group obtained 28% or less for the pre-test, but 50% of the respondents obtained 23% or less in the post-test, implying that more respondents performed worse than the mean of 27,6% in the post-test. In the pre-test, 75% of the respondents of the experimental group obtained 38% or less, whereas 75% of the respondents in the control group obtained 40,5% or less, indicating a slightly better performance of the control group in the pre-test. However, in the post-test , 75% of the respondents of the experimental group obtained 48% or less, whereas 75% of the respondents of the control group again obtained 40,5% or less, indicating an improvement of the lower 75% of the experimental group, but no change in the lower 75% of the control group. As such, it can be deduced that the experimental group improved in terms of their achievement in mathematics following implementation of the ICT intervention. This result correlates with studies conducted by other scholars, such as Adebisi et al. (2015) as well as Ariffin et al. (2017), also indicating positive effects of digital game-based learning, as used in the ICT intervention on the performance of learners who struggle with mathematics.

4.3.2 Comparison of the control and experimental groups using inferential statistics

The Mann-Whitney U test, which compared two independent groups, was used to determine the significance of the difference between the scores of the experimental and control groups. As explained in Section 4.2.1, the Mann-Whitney U test uses rankings of scores, and not the exact values of scores. The results are captured in Table 4.5.

Table 4.5: Ranks of test scores of the experimental group and control group using the Mann-Whitney U test

Test	Group	N	Mean Rank	Sum of Ranks
Total pre-test	Experimental	14	12.50	175.00
	Control	10	12.50	125.00
Total post-test	Experimental	14	14.43	202.00
	Control	10	9.80	98.00

Table 4.5 shows that the mean ranks for both groups were the same for the pre-test scores (12.50) whereas for the post-test scores, the experimental group's mean rank was 14.43 while the control group's mean rank was 9.80, indicating that the

experimental group performed better in the post-test than the control group. The significance of this difference was next determined by using the two-tailed p-value.

Table 4.6: Test statistics of the Mann-Whitney U test for the experimental and control groups

Variable	Pre-test	Post-test
Mann-Whitney U	70.000	43.000
Wilcoxon W	125.000	98.000
Z	0.000	-1.588
Exact Sig. (2-tailed)	1.000	0.117

The p-value (Exact Sig [two-tailed]) was 1.00 for the pre-test and 0.117 for the post-test. Both p-values were bigger than 0.05, indicating that the difference between the two groups for the pre-test and the post-test was not statistically significant.

4.3.3 Comparison of the pre-test and post-test scores

Although the Mann-Whitney U test indicated no statistically significant difference between the experimental group and the control group, the descriptive statistics indicated a lower performance in the post-test than in the pre-test by the control group, while there was an improvement in the scores of the experimental group after the intervention had been completed. Further investigation was done to determine whether this improvement by the experimental group and the weaker scores of the control group were statistically significant.

For this purpose, the Wilcoxon signed-rank test (5% significant level; $p = 0.05$) was used to determine whether there was a significant difference between the scores of the pre-test and the post-test of the experimental group and similarly of the control group. As indicated earlier, the Wilcoxon matched-pairs signed-rank test is the nonparametric equivalent of the parametric paired t-test and is used to examine a set of differences, when two variables in a single sample are compared; for example, the pre-test and post-test scores of the same group. This test was used instead of the paired t-test because of the small sample size. In addition, the p-value (two-tailed) was used to determine the significance of the difference as a whole, as the two-tailed p-value is non-directional. In doing this analysis, I divided the p-value (two-tailed) by two to determine whether the decrease (thus one-sided) in the post-test performance of the control group, and the increase in the post-test performance of the experimental group were statistically significant.

4.3.3.1 Control group pre-test versus post-test performance

In comparing the control group's pre-test and post-test performance, I considered the ranks and p-value (two-tailed) captured in Table 4.7. This was done after running the Wilcoxon matched-pairs signed-rank test to investigate the pre-test and post-test scores of the control group.

Table 4.7: Test statistics of the Wilcoxon matched pairs signed-rank test for the control group

Variable		**N**	**Mean Rank**	**Sum of Ranks**	**Z**	**Exact Sig. (two-tailed)**
Control group: Post-test versus pre-test	Negative Ranks	7[a]	6.64	46.50	-1.956	0.059
	Positive Ranks	3[b]	2.83	8.50		
	Ties	0[c]				
	Total	10				
a. Post-test < pre-test						
b. Post-test > pre-test						
c. Post-test = pre-test						

The sum of the negative ranks (46.5) was more significant than the sum of the positive ranks (8.50), indicating that the respondents in the control group did worse in the post-test than in the pre-test. Of the 10 respondents in the control group, the negative ranks indicate that seven respondents did worse in the post-test than in the pre-test. Likewise, the positive ranks indicate that three respondents did better in the post-test than in the pre-test.

It was also important to determine whether the difference between the pre-test and post-test scores was statistically significant by considering the p-value (two-tailed) of the Wilcoxon signed-rank test in Table 4.7. The p-value (two-tailed) is 0.059, which is higher than 0.05. This indicates the absence of a statistically significant difference in the pre-test and post-test scores of the control group. When considering the decrease in scores of the control group from the pre-test to the post-test, it is no longer two-sided, but one-sided, as it is directional. In this case the p-value for the decreasing of the scores was 0.059/2 = 0.0295, which is less than 0.05, thereby indicating that the decrease in the post-test scores of the control group is statistically significant.

4.3.3.2 Experimental group pre-test versus post-test performance

The total pre-test and post-test scores of the experimental group were used to determine whether there was an improvement in the achievement in mathematics of Grade 6 learners with dyscalculia after participating in an ICT intervention. As indicated in Table 4.4 (Consult Section 4.3.1), the mean of the experimental group increased from 30.57 in the pre-test to 37.57 in the post-test.

I relied on the Wilcoxon-signed rank test to determine whether or not there was a statistically significant increase in the scores of the experimental group, following the ICT intervention. The Wilcoxon signed-rank test does not use the actual values of scores, but the differences between scores. Differences between scores are ordered and then ranks are allocated to them. The null hypothesis tested by the Wilcoxon signed-rank test implies that the median of the difference score is equal to zero. In using symbols this is indicated in the following manor: H_0: $M_e = 0$. Depending on the research questions, the other alternatives are: H_1: $M_e \neq 0$ or H_1: $M_e < 0$ or H_1: $M_e > 0$.

The first hypothesis that I wanted to test was formulated as follows:

- H_0: The performance of Grade 6 learners with dyscalculia in mathematics will not improve following an ICT intervention.

And the alternative:

- H_1: The performance of Grade 6 learners with dyscalculia in mathematics will improve following an ICT intervention.

In symbols this can be stated as follows:

- ❖ H_0: $M_e = 0$
- ❖ H_1: $M_e > 0$

In the alternative hypothesis, the median is greater than zero, which means that the post-test score is greater than the pre-test score. In my study, two variables (pre-test and post-test scores) in a single sample (experimental group) were compared, with the results depicted in Table 4.8.

Table 4.8: Test statistics for the experimental group using the Wilcoxon matched signed-rank test

Variable		N	Mean Rank	Sum of Ranks	Z	Exact Sig. (two-tailed)
Experimental group: Post-test versus pre-test	Negative Ranks	3[a]	2.67	8.00	-2.628[d]	0.006
	Positive Ranks	10[b]	8.30	83.00		
	Ties	1[c]				
	Total	14				
a. Post-test < pre-test						
b. Post-test > pre-test						
c. Post-test = pre-test						
d. Based on negative ranks						

The sum of the positive ranks (83.00) is more prominent than the sum of the negative ranks (8.0), which indicates that the respondents performed better in the post-test than in the pre-test. The negative ranks furthermore indicate that three respondents did worse in the post-test than in the pre-test, whereas the positive ranks indicate that 10 respondents did better in the post-test than the pre-test. There is one tie, indicating that one respondent's score stayed the same. To determine whether or not the difference between the pre-test and post-test scores was statistically significant the p-value (two-tailed) of the Wilcoxon signed-rank test was looked at.

In Table 4.8, the p-value (two-tailed) is indicated as 0.006 which is less than 0.05, thereby implying that the difference between the pre-test and post-test scores is statistically significantly different. It furthermore suggests that the null hypothesis of a zero median difference should be rejected. If the median is significantly different from zero, a statistically significant difference exists between the pre-test and post-test scores of the experimental group. If, however, the median is greater than zero (post-test score greater than pre-test score), the alternative hypothesis (H_1) is one-sided to the right. This means that the two-tailed p-value should be divided by two before coming to a conclusion. As such the p-value of 0.006 /2 = 0.003, which is less than 0.05, indicates that the median is significantly greater than zero. It follows that the ICT intervention can be taken as having had a positive effect on the performance of the respondents in mathematics.

4.4 SECONDARY RESEARCH QUESTIONS AND HYPOTHESES

In both the pre-test and the post-test the questions were divided to test some concepts of number sense (place value, bigger or smaller size of numbers, conservation of number, sequencing of numbers and number concept) as well as mathematical skills (rounding, multiples and factors, addition with carrying, subtraction with borrowing, multiplication of a 3-digit number with a 2-digit number). The respondents in the experimental group played a variety of mathematics games on the computer as part of the intervention they participated in. For example, *Number Race* (Wilson & Dehaene, 2004) is a computer game for remediation of dyscalculia and focuses on number sense. The respondents also played a variety of mathematic games of *Sheppard Software* (Sheppard & Chapgar n. d.). These games, together with *The Rockseries* (RockSeries Educational Software, 2017), were chosen for the participants to be able to practise number sense as well as achievement in mathematical skills, as explained in Appendix H.

As all the subparts of the tests did not have the same allocated marks, all the marks for the sub-parts were converted to percentages. The average of the number sense subparts was then calculated to get a mark for performance in number sense, and likewise the average of the mathematical skills questions was calculated to obtain a final mark for mathematical skills.

For number sense, 13 of the 14 respondents in the experimental group did better in the post-test than in the pre-test, whereas in the mathematical skills tests 10 of the 14 respondents did better in the post-test than in the pre-test.

4.4.1 Comparison of number sense between the control group and experimental group

I considered the results of the respondents in the questions about number sense between the two groups in the pre-test and post-test, using the Mann-Whitney U test to determine whether or not a significant difference existed between the two groups. The results of the analysis of this data are illustrated in Table 4.9. The mean ranks of the experimental and control groups are 14.75 and 9.35 respectively, indicating that the experimental group performed better in number sense than the control group. In elaborating on this analysis, I used the p-value to determine whether or not this difference was significant and to test the second hypothesis formulated in Chapter 1.

Table 4.9: Test statistics of the Mann-Whitney U test for number sense of the experimental and control groups

Variable	Group	N	Mean Rank	Sum of Ranks	Mann-Whitney U	Exact Sig. (two-tailed)
Number sense: Pre-test versus post-test	Experimental	14	14.75	206.50	38.5	0.066
	Control	10	9.35	93.50		

The hypothesis I wanted to test was formulated as follows:

- H_0: The number sense of Grade 6 learners with dyscalculia will not improve following an ICT intervention:
- H_1: The number sense of Grade 6 learners with dyscalculia will improve following an ICT intervention.

The null hypothesis tested by the Mann-Whitney U test indicates that the medians of the two groups are the same. When using the Mann-Whitney U test, it can be put into symbols in the following way: H_0: $Me_1 = Me_2$; with the following alternatives: H_1: $Me_1 \neq Me_2$ or H_1: $Me_1 < Me_2$ or H_1: $Me_1 > Me_2$, where Me_1 is the median of the experimental group and Me_2 the median of the control group. For this study,

H_1: $Me_1 > Me_2$ was used as the alternative hypothesis. As such, the median of the experimental group was expected to be greater than the median of the control group.

The two-tailed p-value of 0.066 (Consult Table 4.9), is bigger than 0.05. If the non-directional alternative hypothesis is used, the difference in group medians is thus not statistically significant at the 5% level. As such, I used the alternative directional hypothesis, indicating that the experimental group performed better in number sense than the control group. The p-value of 0.066/2 = 0.033 was then used, which is less than 0.05. It follows that the null hypothesis was thus rejected and it can be concluded that the experimental group performed statistically significantly better in number sense than the control group at the 5% level. This correlates with the work of both Griffin (2004) and Dehaene (2011), who state that number sense can be improved through carefully planned programs and mathematics games.

4.4.2 Pre-test and post-test performance in number sense by the experimental group

The pre-test and post-test scores were used to determine whether there was an improvement in the number sense of Grade 6 learners with dyscalculia after participating in an ICT intervention. I used the Wilcoxon signed-rank test to determine whether or not there was a statistically significant increase in the scores in number sense of the experimental group after the ICT intervention. The differences between the scores were ordered and then ranks were allocated to them. The null hypothesis assessed by the Wilcoxon signed-rank test implies that the median of the difference score is equal to zero. In symbols, this is indicated in the following way: H_0: $M_e = 0$. Alternatives can take the form of the following: H_1: $M_e \neq 0$ or H_1: $M_e < 0$ or H_1: $M_e > 0$, depending on the research question.

I tested the same hypothesis indicated in Section 4.4.1:

- H_0: The number sense of Grade 6 learners with dyscalculia will not improve following an ICT intervention.
- H_1: The number sense of Grade 6 learners with dyscalculia will improve following an ICT intervention.

In symbols, this can be stated as follows:

- H_0: $M_e = 0$
- H_1: $M_e > 0$

In the alternative hypothesis, the median is greater than zero, which means that the respondents' performance in questions on number sense improved after the intervention.

For further analysis, two variables (pre-test and post-test scores) in a single sample (experimental group) were compared. The results are provided in Table 4.10.

Table 4.10: The Wilcoxon signed-rank test for number sense of the experimental group

Variable		N	Mean Rank	Sum of Ranks	Exact Sig. (two-tailed)
Experimental group number sense: Pre-test versus post-test	Negative Ranks	0[a]	0.00	0.00	0.000
	Positive Ranks	13[b]	7.00	91.00	
	Ties	1[c]			
	Total	14			
a. Total post-test number sense < Total pre-test number sense					
b. Total post-test number sense > Total pre-test number sense					
c. Total post-test number sense = Total pre-test number sense					

The sum of the positive ranks (91.00) is much more significant than the sum of the negative ranks (0.00), which indicates that the respondents performed better in the post-test than in the pre-test. The negative ranks indicate that no respondents did worse in the post-test than in the pre-test, whereas the positive ranks indicate that 13 respondents did better in the post-test than the pre-test. There is one tie, indicating that one respondent's score stayed the same. To determine whether or not the difference between the pre-test and post-test scores was statistically significant the p-value (two-tailed) of the Wilcoxon signed-rank test was considered, as captured in Table 4.10, to assess the hypothesis.

In Table 4.10 the p-value (two-tailed) is 0.000. Even though a p-value cannot be zero, SPSS allocates a value of 0.000 whenever a p-value is smaller than 0.001, which is also less than 0.05. This suggests that the null hypothesis of a zero median difference can be rejected. As such, the median is significantly different from zero. It follows that there is a statistically significant difference between number sense in the pre-test and post-test scores of the experimental group. If tested whether or not the median is greater than zero (post-test score greater than pre-test score); the alternative hypothesis (H_1) is one-sided to the right, and when further considering that the p-value is 0.000/2 = 0.000, it can be concluded that the median is significantly greater than zero. It follows that the ICT intervention had a positive effect on the number sense of the respondents. This result aligns with a study by Butterworth and Laurillard (2010), who suggest number sense games such as *Dots2track* to stimulate activity in the parietal lobes of the brain and to support learners with dyscalculia to obtain some level of number sense.

4.4.3 Comparison of mathematical skills between the control and experimental groups

In considering the results of the respondents in the questions focusing on mathematical skills between the two groups, the Mann-Whitney U test was used to determine whether or not there was a significant difference between the mathematical skills of the two groups. The results of the analysis of this data are captured in Table 4.11. The mean ranks of the experimental and control groups are 14.43 and 9.80 respectively, and the sum of the ranks 202.00 and 98.00. This indicates that the experimental group performed better in mathematical skills than the control group.

Table 4.11: Test statistics of the Mann-Whitney U test for the mathematical skills of the experimental and control groups

Variable	Group	N	Mean Rank	Sum of Ranks	Mann-Whitney U	Exact Sig. (two-tailed)
Mathematical skills: Pre-test versus post-test	Experimental	14	14.43	202.00	43.000	0.114
	Control	10	9.80	98.00		
	Total	24				

The p-value was used to determine whether the difference was significant or not, and to test the third hypothesis formulated as follows in Chapter 1:

- H_0: The basic mathematical skills of Grade 6 learners with dyscalculia will not improve following an ICT intervention.
- H_1: The basic mathematical skills of Grade 6 learners with dyscalculia will improve following an ICT intervention.

When using the Mann-Whitney U test, this can be formulated using the following symbols: H_0: $Me_1 = Me_2$ with the following alternative: H_1: $Me_1 > Me_2$, where Me_1 is the median of the experimental group and Me_2 the median of the control group.

In Table 4.11 the two-tailed p-value for the post-test is indicated as 0.114, which is more significant than 0.05. If the non-directional alternative hypothesis is used, the difference in group medians is not statistically significant at the 5% level. The alternative directional hypothesis was thus used, which indicates that the experimental group performed better than the control group. The fact that the p-value of 0.114/2 = 0.057 is bigger than 0.05 shows that the experimental group did not perform statistically significantly better than the control group at the 5% level in terms of mathematical skills.

Against the background of these results it can be concluded that, although the experimental group showed an increase in performance in mathematical skills, this increase was not significant enough to deduce that the experimental group performed better than the control group that received no intervention. This result does not align with the work of Adebisi et al. (2015), who found that digital game-based intervention strategies will have a positive effect on the performance of learners who experience difficulties in mathematics. This contradictory findings may perhaps be ascribed to factors such as the ICT intervention program not being extensive enough, and the six weeks of intervention not being sufficient to address number sense abilities as well as rectify mathematical skills that were not acquired in earlier years. Furthermore, according to Butterworth (2011), addressing dyscalculia and other mathematical difficulties requires specialised intervention programs.

4.4.4 Pre-test and post-test performance in mathematical skills by the experimental group

The Wilcoxon signed-rank test was used to determine whether there was a statistically significant increase in the scores in mathematical skills of the experimental group or not, following the ICT intervention by comparing two different sets of scores of the same group. The differences between the scores were ordered and then ranked. The null hypothesis of the Wilcoxon signed-rank tests, that the median of the difference score is equal to zero, can be represented as follows: H_0: $M_e = 0$. Alternative forms that can be used are H_1: $M_e \neq 0$ or H_1: $M_e<0$ or H_1: $M_e>0$, depending on the research question.

For the purpose of my study, I tested the hypothesis provided in the previous section, being the following:

- H_0: The basic mathematical skills of Grade 6 learners with dyscalculia will not improve following an ICT intervention.
- H_1: The basic mathematical skills of Grade 6 learners with dyscalculia will improve following an ICT intervention

In symbols this can be presented as follows:

- H_0: $M_e = 0$
- H_1: $M_e>0$

In the alternative hypothesis, the median is greater than zero, which means that the post-test score for mathematical skills will be greater than the pre-test score. For my study, two variables (pre-test and post-test scores) in a single sample (experimental group) were compared. The results are provided in Table 4.12.

Table 4.12: The Wilcoxon signed-rank test for the mathematical skills of the experimental group

Variable		**N**	**Mean Rank**	**Sum of Ranks**	**Exact Sig. (two-tailed)**
Mathematical skills: Pre-test versus post-test	Positive Ranks	10[a]	7.35	73.50	0.004
	Negative Ranks	2[b]	2.25	4.50	
	Ties	2[c]			
	Total	14			
a. Total pre-test skills < total post-test skills					
b. Total pre-test skills > total post-test skills					
c. Total pre-test skills = total post-test skills					

As the sum of the positive ranks (73.50) is much bigger than the sum of the negative ranks (4.50), it can be concluded that the respondents performed better in the post-test than the pre-test in terms of mathematical skills. The negative ranks indicate that two respondents did worse in the post-test than in the pre-test, whereas the positive ranks point to 10 respondents performing better in the post-test than the pre-test. There are two ties, indicating that these respondents' scores stayed the same. As previously explained, the p-value (two-tailed) of the Wilcoxon signed-rank test (Table 4.12) was considered to determine whether the difference between the pre-test and post-test scores is statistically significant to accept or reject the hypothesis.

The p-value (two-tailed) of 0.004 is less than 0.05, suggesting that the null hypothesis of a zero median difference can be rejected. As the median is significantly different from zero, a statistically significant difference exists between the mathematical skills of the pre-test and post-test scores of the experimental group. Based on the test whether or not the median is greater than zero (post-test score greater than pre-test score), that was done, the alternative hypothesis (H_1) is one-sided to the right. In considering the p-value being 0.004/2 = 0.002, which is less than 0.05, it can be concluded that the median of the differences between the pre-test and the post-test scores for mathematical skills of the experimental group is significantly greater than zero on the 5% level. It follows that the ICT intervention had a positive effect on the mathematical skills of the respondents. However, this result then contradicts the results presented in Section 4.4.3. The rationale for this apparent contradiction lies in the experimental group being compared to the control group in Section 4.4.3, while in Section 4.4.4, the performance in mathematics of the experimental group before and after the ICT intervention was compared. This result supports the research of Wilson et al. (2006b) who found that computer games can have a positive effect on learners' performance in mathematics. The difference between the two results stipulated here and in Section 4.4.3 may be ascribed to the factors discussed in Section 4.4.3. This implies that with more time spent on the ICT intervention the performance in mathematics of the experimental group may improve more significantly; however, this is a mere hypothesis that requires more research before drawing conclusions.

4.5 PERFORMANCE OF THE EXPERIMENTAL GROUP IN SUBPARTS OF THE PRE-TEST AND POST-TEST

The results of this study indicate that the ICT intervention had a positive effect on the number sense and mathematical skills of the experimental group and thus on their achievement in mathematics. The tests that the respondents completed contained questions testing different skills and building blocks of number sense. Number sense questions focused on place value, ordering numbers according to size, conservation of numbers, sequencing of numbers, and number concept. Mathematical skills questions tested rounding, multiples and factors, addition with carrying, subtraction with borrowing, and multiplication of 3-digits numbers with 2-digit numbers. Respondents' performance on these subparts of the tests are discussed in this section to indicate which skills improved significantly following the ICT intervention and might thus have had a huge impact on the final results obtained by the respondents. Descriptive statistics were used to compare the means of the subtests of the pre- and post-tests. The results are captured in Table 4.13.

Table 4.13: Descriptive statistics of subtests in the pre- and post-tests of the experimental group

Concepts		Pre-test			Post-test		
		N	Mean	Std. Deviation	N	Mean	Std. Deviation
Tests for number sense	Place value	14	9.524	27.5140	14	40.476	45.6268
	Order of numbers	14	51.786	24.4444	14	56.250	24.8795
	Conservation of numbers	14	69.643	20.0446	14	85.714	23.4404
	Sequencing	14	33.929	21.2997	14	22.024	24.1539
	Number concept	14	30.952	21.5402	14	45.238	22.0998
Tests for mathematical skills	Rounding	14	14.286	21.5402	14	26.190	29.7527
	Multiples and factors	14	0.000	0.0000	14	10.714	21.2908
	Addition with carrying	14	28.571	37.7964	14	46.429	42.5815
	Subtraction with borrowing	14	14.286	30.5625	14	28.571	42.5815
	Multiplication 3-digits with 2-digits	14	0.000	0.0000	14	7.143	18.1568

Sequencing, where the respondents had to complete a sequence of numbers, (e.g. 423; 429; 435; 441; ________; ________; ________) is the only subpart where the mean of the post-test (22.024) was lower than the mean of the pre-test (33.929). In all the other subparts of the tests, the means of the scores were bigger for the post-test than the pre-test. The means of zero for multiples and factors and multiplication are due to the fact that no respondent had any correct answers in the pre-test for these questions.

As described previously, the Wilcoxon matched-pairs signed-rank test, which is used to observe a set of differences, was used to compare two variables (pre-test and post-test scores) in a single sample (experimental group) for all the subparts of the pre- and post-tests to answer the secondary research questions. The p-values (two-tailed) are displayed in Table 4.14 and were used to determine the difference between the pre-test and post-test scores, thus non-directional, with the p-values (one-tailed) used to assess whether the post-test scores were better than the pre-test scores, in other words one-directional.

Table 4.14: Statistics of the Wilcoxon signed-rank test of the subparts of the pre-test and post-test of the experimental group

Test	Concepts	Exact Sig. (two-tailed)	Exact Sig. (one-tailed)
Tests for number sense	Place value	0.031	0.016
	Order of numbers	0.435	0.217
	Conservation of numbers	0.125	0.063
	Sequencing	0.071	0.036
	Number concept	0.048	0.024
Tests for mathematical skills	Rounding	0.250	0.125
	Multiples and factors	0.250	0.125
	Addition with carrying	0.195	0.098
	Subtraction with borrowing	0.406	0.203
	Multiplication 3-digits with 2-digits	0.500	0.250

4.5.1 Secondary research question concerning number sense

The first secondary research question was, *How can software, including Applications (Apps) be utilised to support Grade 6 learners with dyscalculia in terms of number sense skills?* Hypotheses were formulated for each subpart of number sense to determine any possible improvement following the ICT intervention, and thus each part's impact on the final results obtained for the effect of the intervention on the respondents' performance on number sense. The Wilcoxon signed-rank test was used throughout to accept or reject the hypotheses at a 5% significant level, as two different variables (scores in pre-test and scores in post-test) were used, involving a single sample (the experimental group).

4.5.1.1 Place value

The following hypothesis aimed to determine whether or not the ICT intervention had a positive effect on the place value of Grade 6 learners with dyscalculia:

- ❖ H_0: Performance on place value questions by Grade 6 learners with dyscalculia will not improve following the ICT intervention.
- ❖ H_1: Performance on place value questions by Grade 6 learners with dyscalculia will improve following the ICT intervention.

In symbols this hypothesis can be stated as follows:

- ❖ H_0: $M_e = 0$
- ❖ H_1: $M_e > 0$

For the alternative hypothesis, the median is greater than zero, which implies that the post-test score for place value is greater than the pre-test score.

In Table 4.14 the p-value (two-tailed) of place value is indicated as 0.031, which is less than 0.05. This suggests that the null hypothesis of a zero median difference can be rejected and that the median is significantly different from zero. Therefore, a statistically significant difference exists between the place value of the pre-test and the post-test scores of the experimental group. In testing whether the median is greater than zero (post-test score greater than pre-test score), the alternative hypothesis (H_1) was taken as one-sided to the right. As a result, the one-tailed p-value (0.016 in Table 4.14) was considered and found to be less than 0.05. This means that the median of the differences between the pre-test and post-test scores for place value of the experimental group is significantly greater than zero on the 5% level, and that the ICT intervention thus had a positive effect on the place value of the respondents. This result supports the research of Kucian and Von Aster (2015) who state that intervention strategies that include repetition exercises may strengthen the concepts of value and place value among learners.

4.5.1.2 Ordering numbers according to size

The next hypothesis aimed to determine whether or not an ICT intervention had a positive effect on the ordering of numerosities according to size of Grade 6 learners with dyscalculia. It was formulated as follows:

- H_0: Grade 6 learners with dyscalculia's ability to order numerosities according to size will not improve following the ICT intervention.
- H_1: Grade 6 learners with dyscalculia's ability to order numerosities according to size will improve following the ICT intervention.

The symbol format for this is as follows:

- H_0: $M_e = 0$
- H_1: $M_e > 0$

In the case of the alternative hypothesis, the median is greater than zero, which means that the post-test score for the ordering of numerosities is greater than the pre-test score.

When considering the p-value (two-tailed) of ordering numbers according to size, Table 4.14 indicates this as 0.435, which is bigger than 0.05. This suggests that the null hypothesis of a zero median difference cannot be rejected. As such, the median is not significantly different from zero and no statistically significant difference exists between the ordering of numerosities of the pre-test and the post-test scores of the experimental group on a 5% level. It follows that the ICT intervention did not have a positive effect on the ordering of numerosities of the respondents. This result does not support the work of Kiili et al. (2018) who found that game-based learning of conceptual rational numbers can have a positive effect on learners' conceptual rational number knowledge, which can lead to their being able to order numbers according to size more easily. This difference in the results of the current study and that of existing work may be ascribed to the possibility that the ICT intervention may not have included enough time for training related to number lines and conceptual rational numbers. More research is required to confirm this possibility.

4.5.1.3 Conservation of number

The following hypothesis aimed to determine whether or not an ICT intervention had a positive effect on conservation of numbers of Grade 6 learners with dyscalculia:

- H_0: The conservation of number skill of Grade 6 learners with dyscalculia will not improve following an ICT intervention.
- H_1: The conservation of number skill of Grade 6 learners with dyscalculia will improve following an ICT intervention.

The hypothesis can be formulated in symbol format as follows:

- H_0: $M_e = 0$
- H_1: $M_e > 0$

The p-value (two-tailed) of the conservation of number is 0.125, which is bigger than 0.05, thereby indicating that the null hypothesis of a zero median difference cannot be rejected and that the median is not significantly different from zero. Therefore, there is not a statistically significant difference between the conservation of numbers skill of the pre-test and post-test scores of the experimental group on a 5% level, pointing to the ICT intervention not having had a positive effect on conservation of numbers skill by the respondents. This result contradicts the research of Kadosh et al. (2013) who designed interventions specifically focusing on improving number abilities, among other things conservation of numbers. A possible reason for the conservation of numbers skill not improving significantly may be related to limited time spent on number abilities during the ICT intervention program.

4.5.1.4 Sequencing of numbers

The next hypothesis aimed to determine whether or not an ICT intervention had a positive effect on the sequencing of numbers of Grade 6 learners with dyscalculia. The hypothesis was formulated as follows:

- H_0: Performance related to the sequencing of numbers of Grade 6 learners with dyscalculia will not improve following an ICT intervention.
- H_1: Performance related to the sequencing of numbers of Grade 6 learners with dyscalculia will improve following an ICT intervention.

In symbol format this can be stated as follows:

- H_0: $M_e = 0$
- H_1: $M_e>0$

The results captured in Table 4.14 were based on positive ranks, and not on negative ranks as in the previous tests, suggesting that the post-test scores were less than the pre-test scores. The p-value (two-tailed) of the sequencing of numbers is 0.071, which is bigger than 0.05. This indicates that the null hypothesis of a zero median difference cannot be rejected and that the median is thus not significantly different from zero. Therefore, no statistically significant difference exists between the sequencing of numbers of the pre-test and post-test scores of the experimental group on a 5% level.

In further analysis, it was determined whether or not the respondents did significantly better in the post-test when compared to their performance on the pre-test, thereby determining whether the median is greater than zero (post-test score greater than pre-test score), and therefore whether the alternative hypothesis (H_1) is one-sided to the right. For this purpose, the p-value (one-tailed), which is 0.036 (Consult Table 4.14) was considered and found to be less than 0.05, which means that the median of the differences between the pre-test and the post-test scores for sequencing of the experimental group is significantly greater than zero on the 5% level. This result implies that the ICT intervention had a positive effect on the skill of sequencing, demonstrated by the respondents. The result correlates with the research of Kadosh et al. (2013), who similarly found that computer-based interventions, such as *Calcularis* may have a positive effect on basic numerical skills.

4.5.1.5 Number concept

The final hypothesis related to number sense aimed to determine whether or not the ICT intervention had a positive effect on the number concept of Grade 6 learners with dyscalculia, formulated in the following way:

- H_0: The number concept of Grade 6 learners with dyscalculia will not improve following an ICT intervention.
- H_1: The number concept of Grade 6 learners with dyscalculia will improve following an ICT intervention.

In symbol format the hypothesis is stated as follows:

- H_0: $M_e = 0$
- H_1: $M_e > 0$

The p-value (two-tailed) of number concept is 0.048 (Consult Table 4.14), which is less than 0.05. This suggests that the null hypothesis of a zero median difference can be rejected and that the median is thus significantly different from zero. Therefore, a statistically significant difference was found to exist between the number concept scores of the pre-test and the post-test of the experimental group on the 5% level. When testing whether the median is greater than zero (post-test score greater than pre-test score), with the alternative hypothesis (H_1) taken to be one-sided to the right, the one-tailed p-value, which is 0.024 (Consult Table 4.14), and thus less than 0.05 was considered. This implies that the median of the differences between the pre-test and the post-test scores for number concept of the experimental group is significantly greater than zero on the 5% level. It follows that the ICT intervention had a positive effect on the number concept of the respondents, which correlates with research by Butterworth and Laurillard (2010), Räsänen et al. (2009) and Wilson et al. (2006b). These authors conducted research on intervention strategies for dyscalculia, and found that computer games, such as the *Number Race*, may have a positive effect on the number concept of learners with dyscalculia.

4.5.2 Secondary research question concerning mathematical skills

The second secondary research question was formulated as follows: *How can software, including Applications (Apps) be utilised to support Grade 6 learners with dyscalculia, in terms of basic mathematical skills?* Hypotheses were formulated for each subpart of mathematical skills covered in the tests written by the respondents to determine any possible improvement and potential effect on the final results obtained by the respondents. As indicated the Wilcoxon signed-rank test was used to accept or reject the hypotheses at a 5% significant level, relying on two different variables (scores in pre-test and post-test) of a single sample − the experimental group.

4.5.2.1 Rounding of numbers

The following hypothesis aimed to determine whether or not an ICT intervention had a positive effect on the rounding of numbers by Grade 6 learners with dyscalculia:

- H_0: The rounding of numbers by Grade 6 learners with dyscalculia will not improve following an ICT intervention.
- H_1: The rounding of numbers by Grade 6 learners with dyscalculia will improve following an ICT intervention.

In symbol format, this is stated as follows:

- H_0: $M_e = 0$
- H_1: $M_e > 0$

As the p-value (two-tailed) of 0.250 (Consult Table 4.14) is bigger than 0.05, the null hypothesis of a zero median difference cannot be rejected. As such, the median is not significantly different from zero, with no statistically significant difference between the rounding of numbers of the pre-test and post-test scores of the experimental group on a 5% level. This implies that the ICT intervention did not have a positive effect on the skill of rounding of numbers by the respondents. This may perhaps be because of the ICT intervention not including enough intervention strategies specifically focusing on the rounding of numbers. For example, not all the respondents played games that focus on rounding, as some of them worked more slowly than others and spent more time on other intervention strategies.

4.5.2.2 Multiples and factors

The next hypothesis aimed to determine whether or not an ICT intervention had a positive effect on the multiples and factors of Grade 6 learners with dyscalculia, and was formulated as follows:

- H_0: The performance on questions related to multiples and factors by Grade 6 learners with dyscalculia will not improve following an ICT intervention.
- H_1: The performance on questions related to multiples and factors by Grade 6 learners with dyscalculia will improve following an ICT intervention.

This can be formulated as follows:

- H_0: $M_e = 0$
- H_1: $M_e > 0$

Once again, the p-value (two-tailed) of 0.250 (Consult Table 4.14), which is bigger than 0.05, suggests that the null hypothesis of a zero median difference cannot be rejected and that the median is thus not significantly different from zero. Therefore, a statistically significant difference does not exist between the multiples and factors of the pre-test and post-test scores of the experimental group on a 5% level. It follows that the ICT intervention accordingly did not have a positive effect on the multiples and factors of the respondents. This result may be ascribed to the fact that multiples and factors were not covered broadly in the ICT intervention program. The result is in alignment with the work of Butterworth (2011), who proposes that any intervention strategy addressing dyscalculia must be specialised for a significant positive effect to occur.

4.5.2.3 Addition with carrying

The following hypothesis aimed to determine whether or not an ICT intervention had a positive effect on the addition with carrying skill of Grade 6 learners with dyscalculia:

- H_0: The addition with carrying skill of Grade 6 learners with dyscalculia will not improve following an ICT intervention.
- H_1: The addition with carrying skill of Grade 6 learners with dyscalculia will improve following an ICT intervention.

In symbol format this is stated as follows:

- H_0: $M_e = 0$
- H_1: $M_e > 0$

As in the case of multiples and factors, the p-value (two-tailed) of 0.195 is bigger than 0.05 and implies that the null hypothesis of a zero median difference cannot be rejected and that the median is not significantly different from zero. As such, there is not a statistically significant difference between the addition with carrying performance on the pre-test and post-test scores of the experimental group on a 5% level. The ICT intervention did not have a positive effect on the addition with carrying skill displayed by the respondents. The reason for this may be due to the fact that most of the respondents might not have spent sufficient time on addition with carrying activities as part of the intervention, as they might have taken longer with some of the more basic intervention strategies which did not include addition with carrying activities. The result concurs with the view of Shalev (2004), who posits that intervention strategies need to address specific mathematics information gaps as a result of dyscalculia.

4.5.2.4 Subtraction with borrowing

The following hypothesis aimed to determine whether or not an ICT intervention had a positive effect on the subtraction with borrowing of Grade 6 learners with dyscalculia:

- H_0: The subtraction with borrowing skill of Grade 6 learners with dyscalculia will not improve following an ICT intervention.
- H_1: The subtraction with borrowing skill of Grade 6 learners with dyscalculia will improve following an ICT intervention.

In symbols this is represented in the following manner:

- H_0: $M_e = 0$
- H_1: $M_e>0$

Once again, the p-value (two-tailed) of 0.406 (Consult Table 4.14) is bigger than 0.05. This suggests that the null hypothesis of a zero median difference cannot be rejected and that the median is not significantly different from zero. Therefore, a statistically significant difference does not exist on a 5% level between the subtraction with borrowing of the pre-test and post-test scores of the experimental group. As such, the ICT intervention did not have a positive effect on the subtraction with borrowing skill of the respondents, which can perhaps be related to the fact that the respondents did not play many games on subtraction with borrowing as part of the intervention.

4.5.2.5 Multiplication of 3-digit with 2-digit numbers

The last formulated hypothesis aimed to determine whether or not an ICT intervention had a positive effect on the multiplication of 3-digit with 2-digit numbers of Grade 6 learners with dyscalculia. The hypothesis was formulated as follows:

- H_0: The multiplication of 3-digit with 2-digit numbers skill of Grade 6 learners with dyscalculia will not improve following an ICT intervention.
- H_1: The multiplication of 3-digit with 2-digit numbers skill of Grade 6 learners with dyscalculia will improve following an ICT intervention.

In symbols this is presented as follows:

- H_0: $M_e = 0$
- H_1: $M_e > 0$

The p-value (two-tailed) is 0.500 (Consult Table 4.14) in this case, which is bigger than 0.05. This indicates that the null hypothesis of zero median difference cannot be rejected and that the median is thus not significantly different from zero. As such, there is not a statistically significant difference between the multiplication of 3-digit with 2-digit numbers of the pre-test and post-test scores of the experimental group on a 5% level, implying that the ICT intervention did not have a positive effect on the multiplication of 3-digit with 2-digit numbers by the respondents. However, the ICT intervention included only exercises on multiplication with numbers with single digits. In addition, limited time was spent on the improvement of the automatic recall of number facts by way of repetition and rote learning, as suggested by Shalev (2004).

4.6 RESULTS OF THE DYSCALCULIA SCREENER

All respondents were tested with the *Dyscalculia Screener* (GL Assessment, n. d.) before and after the intervention, as explained in Chapter 3. These results were not used to determine whether or not the respondents displayed tendencies of dyscalculia, as a broader definition of dyscalculia was adapted for the current study. Instead, the results obtained were used to determine any changes in the different stanines of the *Dyscalculia Screener* and whether the diagnosis of the Screener changed for any respondents after the intervention had been completed.

From my observations it seemed clear that the respondents were not used to computers when completing the Screener, with some at first being cautious when pressing the keys on the keyboard. What was also evident, was that all of the respondents were guessing or counting the dots on the screen during the dot enumeration test, even when instructed not to do so. They furthermore guessed answers in the numerical stroop test to answer which number was bigger. During the addition and multiplication tests, the respondents all counted on their fingers, and some of them tried to hide it from the researcher by doing so under the table. When something looked confusing to the respondents, they seemed merely to guess the answer.

4.6.1 Examples of reports of the Dyscalculia Screener to teachers and parents

Some examples that were prepared for the respondents of the *Dyscalculia Screener*'s reports are included in this section. The first example is one of a respondent who might have tendencies towards dyscalculia (Learner A), with the second example representing a respondent who, according to the *Dyscalculia Screener,* probably did not have dyscalculia (Learner B). When presenting the reports to the teachers and parents, the content was discussed to help them understand why the learners had difficulties with mathematics and to assist them in developing intervention strategies for the learners.

4.6.1.1 Reports for a respondent who displayed tendencies towards dyscalculia according to the Dyscalculia Screener

The reports prepared for the parents or caregivers consisted of two parts. The first part provided a graphical representation of the results with a description thereof, as depicted in Figure 4.3. The second part of the report entailed recommendations to the parents, as captured in Figure 4.4

The reports that were prepared for teachers or practitioners also consisted of two parts but were slightly different from those for the parents. The teacher report (Consult Figure 4.5) had a column for the stanines obtained, with another column for standard age scores, which are not displayed here, as the Screener was not standardised for learners in South Africa. The recommendations provided to teachers or practitioners were broader than those for parents, as can be seen in Figure 4.6. In addition, a section in the teacher report explained all the subparts of the Screener (Consult Appendix J).

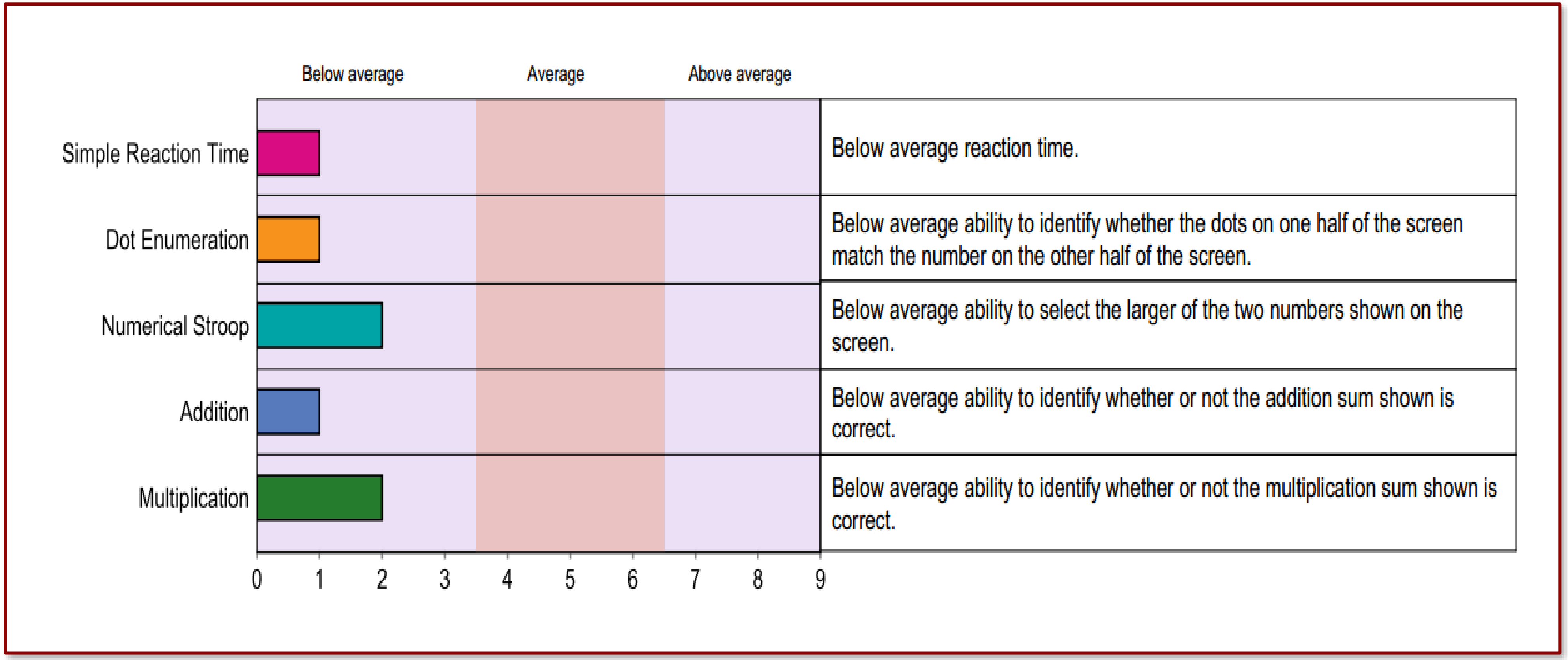


Figure 4.3: Results of Learner A provided to the parents

Recommendations:

The results show us that [redacted] performed low overall across the Dot Enumeration and Numerical Stroop tests and has guessed the answers on the Addition and Multiplication tests. This pattern of results is typical of someone who has dyscalculia.

[redacted] should receive further diagnostic assessment. If this supports the screener results then we would recommend specialist tuition and resources.

Recommendations are based on the author's wide experience of working with dyscalculia. Teachers will use their own professional judgement when interpreting the results and in making decisions about what to do next.

It is important to note that *Dyscalculia Screener* is not a full diagnostic assessment; it is a screener. This means its purpose is to identify children who are having difficulties that are often linked with dyscalculia. These children will then need further investigation. The results from the screener are not intended to give firm evidence that dyscalculia is present at this stage.

Figure 4.4: Recommendations for Learner A to the parents

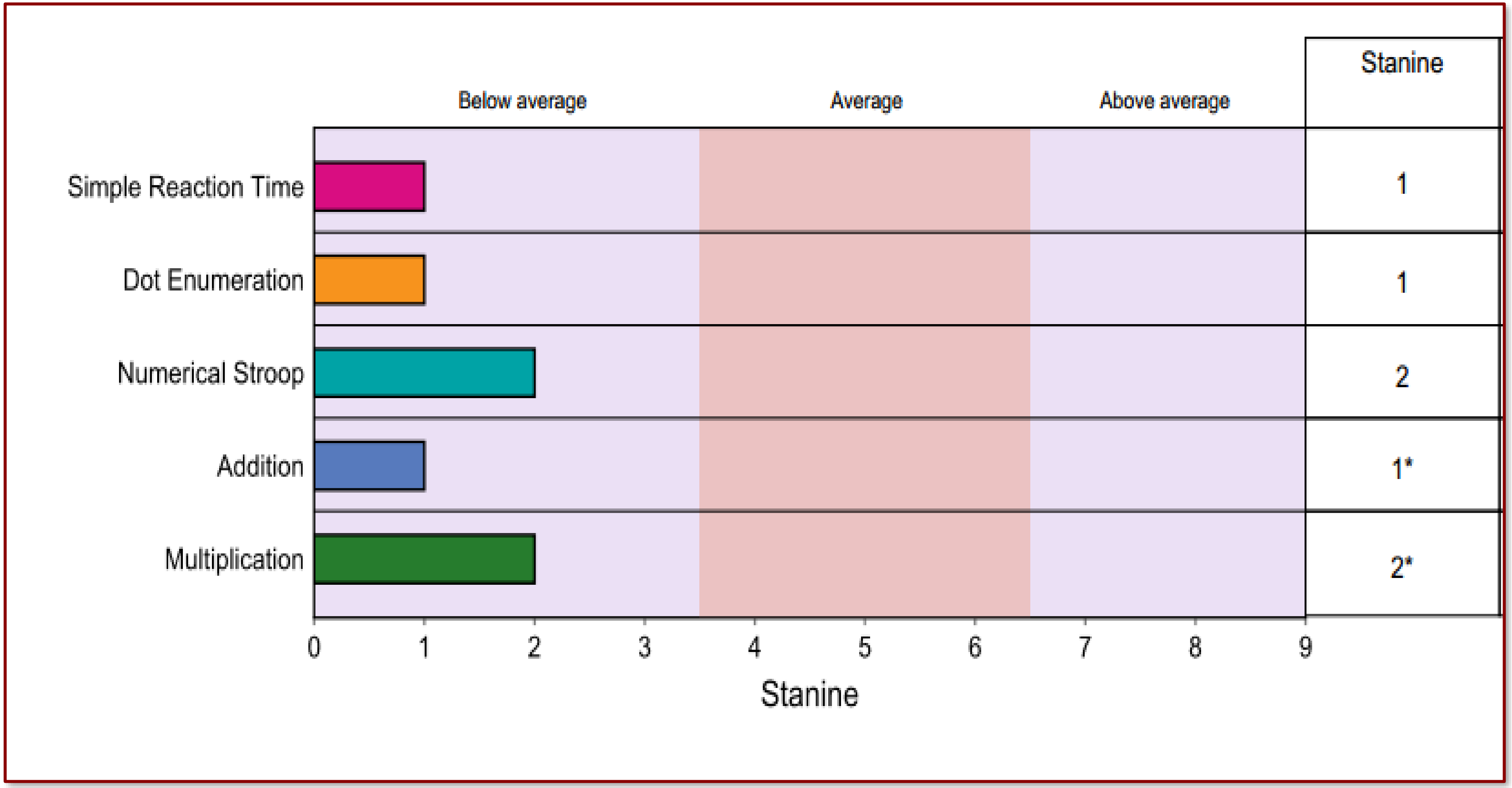


Figure 4.5: Graphical representation of the results of Learner A to the teacher

The results for Addition and Multiplication should be treated with caution as the pupil appears to be guessing on these tests.

Recommendations:
[redacted] has low overall performance across the two capacity tests (Dot Enumeration and Numerical Stroop) and has guessed the answers of the achievement tests (Addition and Multiplication). This pattern of results is typical of someone who has dyscalculia.

[redacted] should receive further diagnostic assessment. If this supports the screener results, individual specialist tuition and support would be recommended. The underlying problem is likely to be in understanding numerosities. Interventions should stress this very basic aspect of arithmetic.

It will not help to practise number bonds until the numerosity concept is firmly established. Attempting to induce rote learning of number bonds and tables could lead to frustration and avoidance. Even if the learner can successfully repeat the bonds and table facts, this does not necessarily mean that they are understood or can be used appropriately.

In our experience, it is sometimes best for all concerned to find ways around the difficulties rather than confront them head-on. With arithmetic, our suggestion is that the learner should focus on trying to master the calculator. This does require understanding, but not calculation skills.

There may also be a need for careful sustained discussion with parents or carers and informal counselling from teachers.

Recommendations are based on the author's wide experience of working with dyscalculia. However, local procedures and resources may need to be taken into account in determining an implementation plan.

The effectiveness of specialist help depends upon the programme of study fitting the individual circumstances. General prescriptions are likely to be of little use.

Figure 4.6: Recommendations of Learner A's results to the teacher

4.6.1.2 Reports for a respondent who did not display tendencies towards dyscalculia according to the Dyscalculia Screener

Even though this respondent also guessed many answers the Screener did not indicate him as having tendencies towards dyscalculia, because of the average score obtained for numerical stroop. The various reports provided to the parents and teachers are captured in Figures 4.7 to 4.10.

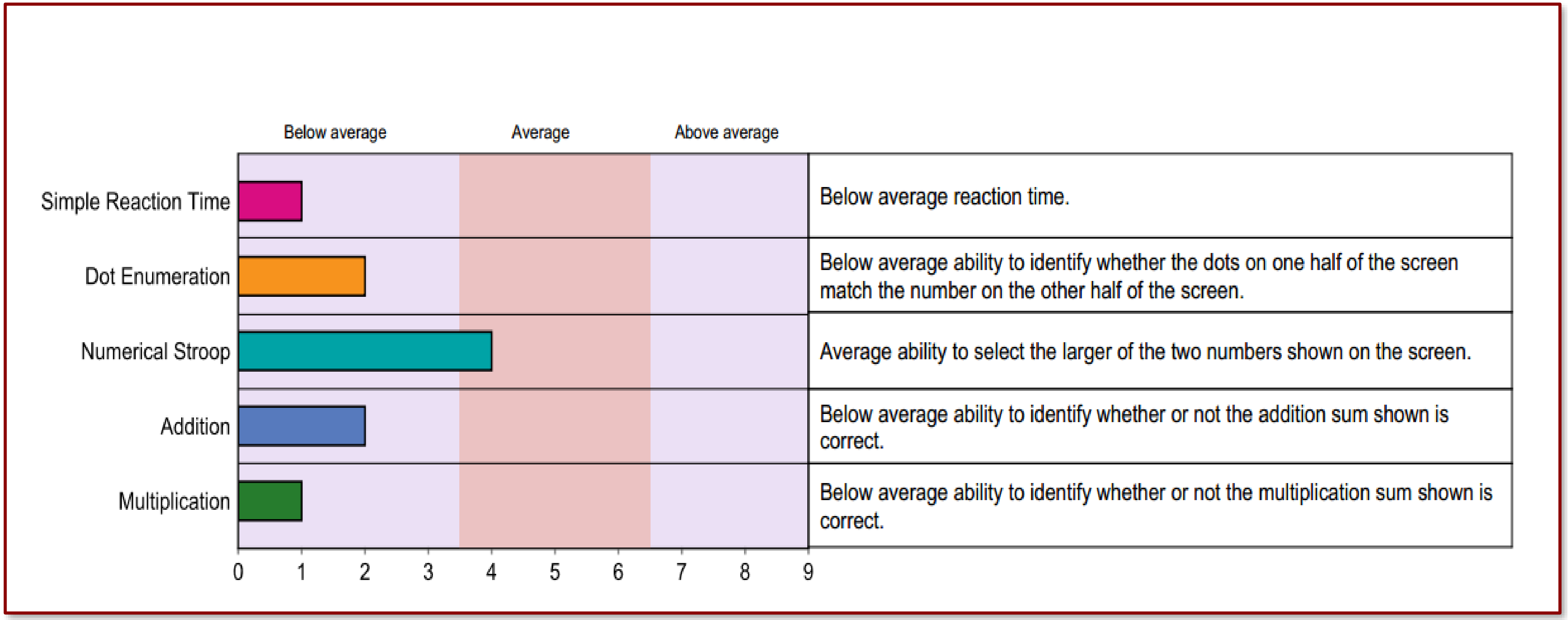


Figure 4.7: Results of Learner B provided to the parent

Recommendations:

The results show us that overall [redacted] scored appropriately for [redacted] age group across the Dot Enumeration and Numerical Stroop tests.

However, the scores on the Addition and Multiplication tests were low. There could be many reasons for this that may need further investigation, but it is unlikely that [redacted] has dyscalculia.

Recommendations are based on the author's wide experience of working with dyscalculia. Teachers will use their own professional judgement when interpreting the results and in making decisions about what to do next.

It is important to note that *Dyscalculia Screener* is not a full diagnostic assessment; it is a screener. This means its purpose is to identify children who are having difficulties that are often linked with dyscalculia. These children will then need further investigation. The results from the screener are not intended to give firm evidence that dyscalculia is present at this stage.

Figure 4.8: Recommendations for Learner B to the parent

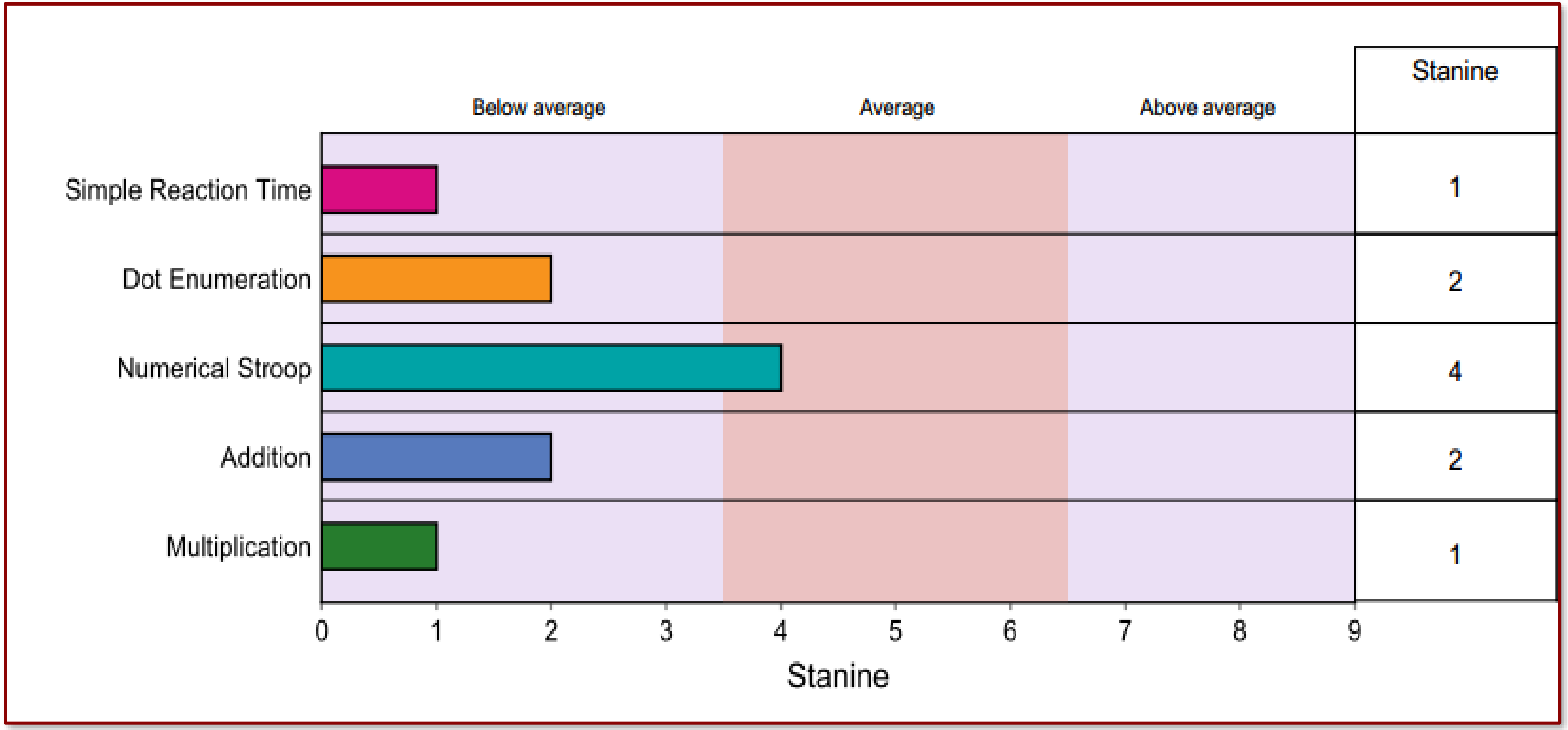


Figure 4.9: Graphical representation of the results of Learner B provided to the teacher

Recommendations:

Overall [redacted] performs appropriately for [redacted] age group across the two capacity tests (Dot Enumeration and Numerical Stroop). However, arithmetic achievement (Addition and Multiplication) is low. This pattern of results suggests that [redacted] is not failing in arithmetic because of dyscalculia.

There are many causes of low mathematical achievement in addition to dyscalculia. The first task is to discover why [redacted] had a low score on the arithmetic sub-tests. [redacted] may not have been trying on this occasion. This can be established by asking [redacted] to re-take the test. Alternatively, another test of achievement can be used.

If achievement is still low on the re-test then something in the learning situation will have been responsible. Possible causes should be investigated such as absence from mathematics classes, anxiety about mathematics or inappropriate teaching at the level needed.

Recommendations are based on the author's wide experience of working with dyscalculia. However, local procedures and resources may need to be taken into account in determining an implementation plan.

The effectiveness of specialist help depends upon the programme of study fitting the individual circumstances. General prescriptions are likely to be of little use.

There are many products, books and services that may be effective in providing support to individuals. Intervention may be planned using GL Assessment's Dyscalculia Guidance handbook. Visit our website http://www.gl-assessment.co.uk for further details.

It is important to note that *Dyscalculia Screener* is not a full diagnostic assessment; it is a screener. This means its purpose is to identify children who are experiencing difficulties known to be associated with dyscalculia that may require further investigation. The results from the screener are not intended to give firm evidence that dyscalculia is present at this stage.

Figure 4.10: Recommendations of Learner B's results to the teacher

4.6.2 Results of the Dyscalculia Screener before and after the intervention

The results of both the experimental and control groups obtained on the *Dyscalculia Screener* are captured in Table 4.15. For each subtest an indication is provided of the groups' performance post intervention compared to the results obtained by the two groups prior to the intervention.

Table 4.15: Analysis of the results of the experimental group and the control group in the pre-test and post-test of the Dyscalculia Screener

Subtest	Result	Experimental group	Control group
Dot enumeration	Better in post-test	35.7%	60.0%
	Worse in post-test	35.7%	10.0%
	Equal in post-test	28.6%	30.0%
Numerical stroop	Better in post-test	42.9%	30.0%
	Worse in post-test	28.6%	30.0%
	Equal in post-test	28.6%	40.0%
Addition	Better in post-test	78.6%	40.0%
	Worse in post-test	0.0%	10.0%
	Equal in post-test	21.4%	50.0%
Multiplication	Better in post-test	78.6%	40.0%
	Worse in post-test	7.1%	10.0%
	Equal in post-test	14.3%	50.0%

In Table 4.15 it can be seen that in both dot enumeration and numerical stroop no deductions can be made about a positive effect of the intervention on the performance of the experimental group. In the addition of single-digit numbers, however, 78,6% of the respondents did better after the intervention, with not one of them performing worse. Of the control group, 40% that received no intervention performed better in the post-test for addition, and 10% worse in the post-test. The results for multiplication remained almost the same, except that for the experimental group 7,1% performed worse after the intervention.

In addition to these deductions made from the results, possible changes in the diagnosis of having tendencies (or not) towards dyscalculia according to the *Dyscalculia Screener* before and after intervention were also considered. Of the 14 respondents in the experimental group, two respondents' diagnosis changed from probably dyscalculic in the pre-test to probably not dyscalculic after the intervention, while four out of the 14 respondents' diagnosis changed from probably not dyscalculic to probably dyscalculic after the intervention. Only one out of the 10 respondents' diagnosis in the control group changed in the post-test, from probably not dyscalculic to dyscalculic. These results align with the work of Butterworth (2011) who regards dyscalculia as a neurological defect that cannot disappear, resulting in the need for specific intervention strategies to teach the brain new pathways to learn certain mathematical skills.

4.7 CONCLUSION

In this chapter, the results of the study were discussed. SPSS software was used to analyse the data and to accept or reject the hypotheses formulated in Chapter 1 to interpret the results of the study. The results of the pre- and post-tests of the control group were compared with those of the experimental group. The pre-test scores of the experimental group were interpreted against the post-test scores. Finally, the results derived from the *Dyscalculia Screener* were presented.

Based on the results of the study, the null hypothesis (H_0) stating that the performance of Grade 6 learners with dyscalculia in mathematics will not improve following an ICT intervention, was rejected for the performance of the pre-test compared to the post-test of the experimental group, thus accepting the alternative hypothesis (H_1) indicating that the ICT intervention can be taken as having had a positive effect on the performance of the respondents in mathematics. Contrary to this finding, this null hypothesis was accepted when comparing the performance in mathematics of the experimental group against the control group, as the difference between the pre-test and post-test scores of the two groups is not statistically significantly different.

The null hypothesis (H_0) stating that the number sense of Grade 6 learners with dyscalculia will not improve following an ICT intervention, was rejected when comparing the pre- and post-test scores of the experimental group with the control group, as well as when comparing the pre-test with the post-test scores of the only the experimental group. The alternative hypothesis (H_1), stating that the number sense of Grade 6 learners with dyscalculia will improve following an ICT intervention was therefore accepted. Furthermore, the null hypothesis (H_0) stating that the basic mathematical skills of Grade 6 learners with dyscalculia will not improve following an ICT intervention was accepted when comparing the results of the experimental group with the control group, thus concluding that the experimental group did not perform statistically significantly better than the control group at the 5% level in terms of mathematical skills. Contrary to this finding, when comparing the pre-test results of the experimental group to the post-test-results, the same null hypothesis (H_0) was rejected and the alternative hypothesis (H_1), stating that the basic mathematical skills of Grade 6 learners with dyscalculia will improve following an ICT intervention, was accepted.

In the next chapter, final conclusions are drawn and the interpretation of the results is discussed. In addition, recommendations for future research and practice, based on the results obtained in the current study, are made.

CHAPTER 5 - CONCLUSIONS AND RECOMMENDATIONS

5.1 INTRODUCTION

The results of the study were discussed in Chapter 4. I utilised the Statistical Package for the Social Sciences (SPSS 25) to determine p-values for the key concepts of the study. In presenting my results, I discussed the hypotheses set to address the research questions in symbolic form and assessed the hypotheses on a 5% significance level. Throughout, the results obtained in this study were related to existing literature.

In this chapter, the research questions that guided the study are addressed. The data interpretation and conclusions are presented, and the implications of the study are foregrounded. The limitations of the study are listed and recommendations for future research formulated.

5.2 SUMMARY OF CHAPTERS

Chapter 1 provided a brief background and overview of the study. In this chapter I discussed the rationale for and purpose of the study, emphasising the importance of diagnosing learners with a mathematical learning disability as early as possible to intervene and provide support to those learners. I briefly discussed the use and importance of ICT in the current digital and technological society. Next I formulated research questions to guide the study and stated the hypotheses to be tested as well as the key concepts underlying this study. I presented a broad overview of the methodology, research design, sampling procedures, data collection and data analysis strategies. Furthermore, I introduced the ethical considerations observed.

In Chapter 2 I discussed relevant existing literature relating to the topic of this study. I discussed the phenomenon of dyscalculia and then explained the concepts of numbers and number sense. I explained the developing of numerical abilities. I used existing literature to explore factors influencing learners' performance in mathematics. Furthermore, I discussed ICT as well as the potential use of ICT during interventions in support of learners with dyscalculia. Finally, I provided and explained the conceptual framework.

In Chapter 3 I discussed in detail the selected paradigm, research design and methodological strategies utilised during the study, and I justified all choices against the background of the purpose of the study and the formulated research question. I explained sampling procedures, data collection and documentation as well as data analysis strategies. I contemplated the validity and reliability of the study and discussed important aspects of ethical clearance.

In Chapter 4 I presented and discussed the results and statistics of the study. I accepted or rejected the hypotheses set to answer the research questions on a 5% significance level, and I interpreted the results I obtained against the existing literature discussed in Chapter 2.

This final chapter of the dissertation includes a summary of the previous chapters and then focuses on the findings of my research in response to the formulated research questions. It also provides conclusions and recommendations derived from the study I completed.

5.3 DISCUSSION OF RESEARCH QUESTIONS

I conducted this study to explore whether and how Grade 6 learners with dyscalculia can be supported to improve their number sense and develop mathematical skills by utilising intervention strategies through ICT. The primary research question focused on how an Information and Communication Technology (ICT) intervention can support or not support the achievement in mathematics of Grade 6 learners with dyscalculia. I formulated two secondary research questions to guide the research to address the following primary research question.

- ❖ How can software, including Applications (Apps) be utilised to support Grade 6 learners with dyscalculia in terms of number sense skills?
- ❖ How can software, including Applications (Apps) be utilised to support Grade 6 learners with dyscalculia in terms of basic mathematical skills?

In this section I first discuss the two secondary research questions. Following on these discussions, I come to conclusions in terms of the primary question.

5.3.1 How can software, including Applications (Apps) be utilised to support Grade 6 learners with dyscalculia, in terms of number sense skills?

This secondary research question relates to the following hypothesis:

- H_0: The number sense of Grade 6 learners with dyscalculia will not improve following an ICT intervention.
- H_1: The number sense of Grade 6 learners with dyscalculia will improve following an ICT intervention.

I relied on a pre-test and post-test to answer this secondary research question. For this purpose, I included questions on the following aspects of number sense: place value and value of numbers, bigger or smaller size of numbers, conservation of numbers, sequencing of numbers and number concept (Consult Appendices F, G and H). The Apps that I utilised for the intervention focusing on number sense were *The Number Race* (Wilson & Dehaene, 2004)*, Pop the Balloon* (Sheppard & Chapgar n. d.), for order of numbers, count and order, greater than and smaller than, skip counting and sequencing, and *Math Man* (Sheppard & Chapgar n. d.) for value of numbers and place value.

To be able to answer this secondary research question, I first compared the total scores for these questions in the pre-test to the scores of the corresponding questions in the post-test of the experimental group to determine whether any improvement in the scores occurred. In the experimental group, 13 of the 14 respondents did better in the number sense questions in the post-test than in the pre-test. I then used the Mann-Whitney U test (SPSS software) to determine whether there was a significant difference between the performance of the experimental and control groups in the questions related to number sense (Consult Table 4.9). Based on these results, the null hypothesis (H_0) was rejected, leading to the conclusion that the experimental group performed statistically significantly better in number sense than the control group, on the 5% level, thus, the number sense of Grade 6 learners with dyscalculia will improve following an ICT intervention.

To determine whether or not there was a statistically significant improvement in the scores of the experimental group for the number sense questions, I applied the Wilcoxon signed-rank test (SPSS 25 software), with the results captured in Table 4.10.

In assessing the related hypothesis, I determined that the median was significantly different from zero, and therefore rejected the null hypothesis. As a result, I can conclude that there was a statistically significant improvement in the scores for number sense by the experimental group. As such, the ICT intervention that was implemented had a positive effect on the number sense skills of Grade 6 learners that formed part of the experimental group.

As number sense is a broad concept, I also considered subparts of number sense to determine the success of the ICT strategies and applications I used for the intervention. I formulated hypotheses for place value, ordering of numbers according to size (bigger or smaller size of numbers), conservation of numbers, sequencing of numbers and number concept. Based on my discussion in Chapter 4 on the acceptance or not of these hypotheses, I can conclude that the ICT intervention and applications I used had a positive effect on place value and value, the sequencing of numbers and number concept. The null hypothesis of zero median difference was not rejected for ordering numbers according to size and conservation of numbers, leading to the conclusion that the ICT intervention and applications I used did not have a positive effect on ordering numbers according to size and conservation of numbers. As it is important for the lower building blocks of number sense to be well-developed for the other number sense skills to build upon these (Consult Figure 2.3), intervention strategies should be expansive and include auditory sequential memory, visual memory and perception and processing speed to ensure a strong foundation for other number sense skills to develop. However, I did not specifically include games focusing on these basic concepts, which could have resulted in some of the number sense skills not improving sufficiently or not improving at all.

With regard to the first secondary research question, I can conclude that in this study, the playing of mathematical games on a laptop, such as *The Number Race* (Wilson & Dehaene, 2004), and *Pop the Balloon* (Sheppard & Chapgar n. d.) for ordering of numbers, count and order, greater than and smaller than, skip counting and sequencing, and *Math Man* (Sheppard & Chapgar n. d.) for place value, supported Grade 6 learners with dyscalculia in terms of number sense, more specifically regarding their ability to complete questions on place value, sequencing of numbers and number concept.

5.3.2 How can software, including Applications (Apps) be utilised to support Grade 6 learners with dyscalculia in terms of basic mathematical skills?

This secondary research question relates to the following hypothesis:

- H_0: The basic mathematical skills of Grade 6 learners with dyscalculia will not improve following an ICT intervention.
- H_1: The basic mathematical skills of Grade 6 learners with dyscalculia will improve following an ICT intervention

To answer this secondary research question, I used the questions that focused on learnt mathematical skills in the pre-test and post-test (Consult Appendices F, G and H). The mathematical skills I tested were rounding, multiples and factors, addition with carrying, subtraction with borrowing and multiplication of 3-digit numbers with 2-digit numbers. The applications I used to practise these mathematical skills were *Sheppard Software Maths*, more specifically *Math Lines* (addition, multiplication), *Math Man* (rounding, addition, multiplication), *Pop the Balloon* (add and order) (Sheppard & Chapgar n. d.) and *The Rockseries* (RockSeries Educational Software, 2017).

As indicated in Chapter 4, I used the Mann-Whitney U test for the scores on the questions about mathematical skills in the pre-test and post-test (Consult Appendices F, G and H) and concluded that although the scores for the respondents in the experimental group were better than for those in the control group, there was not a statistically significant difference on the 5% level (Consult Table 4.11). In support I accepted the hypothesis (H_0) and could conclude that the experimental group did not perform statistically significantly better at the 5% level in mathematical skills than the control group, hence, basic mathematical skills of Grade 6 learners with dyscalculia will not improve following an ICT intervention.

Although there was not a significant difference between the performance of the experimental group and the control group in mathematical skills, and the experimental group did not perform significantly better than the control group according to the Mann-Whitney U test, I applied the Wilcoxon signed-rank test to determine whether the improvement in the scores of the experimental group from the pre-test to the post-test was statistically significant on the 5% level (Consult Table 4.12). This resulted in the conclusion that the experimental group's scores significantly improved from the pre-test to the post-test, implying that the ICT intervention may have had a positive effect on the mathematical skills of the experimental group.

I also considered the subparts of the mathematical skills of the experimental group, as explained in Chapter 4. In this regard I found that there was no statistically significant improvement in any of the mathematical skills on the 5% level, leading to the conclusion that the playing of mathematical games on the laptops did not support the Grade 6 learners with dyscalculia in terms of their mathematical skills. This may be because the lower order skills, as demonstrated in Figure 2.3, were probably not developed enough for the higher order skills to improve significantly. The digital games that the respondents played involved practising skills on different levels, yet as the intervention was not designed to develop the lower order skills before playing games involving skills on higher levels, the mathematical skills on higher levels did not significantly improve.

I used the results of the *Dyscalculia Screener* (Consult Table 4.15) to determine the differences between the screening before and after the intervention for specifically addition and multiplication, as the sums in the *Dyscalculia Screener* involved one-digit number adding or multiplication, which is similar to the *Sheppard Software* games that the respondents of the experimental group played. The results indicate that 78,6% of the respondents in the experimental group performed better in the second screening than in the first screening; none performed worse and 21,4% of the respondents had the same stanines for addition in the second screening when compared to the first screening. However, in the control group 40% of the respondents did better in the second screening, while 10% did worse and 50% had the same stanines for both the first and second screenings.

The results for the control group were precisely the same for multiplication in the first and second screenings. In the experimental group, however, 78,6% of the respondents did better in multiplication in the second screening than in the first screening; 7,1% did worse and 14,3% obtained the same stanines. Therefore I can conclude that the ICT intervention seemingly had a positive effect on the addition and multiplication of one-digit numbers, as the experimental group as a whole performed better in the second screening than the control group. As the results of the *Dyscalculia Screener* entailed stanines and not the real scores of the tests, I decided not to test the results statistically and can therefore not come to a scientifically based conclusion about the results of the *Dyscalculia Screener*.

5.3.3 Primary research question: How can an Information and Communication Technology (ICT) intervention support (or not) the achievement in mathematics of Grade 6 learners with dyscalculia

The results derived from the secondary research questions imply that the ICT intervention supported Grade 6 learners with dyscalculia in terms of number sense but not mathematical skills. As mathematics is a complex field consisting of many concepts, it may not be ideal to comment on the respondents' achievement in mathematics by regarding only a few concepts at the core of the subject. As the achievement of learners in mathematics is usually determined by the learners' performances in a test, I regarded the respondents' performances in the pre-test (Consult Appendix F) and post-test (Consult Appendix G) as broad indicators of their achievement in mathematics. I therefore used the performance of the experimental and control groups before and after the intervention to answer the primary research question.

The primary research question relates to the following hypothesis:

- H_0: The performance of Grade 6 learners with dyscalculia in mathematics will not improve following an ICT intervention.
- H_1: The performance of Grade 6 learners with dyscalculia in mathematics will improve following an ICT intervention.

Based on my discussion of descriptive statistics in Chapter 4, it seems as if the achievement in mathematics of the experimental group increased after the intervention, while the achievement of the control group decreased. In addition, the Mann-Whitney U test indicated no statistically significant difference between the performances of the control group and the experimental group in the post-test. Based on these results, the null hypothesis (H_0) was accepted when comparing the results of the experimental group with the control group, leading to the conclusion that the experimental group did not perform statistically significantly better in mathematics than the control group, on the 5% level, following the ICT intervention. More specifically, according to the Mann-Whitney U test, the experimental group did not perform significantly better than the control group after the intervention despite the descriptive statistics indicating that the control group performed worse in the post-test, while the experimental group performed better. In an attempt to understand this discrepancy, I used the Wilcoxon signed-rank test, with the results included in Chapter 4, indicating that the decrease in the control group's performance was statistically significant on the 5% level of significance.

In discussing the increase of the test scores of the experimental group following the ICT intervention in Chapter 4, I indicated that there was a statistically significant difference between the pre-test and post-test scores and that the performance of the experimental group in the post-test was specifically significantly better on the 5% level when compared to the pre-test. Based on these results, the null hypothesis (H_0) was rejected, leading to the conclusion that the performance of Grade 6 learners with dyscalculia in mathematics will improve following an ICT intervention. This indicates that the ICT intervention had a positive influence on the achievement in mathematics of the respondents.

Therefore, even though there was not a significant difference between the post-test scores of the control group and the experimental group, the increase in the post-test scores of the experimental group was statistically significant. Comparing this to the statistically significant decrease in the control group's post-test scores, the conclusion for the primary research question is that the ICT intervention strategy and applications (mathematical games) supported the participating Grade 6 learners with dyscalculia in their achievement in mathematics.

5.4 LIMITATIONS AND CHALLENGES OF THE STUDY

The findings of the study, as well as the generalisation of the findings, were negatively affected by the limitations of the study. I used non-parametric statistics because of the small sample size, which might have influenced the findings. In addition, I cannot generalise the findings because of the small sample size, as the respondents may not have been representative of the Grade 6 population, and also not of all learners with dyscalculia. Furthermore, as the respondents came from only two schools the findings cannot be regarded as representative of all the schools in South Africa. As the respondents came from two schools, two different teachers taught the learners during school hours, which may have had an effect on the results.

Next, as I used a broad definition of dyscalculia, I selected respondents according to school marks, instead of testing each of them for dyscalculia before including them in the study. I did not investigate the respondents' education and development in earlier years, neither their differences in background nor other learning problems, such as a difficulty to read, which could also have affected the respondents' performances in the tests. In an attempt to address this challenge, I read the tests to the respondents as well as all information and questions on their computer screens when the applications did not have audio.

Another challenge I experienced relates to the fact that I administered all the tests and the intervention sessions in the afternoon after regular school hours. This might have caused some of the respondents to be tired. In addition, they still had to fit in their normal school activities, homework and school tests, which could have added pressure on the respondents. A limitation that I did not foresee was that most of the respondents were not used to working on computers, and as a result had to overcome their fear of technology. As many of them did not know keyboards, they worked very slowly with the *Dyscalculia Screener*, particularly at the beginning of the intervention program. However, as they got used to the use of the laptops, their anxiety levels dropped and their working speed increased, resulting in their enjoying the use of ICT. In addition to this potentially affecting the results of the *Dyscalculia Screener*, many of the respondents were observed to be guessing several of the answers for the screener test, both before and after the intervention, causing the results of the *Dyscalculia Screener* probably not to be reliable.

In reflecting on the pre-test and post-test, the ratio of topics covered by the questions asked could have been better. This would, however, have resulted in longer tests or fewer topics being covered, which were the reason I chose to set the tests as they were set. The intervention program could similarly have covered fewer topics, thus playing more games for longer times on a specific topic to intervene more thoroughly per topic. The intervention program could also have been adapted by keeping the complexity of mathematics in mind for future use. It is furthermore important to strengthen the lower order number sense and mathematical skills before playing games on mathematical skills on higher levels. Due to respondents not spending enough time on each game to strengthen their basic skills, the intervention might not have had the effect it potentially could have had. As such, more time should be spent on games when practising basic number sense skills before proceeding to games honing higher level skills such as rounding, multiplication, factors and multiples, to name a few. Finally, questions on adding with carrying and subtraction with borrowing were included in the pre- and post-test, yet the respondents did not have time to play games involving these skills. The degree of improvement of number sense skills and mathematical skills was as a result lower than anticipated with no improvement in some of the skills that were tested.

5.5 IMPLICATIONS AND RECOMMENDATIONS

It is important that teachers in primary schools be trained to identify learners with probable dyscalculia as early as possible to provide timely support to these learners. Teachers can be trained in terms of the difficulties caused by dyscalculia so that they may be able to use their knowledge of dyscalculic tendencies to provide intervention and support strategies for the learners. They can, for example, use their knowledge of the causes of dyscalculia to adapt their lessons by incorporating games and learning strategies to support learners with mathematical difficulties in the classroom.

Teachers can furthermore use ICT successfully for interventions offered in the classroom, as they can allow learners to use relevant applications on their own levels of development, supporting underachieving learners as well as gifted learners. In this way, each learner can work on his or her own level and at his or her own pace, and learners can use different applications, suitable to each learner's developmental stages. Tablets may be more useful than laptops, as they are smaller, weigh less, and have longer battery hours. If possible, the BYOD principle, according to which learners bring their own devices such as smart mobile phones, phablets or tablets to school to use during interventions or for enriching work should apply. An advantage of BYOD is that learners can continue with the program or games at home. This is, however, not always possible, as not all learners own mobile devices.

Finally, teachers can make use of free or inexpensive mathematics applications that are available for computers, tablets and smartphones, so that learners can focus on specific problem areas in mathematics while playing games. This may lower their anxiety levels regarding mathematics, increase their self-esteem and create a more positive attitude towards mathematics.

5.6 FUTURE RESEARCH

I conducted this study in two full-service schools in one district, with a small sample size of only Grade 6 learners. Future research can be conducted in more schools, mainstream, full service and LSEN schools, with bigger sample sizes. Research can also be conducted to investigate any possible differences between male and female learners, and respondents from urban and rural schools. In addition, the effect of ICT interventions (such as an adapted version of the one implemented in this study) as a support strategy for learners with developmental dyscalculia, from different grades and school levels, can be investigated in future research. The current study can be repeated with a larger sample size from more schools, revised pre- and post-tests, adapted intervention strategies and an intervention over a longer period of time. Longitudinal studies to this effect may reflect on the success of ICT intervention as a support strategy for learners with developmental dyscalculia.

Although the South African Numeracy Chair (SANC) is doing much work in the field, it focuses primarily on young children. Learners who are past the foundational phase may slip through the gaps, resulting in learners with developmental dyscalculia and other mathematical barriers. It is important to find strategies to identify these learners and support them, enabling them to complete their school career with Mathematics or Mathematical Literacy as passed subjects and to be well prepared for their future life in a digital world, often involving mathematical skills.

5.7 CONTRIBUTION OF THE STUDY

Existing studies in this field are mostly international in origin. Studies on dyscalculia and mathematical learning disabilities in South Africa are focused on younger learners, mostly in the Foundation Phase. This study contributes to existing literature in the field of intervention strategies for learners with dyscalculia and mathematical learning difficulties in higher grades and school levels, by using ICT specifically.

The study contributes by providing new insight into the intervention of dyscalculia for mathematical difficulties. It points to the importance of strengthening the building blocks of mathematics and proves that it is possible even when the learners with dyscalculia are already in higher grades and school levels. The findings of the study show that this intervention can be done through playing mathematical games using ICT.

The practical contribution of the study is that parents and teachers can work as a team by providing enough opportunities to learners who experience mathematical difficulties to use ICT, through lessons and by playing games to support them in strengthening their basic concepts of mathematics.

In terms of contributing to the field of Learning Support, Guidance and Counselling, the findings of the study provide insight into the support of learners with dyscalculia. It shows that not only one-on-one intervention can be successful for these learners, but that learning support can be given in groups and can be expanded to the home by using ICT. The practical implication thereof is that the teachers and therapists can provide a successful and fun experience for intervention to this learners, by carefully choosing proper ICT strategies, lessening mathematics anxiety and motivating learners to spend more time on playing mathematical games, strengthening their building blocks of mathematics.

5.8 CONCLUDING REMARKS

Mathematics is a complex subject in which the basic concepts and skills must be firmly established before the next level of skills can be acquired (Butterworth, 1999; Butterworth et al., 2018; Dehaene, 2011). The results of this study show that some aspects of mathematics can improve when implementing an ICT intervention where learners play mathematical games on laptops for 30 minutes at a time, twice a week for six weeks. However, all aspects related to mathematics performance may not improve. More specifically, the number sense of the respondents in this study improved more than the mathematical skills. This findings can be related to existing literature that states that mathematical skills build on one another, implying that number sense must be firmly established before acquiring skills such as adding, subtracting and multiplying, as captured in my conceptual framework (Consult

Chapter 2). This finding implies that ICT-driven activities may be valuable when facilitating the understanding of number sense by learners (potentially young learners) and that further use of ICT interventions may be explored for additional support in other areas of mathematics.

According to Butterworth et al. (2011) as well as Wedderburn (2016), intervention strategies and games are most valuable when implemented daily by specially trained teachers, with single learners or a small group of learners for optimal results. As this is time consuming and expensive, the use of laptops, tablets and mobile phones may pose some problems in especially poor communities, yet it will allow more learners to be part of mathematical intervention programs and the possibility to improve their performance. Moreover, the use of ICT primarily entails interaction between the learner and an ICT device, which makes this option available to learners at any time, even when at home, as frequently as possible. Although a device and applications can never take the place of a teacher or therapist, it is a convenient and enjoyable way of supporting learners with dyscalculia.

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APPENDIX A – APPROVAL OF RESEARCH ETHICS APPLICATION

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Education

Ethics Committee

25 June 2017

Ms L Cronje

Dear Ms Cronje

REFERENCE: EP 17/04/02

This letter serves to confirm that your application was carefully considered by the Faculty of Education Ethics Committee. The final decision of the Ethics Committee is that your application has been approved and you may now start with your data collection. The decision covers the entire research process and not only the days that data will be collected. The approval is valid for two years for a Masters and three for Doctorate.

The approval by the Ethics Committee is subject to the following conditions being met:

1. The research will be conducted as stipulated on the application form submitted to the Ethics Committee with the supporting documents.
2. Proof of how you adhered to the Department of Basic Education (DBE) policy for research must be submitted.
3. In the event that the research protocol changed for whatever reason the Ethics Committee must be notified thereof by submitting an amendment to the application (Section E), together with all the supporting documentation that will be used for data collection namely; questionnaires, interview schedules and observation schedules, for further approval before data can be collected. Non-compliance implies that the Committee's approval is null and void. The changes may include the following but are not limited to:
   - Change of investigator,
   - Research methods any other aspect therefore and,
   - Participants
   - Sites

The Ethics Committee of the Faculty of Education does not accept any liability for research misconduct, of whatsoever nature, committed by the researcher(s) in the implementation of the approved protocol.

Upon completion of your research you will need to submit the following documentations to the Ethics Committee for your Clearance Certificate:

- Integrated Declaration Form (Form D08),
- Initial Ethics Approval letter and,
- Approval of Title.

Please quote the reference number **EP 17/04/02** in any communication with the Ethics Committee.

Best wishes

Prof Liesel Ebersöhn
Chair: Ethics Committee
Faculty of Education

Room 3-3, Level 3, Building 10
University of Pretoria, Private Bag X20
Hatfield 0028, South Africa
Tel +27 (0)12 420 1234
Fax +27 (0)12 420 5656
Email marisa.leask@up.ac.za
www.up.ac.za

Faculty of Education
Fakulteit Opvoedkunde
Lefapha la Thuto

APPENDIX B – NWED APPROVAL OF RESEARCH

Faculty of Education
Fakulteit Opvoedkunde
Lefapha la Thuto

23 June 2017

To: Whom it may concern

North West Education Department

REQUEST TO CONDUCT RESEARCH AT FULL SERVICE PRIMARY SCHOOLS IN THE BOJANALA DISTRICT IN NORTH WEST

I am currently busy studying for a Masters in Education degree in the Department of Educational Psychology at the University of Pretoria on the following topic: "**Utilising Information and Communication Technology to support Grade 6 learners with dyscalculia.**". I hereby request permission to conduct my study at full service primary schools in the Bojanala District in North West. The study will involve Grade 6 learners as participants.

The purpose of the proposed study is thus to investigate how and to what extent Grade 6 learners who have dyscalculia may be supported for number sense and mathematical skills development by means of ICT (Information Communication Technology).I shall involve Grade 6 learners with difficulty in Mathematics.

The learners will be required to complete the Dyscalculia Screener, which is a standardised computer programme to screen for tendencies towards dyscalculia. The learners showing tendencies towards dyscalculia will then be divided into two groups, the experimental group and the control group, where after both groups will complete a pre-test. Intervention using computer applications for number sense and basic mathematical skills will be done with the control group. The intervention will last 30 minutes twice a week for 6 weeks and will take place after school hours, on the school premises.

After the six week intervention period both groups will complete a post-test. After the post-test the intervention will be repeated with the control group in order to ensure that they benefit equally from the study.

The data collected will be treated confidentially and will only be used for academic purposes. The schools will stay anonymous and the anonymity of the learners and their parents will be assured as I shall provide no identifying information when reporting on the study. Data will be stored in a secure place at the University of Pretoria for fifteen years, in accordance with the requirements for conducting ethical research. Participants will have the right to withdraw at any stage, should they wish to do so, and they will not be exposed to any form of harm. No participant will be deceived in any way, and the purpose and process of the study will be explained to the Grade 6 learners and their parents when obtaining informed consent.

The findings received from this research can provide valuable information to report to the North West Department of Education and relevant stakeholders following completion of the study. The learners may also improve their mathematical performance which will benefit the schools as well the learners. If you have any questions, please do not hesitate to contact either my supervisor or myself.

Thank you for your consideration of this request. I look forward to receiving your response.

Mrs Lindi Cronjé (Researcher)
084 463 8095
lindi.cronje4@gmail.com

Prof Ronel Ferreira (Supervisor)
Ronel.Ferreira@up.ac.za

Education and Sport Development
Department of Education and Sport Development
Departement van Onderwys en Sport Ontwikkeling
Lefapha la Thuto le Tlhabololo ya Metshameko
NORTH WEST PROVINCE

cnr Kock and Heystek Street,
Rustenburg 0299
Private Bag X82110
Rustenburg 0300
Tel.: (014) 590-4800
Fax.: (014) 592-3247
e-mail: pmokhutle@nwpg.gov.za

OFFICE OF THE DIRECTOR: BOJANALA DISTRICT

Eng. Dr. ET Matshidiso

To : Mrs. Lindi Cronje – Student
University of Pretoria

From : Mrs. K. Mosala
Acting District Director – Bojanala District

Date : 26 July 2017

Subject: Permission to conduct Research in Full Service Schools

Reference is made to your letter dated the 23 June 2017 regarding the above matter. The content is noted and accordingly, approval is granted to your kind self to conduct research as per your request, subject to the following provisions:-

- That you notify Sub-District and Circuit Managers about your request and this subsequent letter of approval;
- That the onus to notify principals of your target schools about your intended visit and the purpose thereof rests with your good self;
- That participation in your research project will be voluntary;
- That as far as possible the general academic programme of the schools should not be interfered with;
- That the principle of confidentiality will be observed in the strictest terms in relation to information sourced from such schools; and
- That upon completion of your research, a report is avail to my Office detailing the major findings and recommendations of your research.

With my best wishes

Thanking you

K. Mosala

K. Mosala – Acting District Director

cc All Sub-District Managers

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Faculty of Education
Fakulteit Opvoedkunde
Lefapha la Thuto

_____________ 2017

To: ___________________________
Madibeng Subdistrict
North West Education Department

INFORMING OF RESEARCH AT FULL SERVICE PRIMARY SCHOOLS IN THE BOJANALA DISTRICT IN NORTH WEST

I am currently busy studying for a Masters in Education degree in the Department of Educational Psychology at the University of Pretoria on the following topic: "**Utilising Information and Communication Technology to support Grade 6 learners with dyscalculia.**". I hereby attached my permission from the North West Education Department to conduct my study at full service primary schools in the Bojanala District in North West. The study will involve Grade 6 learners as participants.

The purpose of the proposed study is to investigate how and to what extent Grade 6 learners who have dyscalculia may be supported for number sense and mathematical skills development by means of ICT (Information Communication Technology). I shall involve Grade 6 learners with difficulty in Mathematics.

The learners will be required to complete the Dyscalculia Screener, which is a standardised computer programme to screen for tendencies towards dyscalculia. The learners showing tendencies towards dyscalculia will then be divided into two groups, the experimental group and the control group, where after both groups will complete a pre-test. Intervention using computer applications for number sense and basic mathematical skills will be done with the control group. The intervention will last 30 minutes twice a week for 6 weeks and will take place after school hours, on the school premises.

After the six week intervention period both groups will complete a post-test. After the post-test the intervention will be repeated with the control group in order to ensure that they benefit equally from the study.

The data collected will be treated confidentially and will only be used for academic purposes. The schools will stay anonymous and the anonymity of the learners and their parents will be assured as I shall provide no identifying information when reporting on the study. Data will be stored in a secure place at the University of Pretoria for fifteen years, in accordance with the requirements for conducting ethical research. Participants will have the right to withdraw at any stage, should they wish to do so, and they will not be exposed to any form of harm. No participant will be deceived in any way, and the purpose and process of the study will be explained to the Grade 6 learners and their parents when obtaining informed consent.

The findings received from this research can provide valuable information to report to the North West Department of Education and relevant stakeholders following completion of the study. The learners may also improve their mathematical performance which will benefit the schools as well the learners. If you have any questions, please do not hesitate to contact either my supervisor or myself.

Thank you for your support.

Mrs Lindi Cronjé (Researcher)
084 463 8095
lindi.cronje4@gmail.com

Prof Ronel Ferreira (Supervisor)
Ronel.Ferreira@up.ac.za

APPENDIX C – INFORMED CONSENT FORM FOR SCHOOL PRINCIPALS

UNIVERSITEIT VAN PRETORIA
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YUNIBESITHI YA PRETORIA

Faculty of Education
Fakulteit Opvoedkunde
Lefapha la Thuto

____________ 2017

The School Principal
_________________Primary School
____
____

Dear Mr/Mrs_______________________

REQUEST TO CONDUCT RESEARCH AT YOUR SCHOOL

I am currently busy studying for a Masters in Education degree in the Department of Educational Psychology at the University of Pretoria on the following topic: "**Utilising Information and Communication Technology to support Grade 6 learners with dyscalculia.**". I hereby request permission to conduct my study at your school. The study will involve Grade 6 learners from your school as participants.

The purpose of the proposed study is to investigate how and to what extent Grade 6 learners who have dyscalculia may be supported for number sense and mathematical skills development by means of ICT (Information Communication Technology). I shall involve Grade 6 learners with difficulty in Mathematics.

The learners will be required to complete the Dyscalculia Screener, which is a standardised computer programme to screen for tendencies towards dyscalculia. The learners showing tendencies towards dyscalculia will then be divided into two groups, the experimental group and the control group, where after both groups will complete a pre-test. Intervention using computer applications for number sense and basic mathematical skills will be done with the experimental group. The intervention will last 30 minutes twice a week for 6 weeks and will take place after school hours, on the school premises.

After the six week intervention period both groups will complete a post-test. After the post-test the intervention will be repeated with the control group in order to ensure that they benefit equally from the study.

The data collected will be treated confidentially and will only be used for academic purposes. The school will stay anonymous and the anonymity of the learners and their parents will be assured as I shall provide no identifying information when reporting on the study. Data will be stored in a secure place at the University of Pretoria for fifteen years, in accordance with the requirements for conducting ethical research. Participants will have the right to withdraw at any stage, should they wish to do so, and they will not be exposed to any form of harm. No participant will be deceived in any way, and the purpose and process of the study will be explained to the Grade 6 learners and their parents when obtaining informed consent.

The findings received from this research can provide valuable information to report to the North West Department of Education and relevant stakeholders following completion of the study. The learners may also improve their mathematical performance which will benefit the school as well the learners. If you have any questions, please do not hesitate to contact either my supervisor or myself.

Thank you for your consideration of this request. I look forward to receiving your response.

Mrs Lindi Cronjé (Researcher)
084 463 8095
lindi.cronje4@gmail.com

Prof Ronel Ferreira (Supervisor)
Ronel.Ferreira@up.ac.za

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Lefapha la Thuto

INFORMED CONSENT FORM FOR PARTICIPATION IN A RESEARCH PROJECT

I, the undersigned, hereby give consent to Mrs L Cronjé to conduct her research project for her Master's studies, as described in her accompanying letter, in this school, subject to the conditions laid out in her letter. These include the conditions that the school, parents and learners stay anonymous and that pseudonyms will be used when referring to the learners from the school.

Name of principal: ______________________________

Signature of principle: ___________________________

Date: _______________

APPENDIX D – INFORMED CONSENT FORM FOR PARENTS

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Education
Fakulteit Opvoedkunde
Lefapha la Thuto

REQUEST FOR PARTICIPATION AND INFORMED CONSENT PARENTS/CAREGIVERS

Dear Sir/Madam

I am currently busy studying for a Masters in Education degree in the Department of Educational Psychology at the University of Pretoria on the following topic: "**Utilising Information and Communication Technology to support Grade 6 learners with dyscalculia.**". In order for me to establish the effect on mathematical performance of intervention using computer applications I require the input from Grade 6 learners.

The purpose of the proposed study is to investigate how and to what extent Grade 6 learners who have dyscalculia may be supported for number sense and mathematical skills development by means of ICT (Information Communication Technology). I shall involve Grade 6 learners with difficulty in Mathematics.

The learners will be required to complete the Dyscalculia Screener, which is a standardised computer programme to screen for tendencies towards dyscalculia. The learners showing tendencies towards dyscalculia will then be divided into two groups, the experimental group and the control group, where after both groups will complete a pre-test. Intervention using computer applications. for number sense and basic mathematical skills will be done with the control group. The intervention will last 30 minutes twice a week for 6 weeks and will take place after school hours, on the school premises.

After the six week intervention period both groups will complete a post-test. After the post-test the intervention will be repeated with the control group in order to ensure that they benefit equally from the study.

With this letter I request your permission to involve your child in the research project. The data collected will be treated confidentially and will only be used for academic purposes. The school will stay anonymous and the anonymity of the learners and their parents will be assured as I shall provide no identifying information when reporting on the study. Data will be stored in a secure place at the University of Pretoria for fifteen years, in accordance with the requirements for conducting ethical research. Participants will have the right to withdraw at any stage, should they wish to do so, and they will not be exposed to any form of harm. No participant will be deceived in any way, and the purpose and process of the study will be explained to the Grade 6 learners and their parents when obtaining informed assent from them.

The findings received from this research can provide valuable information to report to the North West Department of Education and relevant stakeholders following completion of the study. The learners may also improve their mathematical performance which will benefit them. If you have any questions, please do not hesitate to contact either my supervisor or myself.

If you give permission that your child may participate in this research study, please complete the attached consent form. Thank you for your consideration of this request. I look forward to receiving your response.

Mrs Lindi Cronjé (Researcher)
084 463 8095
lindi.cronje4@gmail.com

Prof Ronel Ferreira (Supervisor)
Ronel.Ferreira@up.ac.za

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INFORMED CONSENT FORM

PARENTS/CAREGIVERS

Dear Lindi

Please see my decisions below.

	YES	**NO**
My child may participate in the project		

Child's name and surname ______________________________

Grade 6 class: ____________________ Home language: ______________________

Parent/caregiver's name and surname:

____

Parent/caregiver's signature: ____________________________

Date: ___________________________

Researcher's signature: ________________________________

APPENDIX E – ASSENT FORM FOR LEARNERS

UNIVERSITEIT VAN PRETORIA
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Fakulteit Opvoedkunde
Lefapha la Thuto

RESEARCH ASSENT FORM

Good afternoon everyone, we hope you are well!

We would like you to help us with some research we are going to do here at your school. You and your friends play a very important role in our researh. Without you, we cannot do the research.

What is research?

Research help us learn new things. We can test new ideas and try new ways of doing things

Why are we doing this research?

We are doing this research to learn if playing mathematical games on the computer will help you better your performance in mathematics.

What would happen if I join this research?

If you decide to be in the research, we would ask you to do the following:

- ☺ Answer questions about numbers on the computer.
- ☺ Write a mathematics test.
- ☺ Play with the mathematics applications on the computer twice a week after school for 6 weeks.
- ☺ Write again a mathematics test.

Could bad things happen if I join the research?

We will try our best to make sure that no bad things happen to you.

Could the research help me?

We think the research may help you to improve your mathematics performance.

Important things you need to remember!

- ☺ You can decide if you want to take part in the activities. You can say 'yes' or 'no'
- ☺ No one will be upset or angry if you say no. You can say 'no' at any time.
- ☺ We would still take good care of you no matter what you decide

What must I do now?

If you want to be part of the research we talked about, please write your name below. This is just to show that we talked about the research and that you want to take part in the activities.

Name of participant:

____

Printed name of researcher:

____

Signature of researcher:

____

Witness

____

Date: ____________________

_______________________ _______________________

Mrs Lindi Cronjé (Researcher)
084 463 8095
lindi.cronje4@gmail.com

Prof Ronel Ferreira (Supervisor)
Ronel.Ferreira@up.ac.za

Faculty of Education
Fakulteit Opvoedkunde
Lefapha la Thuto

NAVORSINGSTOESTEMMINGVORM

Goeie middag almal. Ons hoop dit gaan goed met julle almal en dat julle almal gesond is!

Ons wil graag hê dat julle ons moet help met navorsing wat ons hier by julle skool gaan doen. Jy en jou vriende speel 'n baie belangrike rol in ons navorsing. Ons kan nie die navorsing sonder jou doen nie.

Wat is navorsing?

Navorsing help ons om nuwe dinge te leer. Ons kan nuwe idees toets en nuwe maniere probeer om dinge te doen.

Hoekom doen ons hierdie navorsing?

Ons doen hierdie navorsing om uit te vind of dit jou sal help om jou prestasie in Wiskunde te verbeter as jy wiskundige speletjies op die rekenaar speel.

Wat sal gebeur as jy by hierdie navorsingsgroep aansluit?

As jy besluit om deel te wees van hierdie navorsing, gaan ons jou vra om die volgende te doen:

- ☺ Antwoord vragies oor getalle op die rekenaar.
- ☺ Skryf 'n Wiskunde toets.
- ☺ Speel twee keer 'n week in die middae na skool met wiskundige toepassings op die rekenaar. Ons gaan dit vir 6 weke doen.
- ☺ Skryf weer 'n Wiskunde toets.

Kan slegte dinge met my gebeur as ek deel word van hierdie navorsing?

Ons sal ons bes doen om te verseker dat geen slegte dinge met jou gebeur nie.

Kan die navorsing my help?

Ons dink die navorsing kan jou help om jou prestasie in Wiskunde te verbeter.

Belangrike dinge wat jy moet onthou!

- ☺ Jy kan besluit of jy aan hierdie aktiwiteite wil deelneem. Jy kan "ja" of "nee" sê.
- ☺ Niemand gaan ontsteld of kwaad wees as jy "nee" sê nie. Jy kan enige tyd "nee" sê.
- ☺ Dit maak nie saak wat jy besluit nie, ons gaan steeds goed na jou kyk.

Wat moet ek nou doen?

As jy wil deel wees van die navorsing waaroor ons gepraat het, moet jy asseblief jou naam onderaan die vorm skryf. Dit is net om te wys dat ons oor die navorsing gepraat het en dat jy aan die aktiwiteite wil deeneem.

Naam van deelnemer:

____

Naam van navorser in drukskrif:

____

Handtekening van navorser:

____

Getuie:

____

Datum: ____________________

____

Mev Lindi Cronjé (Navorser)
084 463 8095
lindi.cronje4@gmail.com

____

Prof Ronel Ferreira (Toesighouer)
Ronel.Ferreira@up.ac.za

APPENDIX F – PRE-TEST

Pre-toets Graad 6

Naam: ______________________________ **Kode:** ____________

1. Gee die plekwaarde van die onderstreepte syfer in die volgende getalle:

a) 2 3<u>4</u>6 701 ____________________

b) 821 <u>9</u>04 ____________________

c) 3 <u>2</u>07 918 ____________________ (3)

2. Rangskik die volgende getalle van die kleinste tot die grootste:

34 589 35 987 34 876 35 876 35 789

____ (1)

3. Rangskik die volgende getalle van die grootste tot die kleinste:

964 237 99 987 974 235 999 234 964 972

____ (1)

4. Rangskik die volgende volumes van die minste tot die meeste:

4ℓ 40 mℓ 400mℓ

____ (1)

5. Gee die waarde van die onderstreepte getalle:

a) 1 4<u>3</u>7 872 ____________________

b) 54<u>9</u> 264 ____________________

c) 925 86<u>4</u> ____________________ (3)

6. Voltooi die volgende getalpatrone:

a) 312 ; 318 ; 324 ; 330 ; ______ ; ______ ; ______ (3)

b) 30,4 ; 30,3..; 30,2 ; ______ ; ______ ; ______ (3)

c) 4 065 ; 4 075 ; 4 085 ; ______ ; ______ ; ______ (3)

d) 1 004 ; 1 002 ; 1 000 ; ______ ; ______ ; ______ (3)

7. Skryf die volgende getalle in woorde:

a) 467 715 ____

____

b) 300 004 ____ (2)

8. Skryf die volgende woorde as getalle:

a) driehonderd ses en negentig duisend vierhonderd en agttien:

________________________________ (1)

b) sestig duisend negehonderd en twaalf:

________________________________ (1)

9. Vergelyk die pare getalle hieronder en vul < of > in:

a) 467 990 ☐ 709 008

b) 823 617 ☐ 822 399

10 Skryf die getalle neer wat deur die volgende uitgebreide vorms voorgestel word:

a) 60 +3 000 + 500 000 + 400 = ________________________________ (1)

b) 500 + 6 000 + 30 + 400 000 + 1 + 20 000 =________________________(1)

11 Rond die volgende getalle af soos gevra:

a) 215 547 afgerond tot die naaste 1 000 ______________________________ (1)

b) 1 423 367 afgerond tot die naaste 10 ______________________________ (1)

c) R 43 874,47 afgerond tot die naaste rand ____________________________ (1)

12 Skryf die veelvoude van 40 tussen 0 en 100 neer:

____ (1)

13 Skryf die faktore van 18 neer:

____ (1)

14 As 38 + 16 = 54, dan is 54 - 16 = ____________________________ (1)

15 Bereken die antwoorde vir die volgende vrae:

a) 7 000 + 456 + 98 734 =

(2)

b) 843 509 + 327 096 =

(2)

c) 78 954 - 4 563 =

(2)

d) 96 974 - 7 381 =

(2)

e) 547 x 43

(2)

f) 932 x 65

(2)

TOTAAL: 50 punte

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Pre-test Grade 6

Name: ______________________________ **Code:** ____________

1. Write down the place value of the underlined digit in the following numbers:

a) 2 3<u>4</u>6 701 ____________________

b) 821 <u>9</u>04 ____________________

c) 3 <u>2</u>07 918 ____________________ (3)

2. Write down the following numbers from the smallest to the biggest

34 589 35 987 34 876 35 876 35 789

____ (1)

3. Write down the following numbers from the biggest to the smallest

964 237 99 987 974 235 999 234 964 972

____ (1)

4. Write down the following volumes from the least to the most

4ℓ 40 mℓ 400mℓ

____ (1)

5. Write down the value of the underlined digits

a) 1 4<u>3</u>7 872 ____________________

b) 54<u>9</u> 264 ____________________

c) 925 86<u>4</u> ____________________ (3)

6. Complete the following number sequences

a) 312 ; 318 ; 324 ; 330 ; ______ ; ______ ; ______ (3)

b) 30,4 ; 30,3..; 30,2 ; ______ ; ______ ; ______ (3)

c) 4 065 ; 4 075 ; 4 085 ; ______ ; ______ ; ______ (3)

d) 1 004 ; 1 002 ; 1 000 ; ______ ; ______ ; ______ (3)

7. Write the following numbers in words

a) 467 715 ____

____

b) 300 004 ____ (2)

8. Write the following words as numbers

a) three hundred and ninety six thousand four hundred and eighteen

________________________________ (1)

b) sixty thousand nine hundred and twelve

________________________________ (1)

9. Compare the following numbers and fill in < or >

a) 467 990 ☐ 709 008

b) 823 617 ☐ 822 399

10 Write the following numbers in their simplest forms

a) 60 +3 000 + 500 000 + 400 = ______________________________ (1)

b) 500 + 6 000 + 30 + 400 000 + 1 + 20 000 =______________________(1)

11 Round the following numbers as asked:

a) round 215 547 off to the nearest 1 000 ______________________________ (1)

b) round 1 423 367 off to the nearest 10 ______________________________ (1)

c) round R 43 874,47 off to the nearest rand ____________________________ (1)

12 Write down the multiples of 40 between 0 and 100:

____ (1)

13 Write down the factors of 18:

____ (1)

14 If 38 + 16 = 54, then 54 - 16 = ______________________________ (1)

15 Calculate the following

a) 7 000 + 456 + 98 734 =

(2)

b) 843 509 + 327 096 =

(2)

c) 78 954 - 4 563 =

(96

d) 96 974 - 7 381 =

e) 547 x 43

(2)

g) 932 x 65

(2)

TOTAL: 50 marks

APPENDIX G – POST-TEST

Post-toets Graad 6

Naam: ______________________________ **Kode:** ______________

1. Gee die waarde van die onderstreepte getalle:

a) $2\ 873\ 65\underline{9}$ ______________________

b) $1\ 6\underline{8}2\ 104$ ______________________

c) $45\underline{7}\ 254$ ______________________ (3)

2. Rangskik die volgende volumes van die minste tot die meeste:

350 mℓ   5 ℓ   50 mℓ

____ (1)

3. Rangskik die volgende getalle van die grootste tot die kleinste:

854 398   863 124   88 876   854 978   888 213

____ (1)

4. Rangskik die volgende getalle van die kleinste tot die grootste:

46 987   45 786   46 578   45 687   46 786

____ (1)

5. Gee die plekwaarde van die onderstreepte syfer in die volgende getalle:

a) $684\ \underline{5}07$ ______________________

b) $4\ \underline{3}08\ 827$ ______________________

c) $2\ 4\underline{5}7\ 902$ ______________________ (3)

6. Voltooi die volgende getalpatrone:

a) 423 ; 429 ; 435 ; 441 ; ______ ; ______ ; _______ (3)

b) 1 006 ; 1 003 ; 1 000 ; ______ ; ______ ; _______ (3)

c) 5 063 ; 5 073 ; 5 083 ; _______ ; _______ ; _______ (3)

d) 40,3 ; 40,2 ; 40,1 ; _________ ; _________ ; _________ (3)

7. Vergelyk die pare getalle hieronder en vul < of > in:

a) 572 890 ☐ 601 007

b) 745 624 ☐ 743 989

8. Skryf die volgende woorde as getalle:

a) seshonderd vier en tagtig duisend agthonderd en veertien:

____ (1)

b) veertig duisend sewehonderd en elf:

____ (1)

9. Skryf die volgende getalle in woorde:

a) 598 817 ____

____

b) 600 005 ____

____(2)

10 Skryf die getalle neer wat deur die volgende uitgebreide vorms voorgestel word:

a) 40 + 2 000 + 600 + 300 000 = ________________________________ (1)

b) 30 000 + 700 + 2 + 500 000 + 8 000 + 40 = ________________________(1)

11 Rond die volgende getalle af soos gevra:

a) 473 548 afgerond tot die naaste 1 000 ______________________________ (1)

b) 2 652 786 afgerond tot die naaste 10 ______________________________ (1)

c) R 25 863,48 afgerond tot die naaste rand ____________________________ (1)

12 As 46 + 32 = 78, dan is 78 - 23 = _____________________________ (1)

13 Skryf die faktore van 24 neer:

____ (1)

14 Skryf die veelvoude van 30 tussen 0 en 100 neer:

____ (1)

15 Bereken die antwoorde vir die volgende vrae:

a) 657 + 8 000 + 67 584 =

(2)

b) 769 904 + 520 097 =

(2)

c) 69 845 − 7 672 =

(2)

d) 75 865 − 8 672 =

(2)

e) 427 x 53 =

(2)

f) 296 x 57 =

(2)

TOTAAL: 50 punte

Post-test Grade 6

Name: ______________________________ Code: ____________

1. Write down the value of the underlined digits

a) 2 873 65<u>9</u> ____________________

b) 1 6<u>8</u>2 104 ____________________

c) 45<u>7</u> 254 ____________________ (3)

2. Write down the following volumes from the least to the most

350 mℓ 5 ℓ 50 mℓ

____ (2)

3. Write down the following numbers from the biggest to the smallest

854 398 863 124 88 876 854 978 888 213

____

____ (2)

4. Write down the following numbers from the smallest to the biggest

46 987 45 786 46 578 45 687 46 786

____

____ (2)

5. Write down the place value of the underlined digit in the following numbers:

g) 684 <u>5</u>07 ____________________

h) 4 <u>3</u>08 827 ____________________

i) 2 4<u>5</u>7 902 ____________________ (3)

6. Complete the following number sequences

a) 423 ; 429 ; 435 ; 441 ; ________ ; ______ ; _______ (3)

b) 1 006 ; 1 003..; 1 000 ; ________ ; ______ ; _______ (3)

c) 5 063 ; 5 073 ; 5 083 ; _______ ; _______ ; _______ (3)

d) 40,3 ; 40,2 ; 40,1 ; _________ ; _________ ; _________ (3)

7. Compare the following numbers and fill in < or >

a) 572 890 ☐ 601 007 (1)

b) 745 624 ☐ 743 989 (1)

8. Write the following words as numbers

a) six hundred eighty four thousand eight hundred and fourteen

_________________________________ (1)

b) forty thousand seven hundred and eleven

_________________________________ (1)

9. Write the following numbers in words

a) 598 817 ____

____ (1)

b) 600 005 ____

____ (1)

10 Write the following numbers in their simplest forms

a) 40 + 2 000 + 600 + 300 000 = ________________________________ (1)

b) 30 000 + 700 + 2 + 500 000 + 8 000 + 40 = ________________________ (1)

11 Round the following numbers as asked:

a) round 473 548 off to the nearest 1 000 ______________________ (1)

b) round 2 652 786 off to the nearest 10 ______________________ (1)

c) round R 25 863,48 off to the nearest rand ______________________ (1)

12 If 46 + 32 = 78, then 78 - 32 = ______________________ (1)

13 Write down the factors of 24:

____ (1)

14 Write down the multiples of 30 between 0 and 100:

____ (1)

15 Calculate the following

a) 657 + 8 000 + 67 584 =

(2)

b) 769 904 + 520 097 =

(2)

c) 69 845 – 7 672 =

(2)

j) 75 865 – 8 672 =

(2)

k) 427 x 53

(2)

l) 296 x 57

(2)

TOTAL: 50 marks

APPENDIX H – ITEM ANALYSIS OF PRE-TEST

Pre-test question	Place value and value	Bigger or smaller	Conservation of number	Sequencing	Number concept	Rounding	Multiples and factors	Addition	Addition with carrying	Subtraction with borrowing	Multiplication	Multiplication with bigger numbers	The Number Race	Pop the balloon count and order	Pop the the balloon greater than smaller than	Pop the the balloon add and order	Pop the balloon order numbers	Pop the balloon skip counting and sequencing	Math man Place value	Math man rounding	Mathman Addition	Mathman multiplication	Math lines addition	Math lines multiplication	The Rockseries
	Concept tested												Game or program utilised for strengthening concept												
1a	X		X		X														X						
1b	X		X		X														X						
1c	X		X		X														X						
2		X	X		X								X		X		X								
3		X	X		X								X		X		X								
4		X	X		X								X	X	X		X								
5a	X		X		X														X						
5b	X		X		X														X						
5c	X		X		X														X						

Pre-test question	Place value and value	Bigger or smaller	Conservation of number	Sequencing	Number concept	Rounding	Multiples and factors	Addition	Addition with carrying	Subtraction with borrowing	Multiplication	Multiplication with bigger numbers	The Number Race	Pop the balloon count and order	Pop the the balloon greater than smaller than	Pop the the balloon add and order	Pop the balloon order numbers	Pop the balloon skip counting and sequencing	Math man Place value	Math man rounding	Mathman Addition	Mathman multiplication	Math lines addition	Math lines multiplication	The Rockseries
6a			X	X	X									X				X							
6b			X	X	X									X				X							
6c			X	X	X									X				X							
6d			X	X	X									X				X							
7a			X		X																				X
7b			X		X																				X
8a			X		X																				X
8b			X		X																				X
9a		X	X		X										X										
9b		X	X		X										X										
10a	X																		X						
10b	X																		X						
11a					X	X														X					

Pre-test question	Place value and value	Bigger or smaller	Conservation of number	Sequencing	Number concept	Rounding	Multiples and factors	Addition	Addition with carrying	Subtraction with borrowing	Multiplication	Multiplication with bigger numbers	The Number Race	Pop the balloon count and order	Pop the the balloon greater than smaller than	Pop the the balloon add and order	Pop the balloon order numbers	Pop the balloon skip counting and sequencing	Math man Place value	Math man rounding	Mathman Addition	Mathman multiplication	Math lines addition	Math lines multiplication	The Rockseries
11b					X	X														X					
11c					X	X														X					
12							X															X		X	X
13							X															X		X	X
14			X		X																				X
15a								X	X												X		X		X
15b								X	X												X		X		X
15c										X															X
15d										X															X
15e											X	X										X		X	X
15f											X	X										X		X	X

APPENDIX I – PROGRESSION OF THE ICT INTERVENTION

	10 minutes	10 minutes	5 minutes	5 minutes
Week 1	The Number Race	Math lines Addition	Math Man Place value	Pop the balloon Count and order
Week 2	The Number Race	Math lines Addition	Math Man Place value	Pop the balloon Greater and smaller than
Week 3	The Number Race	Math lines Multiplication	Math Man Rounding	Pop the balloon Add and order
Week 4	The Number Race	Pop the Balloon Order numbers	Math Man Addition	
Week 5	The Number Race	Rockseries Numbers as words and Words as numbers Multiples and Factors	Math Man Addition	Pop the balloon Skip counting
Week 6	The Number Race	Rockseries Addition with carrying Subtraction with borrowing	Math Man Multiplication	Pop the balloon Sequencing