UNIVERSITY OF THE WESTERN CAPE

Faculty of Community and Health Sciences

RESEARCH PROJECT

Title: A systematic review of interventions for children presenting with dyscalculia in primary schools.

Student Name: Thato Omphemetse Monei

Student Number: 3508286

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Department: Department of Psychology

Supervisor: Dr. Athena Pedro

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Declaration

I declare that the current study ***A systematic Review of interventions for children presenting with dyscalculia in primary schools*** is my own work. It has not been submitted before any degree or examination in any university, and that all the sources I have sued have been indicated and acknowledged as complete references.

t.monei

Thato Omphemetse Monei

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Contents

Abstract

Background: The acquisition of numerical competency is imperative for individuals in society for quality of life and economic well-being. Many children have significant mathematical learning difficulties, this is known as dyscalculia. The prevalence rate for dyscalculia ranges between 3.5%–6.5% of the school-age population. Primary studies report on interventions for children presenting with dyscalculia, however it is difficult to compare these studies without a systematic approach to an evaluation for methodological rigor.

Aim: To systematically review available literature of interventions for children presenting with dyscalculia in primary schools in order to provide an evidence base of filtered information assessed for methodological rigor and coherence.

Method: The study evaluated literature from 2004 to 2014 that report on interventions for primary school children presenting with dyscalculia. Studies that were included in the review were only full-text, English articles published within the specified timeframe reporting on the focus of the study. University of Western Cape databases were accessed for literature for inclusion in the study. The studies were assessed at title, abstract and full text levels for quality based on the inclusion and exclusion criteria. Meta-synthesis of included texts was conducted incorporating it with the RE-AIM framework. Permission to conduct the proposed study was obtained from relevant Ethics Committee at the University of the Western Cape. Plagiarism was avoided by acknowledging other people's work and collaboration was taken into consideration as the review entailed working with paired reviewers.

Findings: The findings in the studies provide a base of effective interventions that can be used in the school setting in different domains and levels such as individually, holistically or through various instructions for children presenting with dyscalculia.

Keywords*: Arithmetic difficulties; children; co-morbid disorders; developmental dyscalculia; dyscalculia; interventions; math difficulties; numeracy problems; primary school; systematic review.*

List of abbreviations and acronyms

DSM–IV	Diagnostic and Statistical Manual of Mental Disorders, 4th ed.
ADHD	Attention deficit hyperactivity disorder
IPS	Intraparietal sulcus
DD	Developmental Dyscalculia
BNB	Basic Numeric Battery
RE-AIM	Reach, Effectiveness, Adoption, Implementation, and Maintenance
QAT	**The Quality Assessment Tool**
CAI	Computer-assisted instruction
CMI	Computer-mediated instruction
TMI	Teacher-mediated instruction
TEMI-PM	Texas Early Mathematics Inventory-Progress Monitoring
NC	Number combination
WMC	Working memory capacity
TOMA	Test of Mathematical Abilities
WRAT	Wide Range Achievement Test
WISC	Wechsler Intelligence Scale for children
CMAT	Comprehensive Mathematical Abilities Test

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CHAPTER 1

1. INTRODUCTION

1.1 Background

There is consensus among educators about the importance of mathematics to success in life. However, mathematical conceptualization, logic, reason and analysis are utmost requirements for everyday problems (Ramaa & Gowramaa, 2002). As Kucian and von Aster (2015) asserts that numerical skills are essential in our everyday life, impairments in the development of number processing and calculation have a negative impact on schooling, professional careers and self-esteem. As a result, dyscalculia is one of the specific learning disorders which are characterized by impairments in learning and remembering arithmetic facts and in executing calculation procedures (Butterworth, 2005). Cowan and Powell (2014) stress that mathematical learning disability is acknowledged to be the same construct as a mathematics disorder (American Psychiatric Association, 1994), developmental dyscalculia (Butterworth, 2010; Wilson & Dehaene, 2007) and specific arithmetic difficulties (Lewis et al., 1994). Consequently, all terms refer to cases where poor arithmetic performance is combined with at least average intelligence (Cowan & Powell, 2014). These terms in this study will however be used interchangeably.

Researchers generally agree that dyscalculia is partly caused by biological factors and might arise from multiple brain dysfunctions and cognitive deficits (Skagerlund & Träff, 2014). However, according to Jordan and Hanich (2000), much of the current interest in young children with mathematics difficulties can be attributed to a growing number of studies on the normal development of mathematical cognition. Other factors that could be responsible for difficulty in mathematics include deficient cognitive development, poor linguistic competence, neuropsychiatric problem, minimal brain damage, attention deficit hyperactivity disorder (ADHD), Asperger's and Tourette's syndromes, dyslexic difficulties, other reading difficulties and inappropriate teaching methods (Ramaa & Gowramaa, 2002).

According to Kaufmann and von Aster (2014) a detailed diagnostic evaluation is needed when dyscalculia is suspected in order to take proper account of the complexity of the learning disorder and to produce an accurate picture of the affected child's particular strengths and weaknesses in the area of numbers and calculations. Moreover, the Diagnostic and Statistical Manual of Mental Disorders (American Psychiatric Association, 2013) states that 5% to 15% of school-aged children may suffer from a specific learning disorder that may hamper the acquisition of numerical competency.

In a study conducted in India, Ramaa and Gowramma (2002) attempted to identify the arithmetic difficulties among grade 5 students in government primary schools from low socio-economic status families. The results indicated that all students had serious difficulty in arithmetic. However, no attempt was made in the study to identify the factors responsible for these difficulties; as a result, there could have been some percentage of children showing the specific syndrome of developmental dyscalculia among the subjects (Ramaa & Gowramma, 2002). Researchers have reported that between 70% and 80% of South African primary school children, overwhelmingly from disadvantaged schools, are completing their primary schooling acquiring only a rudimentary knowledge and understanding of mathematics and have limited proficiency in even basic arithmetic (Kay & Yeo, 2012). They further add that children from predominately black and middle-class families that attend relatively well resourced schools are said to become proficient readers and competent mathematics users by the end of their primary school years. However mathematics educationalists frequently expressed concern about the disappointing standards that the majority of pupils manage to attain in mathematics (Kay & Yeo, 2012).

1.2 Rationale

Research in the area of dyscalculia is a relatively new field in which not much literature has been reported on. However, Gillum (2014) stipulates that there has been a growing awareness on the impact that difficulties in mathematics can have on the life chances of children and young people. Historically school mathematics has been widely perceived as a difficult subject to pass (Kay & Yeo, 2012). However, difficulty in mathematics has been said to be an unexpectedly neglected area by both clinicians and researchers, despite its importance in health management, schooling, everyday life and employment (Rubinsten & Henik, 2008). Kay and Yeo (2012) specify that in order to be able to reason about number, pupils have to understand the ways in which numbers are made up of patterns and structures. They add that in order to think creatively and flexibly, pupils need to develop good basic mental mathematics skills. It is estimated that at least 15% of children in a developed country will experience difficulties at school and approximately 10% of school children have some form of specific learning disability (Springer, 2007). Nevertheless, pre-school educators prepare children for formal schooling and should attempt to identify children with potential learning difficulties with a view to early intervention (Springer, 2007). Consequently, a range of targeted interventions have been developed to support learners, however, when difficulties persist in spite of such interventions, next steps are always not clear (Gillum, 2014). From identified literature, many researchers (Xin, 1999; Kroesbergen, 2003; Gersten, 2009; Slavin, 2009; Codding, 2011, & Fischer, 2013) conducted a study examining the effectiveness of specific arithmetic interventions to improve mathematical skills. However, in the pool of literature that has been identified on the topic of interventions for children presenting with dyscalculia in primary schools, there is no body of literature reported on the methodological quality and coherence of the studies. As a result, there is a need for filtered information to systematically examine and assess primary studies for methodological rigor and coherence and provide a base of empirical evidence of interventions for children presenting with dyscalculia in primary schools.

The current chapter discussed the background of mathematical difficulty/ dyscalculia by stipulating the importance of having numerical skills to the success of life. Moreover, the chapter also indicated the same constructs that are acknowledged to be the same as dyscalculia such as mathematical learning disability, mathematics disorder, and developmental dyscalculia. The chapter further mentioned the causes of dyscalculia and its prevalence among primary school students. With a range of interventions developed to support learners in primary schools, the rationale of the study was thus built and discussed in this chapter.

The next chapter will discuss the body of literature for children presenting with dyscalculia by stipulating the causes and challenges that primary school children encounter if no intervention is put in place. As such, the chapter will further discuss interventions for children presenting with dyscalculia in primary schools and interventions for identifying children presenting with dyscalculia in primary schools.

CHAPTER 2

2. LITERATURE REVIEW

This chapter presents a discussion on dyscalculia by elaborating more on the causes of the disorder and its consequences if intervention is not put in place. This chapter also discusses interventions for children presenting with dyscalculia in primary school and for identifying children presenting with dyscalculia in primary schools.

The main field of research in mathematics education focuses on the development of mathematical competency, which is regarded as a complex construct and essentially encompasses arithmetic problem solving (Obersteiner et al., 2010). Obersteiner et al. (2010) explain that mathematical competency is concerned with applying arithmetic knowledge to varying situations and to develop this skill, word problems are part of mathematics instruction in primary school. Geary (2013) on the other hand states that poor mathematical skills impede lifelong achievements such as academic and occupational attainment as well as social functioning (Geary, 2013). Low self-esteem, low motivation to learn, poor coping skills, anxiety, and overdependence on others are likely to occur as a result of academic failure (Kucian & von Aster, 2015). Moreover, Yeo (2003) indicates that children with mathematical difficulties are said to often rely on counting strategies in mathematics at ages when their age-mates are relying much more on fact retrieval. Dowker (2005) further notes that although difficulty in remembering number facts is a very common component of mathematical difficulty, not all children with mathematical difficulty have this problem.

In this review, an overview of the body of literature is provided for interventions for children presenting with dyscalculia in primary schools. In order to attain the aim of the study for providing an evidence base of filtered information assessed for methodological quality and coherence, the review focuses on interventions that are used on children presenting with dyscalculia as well as those used for identifying children presenting with dyscalculia in primary schools.

2.1 Dyscalculia

Individuals presenting with dyscalculia are poor in performance, either in accuracy or in time and on very simple numerosity tasks, such as number comparison (Butterworth & Laurillard, 2012). As a result, new research in the neurosciences has led to an increased understanding of the brain's role in mathematical development (e.g. Kaufman, 2008; Butterworth, 2005). Butterworth and Laurillard (2012) point out that well established neuroimaging studies (Pinel, Dehaene, Riviere & Le Bihan, 2001; Tang, Critchley, Glaser, Dolan & Butterworth, 2006) indicate the critical area for processing numbers in the human brain lies in the intraparietal sulcus (IPS), with an impressive body of work showing that this area of the brain deals with the comparison of digits. Rubinsten and Henik (2008) affirm the intraparietal sulcus (IPS) abnormality as being a single biological marker in developmental dyscalculia. However, Wilson and Dehaene (2007) in their review of the idea of Developmental Dyscalculia (DD) being caused by a core numerical deficit involving a single brain area, suggested that other subtypes of DD could exists and would involve brain areas other than the IPS. Moreover, neuro-behavioural and genetic research suggests that dyscalculia is a coherent syndrome that reflects a single core deficit of severe disability in learning arithmetic (Butterworth, Varma & Laurillard, 2011). Butterworth, Varma and Laurillard (2011) in their multivariate genetic analysis of a sample of 1500 pairs of monozygotic and 1375 pairs of dizygotic 7-year old twins, they found that about 30% of the genetic variance was specific to mathematics. Moreover, Shalev et al. (2001) posit that siblings of individuals with dyscalculia are more likely to present with dyscalculia than siblings of individuals who do not present with dyscalculia, indeed about 15 times more. However, there is evidence to suggest that environmental and developmental factors likewise play a role (Gillum, 2014). By contrast, dyscalculia is also caused by several cognitive deficits such as deficient working memory, inferior visual-spatial processing or attention (Rubinsten & Henik, 2008). It is clear that general cognitive factors can affect learning arithmetic (Ansari & Karmiloff-Smith, 2002) and individual differences in working memory have been related to individual differences in arithmetical attainment in school (Butterworth & Laurillard, 2012).

Dyscalculia also referred to as mathematical difficulty is a disability that can be highly selective, affecting learners with normal intelligence and normal working memory, although it co-occurs with other developmental disorders, including reading disorders and ADHD (Butterworth, Varma & Laurillard, 2011). However, Molko (2003); Butterworth (2010); and Kaufmann (2011) express it as a brain-based disorder, with the left parietal-temporal sulcus being of particular significance.

Children are diagnosed with dyscalculia when there is a clear discrepancy between their mathematic achievement scores and expected performance based on IQ and age (Jaekel & Wolke, 2014). However, most diagnostic criteria use the term Developmental Dyscalculia (DD) to describe moderate to extreme difficulties in fluent numerical computations that cannot be attributable to sensory difficulties, low IQ or educational deprivation (Rubinsten & Henik, 2008).

Although the prevalence of dyscalculia is comparable to the incidence of dyslexia, children with dyscalculia are often not diagnosed or treated properly due to a persisting lack of knowledge about the disorder (Dowker, 2004). Ramaa (2002) states that dyscalculia's comorbidity with ADHD or dyslexia occurs in approximately one quarter of cases although comorbidity with dyslexia appears to produce the most profound impairments when compared to those with dyscalculia alone, or those with dyscalculia and ADHD. However, it is vitally important to have clear diagnostic criteria in order to understand the prevalence of dyscalculia (Devine et al., 2013).

Epidemiological studies have indicated that dyscalculia is as common as reading disorders and affects 3.5%–6.5% of the school-age population (Rubinsten & Henik, 2008). Furthermore, Kucian et al., (2011) also indicate that with regards to gender, dyscalculia is common in girls as it is in boys. It is important to ensure that these children presenting with dyscalculia are identified and receives early intervention.

2.2 Interventions

Early intervention is critical to prevent a life-course of suffering and secondary emotional and behavioural problems (Molko 2003; Butterworth 2010; Kaufmann 2011). Gillum (2014) posits that child numeracy leading to the development of a range of different interventions to treat dyscalculia has been a growing interest. The context for preventing academic difficulty in the schools has thus changed over the past 5 years with the introduction of multi-tiered prevention systems (Fuchs et al., 2008). As a result, a range of targeted interventions have also been developed to support learners (Gillum, 2014). Among others, Dowker (2005) mentions that such interventions include those that tackle the knowledge of mathematical facts, the ability to carry out mathematical procedures, understanding and using mathematical principles and so forth. It is thus important to identify early signs and predictors of mathematical difficulties to ameliorate and perhaps prevent later mathematical difficulties (Dowker, 2005).

2.3 Interventions for children presenting with dyscalculia

Cowan and Powell (2014) in their study focused on a Domain-General and Numerical Factors to Arithmetic Skills. In their study groups were defined by a single point assessment and subsets with persistent difficulties to enhance comparability with other studies. Their study furthermore examined prevention of conclusions that are specific to the method of group construction. It indicated both number system knowledge and estimation as substantial predictors of basic calculation fluency. Furthermore, they stipulate that both domain-general factors (working memory components such as phonological loop, visuo-spatial sketchpad, and central executive), and numerical factors make important contributions to arithmetic skills and to number difficulties and as a result have been the targets for successful interventions that have yielded transferable gains in mathematical skills.

Fuchs et al. (2008) on the other hand did a study in which they assessed the effects of small-group tutoring with and without validated classroom instruction on at-risk students' math problem solving. In their study, they reported that students that were identified as at risk were randomly assigned, within classroom conditions and were then tested on problem solving and mathematics applications measures before and after intervention.

2.4 Interventions for identifying children presenting with dyscalculia

Dowker (2005) indicates that Butterworth (2002,) devised a computerized screening test, the Mathematics Recovery program (Wright, Martland & Stafford 2000; Wright, Martland, Stafford, & Stanger, 2002) and the Numeracy Recovery program (Dowker, 2001, 2003) of basic numerical skills, which is more specifically directed at incorporating the recognition of small numerosities; estimation of somewhat larger numerosities; and comparisons of number size. Numerosities have been explained by Butterworth (2005) as properties of sets. The numerosity processing brain areas are part of the calculation network. For example, counting and manipulating sets are the way that most individuals learn mathematics (Butterworth, 2005). Dowker (2005) nonetheless further expands that these programs are intended to identify severe arithmetical difficulties (dyscalculia) rather than to assess individual differences in the general population as most assessment techniques/interventions involve testing children across the range of ability.

Other interventions implemented include those of Reigosa-Crespo et al. (2012) in which a non-standardized curriculum-based measurement of mathematics attainment was group administered to children. At the end of the year, children that that were carried out of the first stage of the mathematics attainment were administered the Basic Numeric Battery (BNB) which is a battery of item-timed computerized tests in order to identify those with basic numerical deficits (Reigosa-Crespo et al., 2012).

These studies report on the interventions that are being used for children presenting with dyscalculia in primary schools as well as those that identify children presenting with dyscalculia in primary schools. However, the studies do not comment on the methodological rigor and coherence of the interventions. As a result, there is a lack of filtered information in providing a base of empirical evidence of interventions for children presenting with dyscalculia in primary schools. Therefore this study will add to the gap in the body of knowledge. The study will also inform practice by means of the identification and implementation of interventions that have met a threshold of methodological quality.

The chapter discussed the in detail the meaning of dyscalculia, the challenges encountered in the pupils that have the disorder as well as interventions for children presenting with dyscalculia in primary schools and interventions for identifying children presenting with dyscalculia in primary schools.

The next chapter will discuss the research methodology of the study. The chapter discusses the aims and objectives of the study, the operational steps undertook in the study, the methodological framework by providing the research design of the study, stipulating the inclusion and exclusion criteria as well as the retrieval and assessment strategies used in the review. The chapter further explains the process involved in the methodological quality appraisal of the intervention studies in the review and the instruments/tools used in the review. The chapter also discusses the method of analysis for the study, stipulates the ethical considerations of the study and lastly concludes the chapter.

CHAPTER 3

3. RESEARCH METHODOLOGY

3.1 Introduction

This chapter outlines the methodology used to conduct the present study in order to accomplish its specific aims and objectives. The chapter provides a detailed explanation of the operational steps that were undertaken in the study, the methodological framework as well as the research design used in the study. An explanation for the inclusion and exclusion criteria, the retrieval and assessment strategy study is also provided. Furthermore, this chapter provides an explanation of the methodological quality appraisal. It presents the instruments used to collect the data for analysis and the analysis procedures are also discussed. Lastly, the ethical considerations are discussed.

3.2 Aim and objectives of the study

3.2.1 Aim of the study

The aim of the study was to provide an evidence base of filtered information assessed for methodological rigor and coherence on interventions for children presenting with dyscalculia in primary schools.

3.2.2 The objectives of the study were to:

- Investigate interventions for children presenting with dyscalculia in primary schools as well as their theoretical orientation.
- Determine the nature of activities that are involved and used in the interventions as well as the description of the interventions.
- Critically examine the methodological quality of studies on interventions.
- Examine the empirical evidence of the studies such as efficacy and the extent to which the intervention has been adopted.

3.3 Operational steps undertaken were to:

- Identify appropriate literature for inclusion.
- Evaluate the literature for methodological quality.
- Provide a meta-synthesis of the findings of included studies.

3.4 Methodological Framework

3.4.1 Research design

Research designs are procedures for collecting, analyzing, interpreting and reporting on data in research studies (Creswell & Clark, 2007). Research designs also guide the methods decisions that researchers must make during their studies and set the logic by which they make interpretations at the end of their studies (Creswell & Clark, 2007). They involve a set of decisions regarding what topic is to be studied, among what populations, with what research methods and for what purpose (Babbie, 2011).

The current study took on a systematic review approach to identify interventions for children presenting with dyscalculia in primary schools. Korhonen et al. (2010) define systematic review as a scientific approach used to identify, critically evaluate and synthesise the results of all high-quality studies published on a given subject, so that research evidence that has been assessed as reliable is available in a usable form. That is to say, systematic reviews attempt to identify, appraise and synthesize all the empirical evidence that meets pre-specified eligibility criteria to answer a given research question (Mulrow, 1994; p 597) based on a scientific methodology.

This design was appropriate for the current study's aims as it provided an evidence base of filtered information assessed for methodological rigor and coherence and in doing so addressed the gaps identified in the literature review. Systematic and explicit methods were used to collect and analyze data aimed at minimizing bias in order to produce more reliable findings that can be used to inform decision making (Antman et al, 1992; Oxman & Guyatt, 1993).

3.5 Inclusion criteria

Studies were eligible for inclusion if they:

i. Were intervention studies reporting on dyscalculia in primary schools.
ii. Were full text and were reported in English language only in order to enable the identification of current evidence of interventions.
iii. Were only quantitative studies.
iv. Were published between 2004 and 2014 so as to provide evidence of recent literature.

3.6 Exclusion criteria

Studies were excluded in the review if they were not:

i. Published within the designated time frame.
ii. In English language, full text, and if they were not found in one of the databases available at UWC.
iii. Intervention studies.
iv. Targeting children participants but other participants such as teachers and parents.

3.7 Retrieval strategy

A widespread search was conducted in all accessible library databases available at the University of the Western Cape. To find eligible articles, the following databases were searched: Cochrane, Ebscohost (Eric, Academic Search Complete, Psych Info, Education Search Complete, Psychological and Behavioural Sciences), SAGE, Jstor and Science Direct. A comprehensive search was done across the Psychology, Occupational Therapy, Health, Education and Social Sciences. Keywords such as: interventions; dyscalculia; children, primary school, math difficulty, number difficulty were used. The reference list of all identified publications was also searched for additional studies. Lastly, a 10 year time frame was applied starting from 2004 to 2014 in searching for literature in order to identify more recent and current literature.

3.8 Assessment strategy

This review made use of a 3 step assessment strategy in order to identify any possible sources of bias: title reading, abstract reading and full-text reading in determining appropriate literature for inclusion in the review.

Title reading. The title stage was used to select articles for inclusion based exclusively on the relevance of the title by two reviewers. Keywords that were used included a*rithmetic difficulties; children; co-morbid disorders; developmental dyscalculia; dyscalculia; interventions; math difficulties; numeracy problems; primary schools and systematic review*. The articles identified as appropriate for inclusion were then assessed at the abstract reading stage.

Abstract reading. The articles which were selected at the title stage were then assessed at the abstract reading stage. At this stage articles were assessed for relevance by reading through the abstracts based on the inclusion and exclusion criteria by two reviewers working independently and then coming together to compare studies for inclusion.

Full text reading. The abstracts meeting the inclusion criteria at the abstract stage were considered for full text reading. In this stage, two reviewers assessed the selected articles using a quality assessment tool.

3.9 Methodological quality appraisal

The methodological quality of the studies included in the review were assessed using a methodological quality appraisal tool (Appendix C) developed by Smith, Franciscus and Swartbooi (under review). Further quality of evidence was assessed using the Reach, Effectiveness, Adoption, Implementation, and Maintenance (RE-AIM) framework (Dzewaltowski et al., 2004) which is a useful tool to translate research into practise by promoting the development and evaluation of interventions (Matthews, Kirk & Mutrie, 2014). This framework offers a comprehensive approach to considering five dimensions important for evaluating the potential public health impact of an intervention (Glasgow et al., 2006). Matthews, Kirk and Mutrie (2014) describe these dimensions as follows:

- *Reach* of the intervention for the intended target population
- *Effectiveness* of the intervention in achieving the desired positive outcomes
- *Adoption* of the intervention by target staff, venues and/or organisations
- *Implementation*, consistency and adaptation of the intervention protocol in practise
- *Maintenance* of intervention effects on individuals or settings over time.

Sweet, Ginis, Estabrooks and Latimer-Cheung (2014) suggest that the RE-AIM framework has been applied to understand the impact of implementation of interventions. Furthermore, Sweet et al. (2014) add that pair of reviewers needs to work together at every level and record relevant information in order to work with this framework. However, in the case in which the reviewers disagreed, they are to consult their supervisor and engage in a discussion to reach an agreement.

3.10 Instruments

Four instruments were utilized to ensure that all relevant data was collected, allowed accuracy of data to be checked as well as served as a record of the data collected.

Title Reading and Extraction Tool (Appendix A). This tool was used to select journal articles for inclusion based on the relevance of the title. The tool recorded information such as name of author(s), date of the study, the title and source of the study, name of the database in which the study was extracted, the location in which it was stored. The title reading and extraction tool is provided in Table 1 below.

Table 1: Title reading and extraction tool

Author	Date	Title and Source	Database	Location where stored	OUTCOME: Exclude/Include

Abstract Reading Extraction Tool (Appendix B). Abstracts were assessed for relevance based on the inclusion and exclusion criteria. The tool was used to record a summary of information entailing the type of design, population, the instruments, study aims and lastly the quality or results of the study analysis. See Table 2 below of the abstract reading extraction tool.

Table 2: Abstract reading extraction tool

Type of Design	Study population	Instrument used	Outcomes	Quality or results of study analysis

The Quality Assessment Tool (QAT-Appendix C). The QAT developed by Smith, Franciscus, and Swartbooi (under review) assesses aspects of the methodologies employed and awards scores on a Likert-type scale (see Appendix C). This tool was used to assess the quality of the selected articles for methodological quality in critically appraising the literature of primary studies using rating scales. Each full text article obtained a score that was used to determine the overall quality of the article reviewed. These scores are categorized as weak (<40%), moderate (41-60%), strong (61-80%), or excellent (>81). Studies that were excluded from the systematic review were those rated as weak (<50%) for the quality of evidence.

The Synthesis tool (Appendix D): For each eligible study that met the threshold level at the Quality Assessment Tool (QAT), a summary of information was done by using a self-constructed data extraction synthesis tool that was based on the objectives of the study and the different levels of the analysis.

3.11 Analysis

According to Schreiber et al. (1997, p.314), a meta-synthesis "is bringing together and breaking down of findings, examining them, discovering essential features and, in some way , combining phenomena into a transformed whole". The goal of meta-synthesis is to produce a new and integrative interpretation of findings that is more substantive than those resulting from individual investigations (Finfgeld, 2003). Sandelowski, Docherty and Emden (1997) identified three complementary types of meta-synthesis used for systematic reviews: *theory building* which brings together findings on a theoretical level to build a tentative theory; *theory explication* which is a way of reconceptualising the original phenomenon; and *descriptive meta-synthesis* which aims to provide a broad description of the research phenomenon. There are various approaches to conducting a meta-synthesis (Walsh & Downe, 2005); however the final choice reflects the choice of the researcher and the aim of the study. This technique however has been proven to be successful in synthesizing evidence from both quantitative and qualitative research (Barnett-Page & Thomas, 2009).

For the purpose of this study, a descriptive meta-synthesis was employed incorporating it with the RE-AIM framework as the framework can play an important role in further strengthening the evidence base for the effectiveness of interventions for children presenting with dyscalculia.

The process of synthesis began with reviewing the literature by ranking studies based on the breadth of the information on the intervention such as the scope of the intervention, the theoretical orientations etc. (as reflected in the objectives). Furthermore, classification of studies was ranked according to the methodological rigor as measured by the quality appraisal tool. In addition, the RE-AIM framework was in part assessed and reported on the Reach (proportion of the target population); Efficacy (success rate of the intervention defined by positive outcomes); Adoption (proportion of settings, practices and plans that will adopt this intervention); Implementation (extent to which the intervention is implemented as intended in the real world) and Maintenance (extent to which a program is sustained over time).

3.12 Ethics

As a fully registered student at the University of the Western Cape, permission to conduct the study was obtained from the University of Western Cape Research and Ethics committee. Since this study was non-reactive, ethical guidelines such as confidentiality, informed consents, avoiding harm to individuals did not apply. Plagiarism however was avoided by acknowledging other people's work and collaboration was taken into consideration as the review entailed working with paired reviewers. This systematic review is funded by the Botswana Government.

Conclusion

This chapter provided the methodological design of the study. A systematic review design was used to achieve the aims and objectives of the study. Furthermore, the chapter provided operational steps that were undertaken in the review, the methodological framework which included the inclusion and exclusion criteria, retrieval and assessment strategies in the review. This chapter additionally provided information about the instruments used in the study, the methodological quality appraisal process as well as the method for analysing the results of the study. The following chapter (4) provides the findings of the systematic review.

CHAPTER 4

4. FINDINGS OF THE SYSTEMATIC REVIEW

4.1 Introduction

This chapter presents the findings of the systematic review. These findings provide an evidence base of filtered information assessed for methodological rigor and coherence on interventions for children presenting with dyscalculia in primary schools. The chapter presents a brief background on the importance of the study as well as a detailed explanation of the process and methods utilized in conducting the review. It further presents the results and provides a discussion of the results of the review.

4.2 Background

Research has been and is currently being carried out on programs for young primary school children that include individualized assessments that take into account individual children's strengths and weaknesses in specific components of mathematics (Dowker, 2005). Moreover, Dowker (2005) adds that in order to study the nature of mathematical difficulties that are experienced by children as well as the best way to intervene in helping them, it is of utmost importance to understand that mathematics is not a single entity a sit is made up of many components. As a result, a range of targeted interventions have been developed to support learners, however, when difficulties persist in spite of such interventions, the next steps to assist these individuals are not clear (Gillum, 2014). The aim of this systematic review was therefore to provide an evidence base of filtered information assessed for methodological rigor and coherence on interventions for children presenting with dyscalculia in primary schools.

4.3. Methods

This section outlines the methodology used to conduct the present study to accomplish the specific aims and objectives as described in Chapter 1. A detailed explanation on the findings of the operational steps undertaken is provided for which includes the title search, the abstract search and a review at the quality appraisal stage.

4.3.1 Title Search

In the title search, 1551 articles were identified and 172 articles were recorded after screening per title. A total of 164 articles then proceeded to the abstract analysis after removal of duplicates. In selecting the 164 articles, the pair of reviewers selected articles exclusively on the relevance of the title of the article. That is, if the title did not read as an intervention or include children in primary schools as participants, the article will be excluded as they would not have met the requirements of the inclusion criteria.

4.3.2 Abstract Search

A total number of 164 articles proceeded to the abstract search from the title search however 131 articles were excluded after screening. Studies that were not in English, non-full texts were not included in the review. In addition to the reasons for exclusion, studies that fell outside the specified time period of inclusion were excluded as well as those that did not focus on interventions aimed for children presenting with dyscalculia. Qualitative studies and studies that focused on interventions that focused on teachers or communities or staff were also excluded. Hence, 33 articles proceeded for review to be assessed for eligibility at the Quality Appraisal Tool (QAT).

4.3.3 Review at the Quality Appraisal Tool

A total of 27 articles were assessed for methodological quality using the Quality Appraisal Tool. However, 16 articles that did not meet the threshold score of 50% and above were removed. Hence, only 11 articles were included for the summation in the review. Studies that were included in the systematic review are those with the quality of evidence rated from 50% to 100%. Of these 11 articles, 6 scored between 50-59% (Re et al., 2014; Fuchs et al., 2006; Leh & Jitendra, 2013; Swanson, Orosco & Lussier, 2014; Faramarzi & Sadri, 2014; Powel et al., 2010) and 5 studies scored between 60-69% (Bryant et al., 2008; Rouselle & Noel, 2008; Swanson, Lussier & Orosco, 2013; Fuchs at el., 2008; Bryant et al., 2014). The studies that were excluded at this level failed to explicitly state and motivate the method of analysis used in the studies and the appropriateness of the method of analysis relative to the research question. Furthermore, they failed to report on the psychometric properties used in the study, scored low in identifying a population and sampling frame, in reporting on the use of probability or non-probability sampling as well as motivation for sampling choice and appropriateness of sampling method.

However, studies that are included rated high as they report on the purpose of the studies were clearly stated with provision of the rational and aim of the studies which were explicitly related to the problem statement. Furthermore, the studies also had a clear theoretical orientation reported and described in detail, identified a population and a sampling frame by making use of probability or non-probability sampling as well as motivating the sampling choice. Nonetheless, these studies did not explicitly report on ethics consideration but they further reported on the instruments used, their psychometric properties and the type of data produced by these instruments. They explicitly stated and motivated the method of analysis and the appropriateness of the method of analysis relative to the research question and lastly, they provided correct interpretation of results and drew a clear conclusion supported by the findings. Figure 4.1 depicts the process of evaluation of articles and Table 4.1 shows the threshold scores.

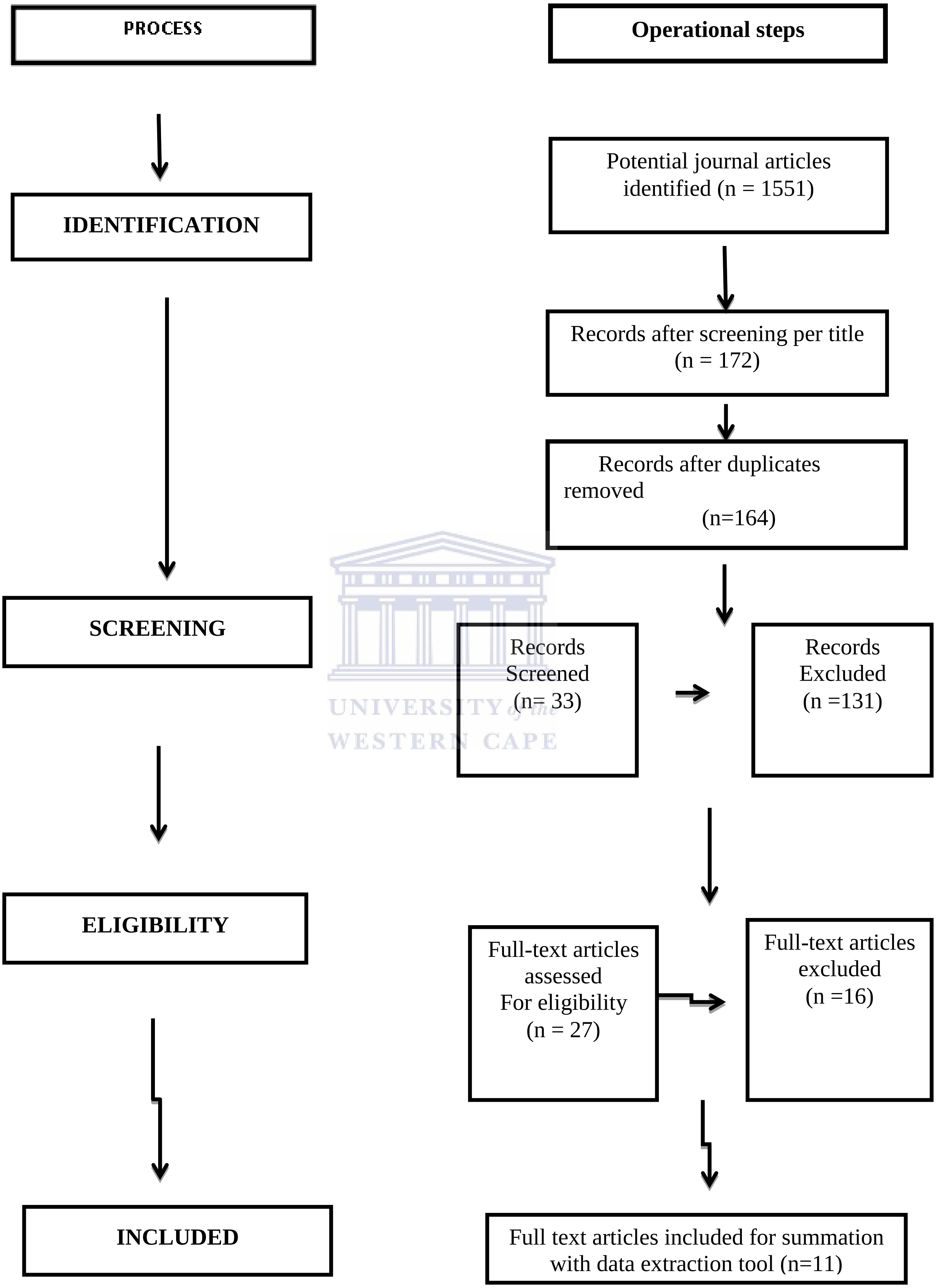

Figure 4.1 Evaluation of Journal articles

Table 4.1 ***Threshold scores***

Author and year	Intervention	Threshold score
Re et al. (2014)	Specific, individualized training	52%
Fuchs et al. (2006)	Computer-assisted instruction (CAI)	52%
Faramarzi and Sadri (2014)	Neuropsychological Intervention on Performance	54%
Powell et al. (2010)	Strategic Counting Instruction with and without deliberate practice with those counting strategies, on number combination (NC)	55%
Leh and Jitendra (2013)	Computer-mediated instruction (CMI) and Teacher-mediated instruction (TMI)	57%
Swanson, Orosco & Lussier (2014)	Strategy instruction on solution accuracy	57%
Fuchs et al. (2008)	Preventative tutoring on the math problem solving (Schema-broadening tutoring)	60%
Bryant et al. (2008)	Tier 2 intervention in a multitiered model	60%
Rouselle and Noel (2008)	The Adaptive Use of Approximate Calculation in an Addition Verification Task	63%
Bryant et al. (2014)	Tier 3 Intervention	65%
Swanson, Lussier & Orosco (2013)	Strategy instruction and working memory capacity (WMC)	65%

4.4 RESULTS

This section of Chapter 4 provides a general description of the studies reviewed in the study. It further provides the aims of the studies reviewed, a full description of the sample, the databases, geographical locations and the design of the studies reviewed. The chapter also provides a detailed description of the measures/ instruments used in the reviewed studies.

4.4.1 General description of the studies reviewed

This systematic review examined the quality of primary studies in order to minimize bias in drawing conclusions. Using the descriptive meta-synthesis which aims to provide a broad description of the research phenomenon as proposed by Sandelowski, Docherty and Emden (1997), the results of the review are structured according to the following aspects: the purpose/aims of the studies, the sampling, the sources in which the studies were found, the geographical location in which they were conducted, the study designs, measure/instruments used as well as the interventions in the studies. See Table 4 for the synthesis table of the 11 studies that met the threshold of methodological quality which is inclusive of information on the journals in which the studies were published, the source were the studies were located, the study deigns, population, geographical location, instruments as well as the data analysis that was used in the reviewed studies.

4.4.1.1 Purpose/aims of studies.

Most studies focused on determining and assessing the value or efficacy of interventions for children presenting with dyscalculia in primary schools (Re, Pedron, Tressoldi & Lucangeli, 2014; Fuchs, Fuchs, Hamlet, Powell, Capizzi & Seethaler, 2006; Swanson, Orosco & Lussier, 2014; Fuchs, Seethaler, Powell, Fuchs, Hamlett & Fletcher, 2008). However, two studies focused on determining and evaluating the effectiveness of the Tier 3 intervention and a computer-mediated instruction (CMI) and teacher-mediated instruction (TMI) for students struggling in mathematics (Bryant et al., 2014; Leh & Jitendra, 2013). Having one study aimed at investigating the effectiveness of basic neuropsychological interventions in improving mathematics performance (Faramarzi & Sadri, 2014), the study by Rousselle and Noel's (2008) examined the adaptive use of approximate calculation using a verification task with children with mathematical disabilities. In addition, Swanson, Lussier and Orosco (2013) study aimed to investigate the role of working memory capacity (WMC) in strategy training in children with mathematical difficulties, whereas Bryant, Bryant, Gersten and Chavez (2008) and Powel et al. (2010) study determined and assessed the effects of the Tier 2 intervention and strategic counting instruction used among students with mathematical difficulties. A summary of the findings of the purpose/aims of the studies included in the review are provided in Table 4.2.

4.4.1.2 Sample/Participants.

Eight studies in the review had children as participants that were in grades 1-5 who had mathematical difficulties (Swanson, Orosco & Lussier, 2014; Fusch et al., 2008; Rousselle & Noel, 2008; Leh & Jitendra, 2013; Bryant, 2014; Bryant, 2008; Swanson, Lussier & Orosco, 2013; Faramarzi & Sadri, 2014). However, two studies included student participants with either severe mathematical difficulties or mild mathematical difficulties (Powell at al., 2010; Re at al., 2014) whereas the study by Fuchs et al. (2006) had children with concurrent risk for math disability and reading disability as their participants. A summary of the sample/participants of the intervention studies included in the review are provided in Table 4.2.

4.4.1.3 Source/Databases.

Of these studies that made it at the QAT, 36.36% were retrieved from the Journal of Learning Disabilities, 18.18% from Exceptional Children Journal, 18.18 from Learning Disability Quarterly, 9% from Remedial and Special Education, 9% from Learning and

Individual Differences 2 and 9% from the Council for Exceptional Children. However, only 9% were retrieved from the Science Direct database and 91% from Sage Journals Online. A summary of the source/databases of the intervention studies included in the review are provided in Table 4.2

4.4.1.4 Geographical location/setting.

The studies included the review were conducted in various locations. Two studies were conducted in Central Texas (Bryant et al., 2008; Bryant et al., 2014), one in Italy (Re et al., 2014), one in Belgium (Rouselle & Noel, 2008), one in a Metropolitan Public School (Fuchs et al., 2006), one in Northeast United States (Leh & Jitendra, 2013), one in Isfahan city in Iran (Faramarzi & Sadri, 2014), one in South Western Public School District (Swanson, Lussier & Orosco, 2013), one in Southern Carlifornia Public School District in the United States (Swanson, Orosco & Lussier, 2014), one in schools in South Eastern Urban District (Fuchs et al., 2008) and one study was conducted both in Nashville and Houston in the United States (Powell et al., 2010). A summary of the geographic location/setting of the intervention studies included in the review are provided in Table 4.2

4.4.1.5 Design of studies

Of the 11 studies included in the review, 4 used an experimental design (Rouselle & Noel, 2008; Powel et al., 2010; Re et al., 2014; Faramarzi & Sadri, 2014), 1 study used a regression discontinuity design (Bryant et al., 2008). Bryant et al. (2014) study used a multi-baseline design whereas Swanson, Lussier and Orosco’s (2013) study used a covariate interaction design. Furthermore, 1 study used an exploratory design (Swanson, Orosco & Lussier, 2014), 1 study used a randomized control trial design (Fuchs et al., 2008) and Fuchs et al. (2006) used a computer instruction software design. Moreover, of the included studies, 1 did not report on the type of design that was used in conducting the study (Leh & Jitendra, 2013). A summary of the design of the intervention studies included in the review are provided in Table 4.2.

4.4.1.6 Measures/Instruments used.

There are a variety of standardized tests used for assessing children's mathematical abilities. Many test batteries for measuring abilities include tests both of calculation efficiency and of mathematical reasoning which is taking the form either of number pattern recognition or of word problem solving (Dowker, 2005). The instruments used in the studies included in this review are different mathematical batteries and computer assisted measures. A summary of the measures/instruments used in the intervention studies included in the review are provided in Table 4.2.

Battery measures. Re et al. (2014) used the AC-MT battery (Cornoldi, Lucangeli & Bellina, 2002) used to assess calculation ability and the ABCA battery (Lucangeli, Tressoldi & Fiore, 1998) used for the assessment of mathematical ability and provides a specific profile identifying each child's calculation components to assess the students' mathematical skills. Nonetheless, subset measures such as mental calculations, written calculation subtest which examined the child's application of the procedures needed to complete written computational operations such as additions, subtractions, multiplications and divisions and the degree of automaticity involved and arithmetic facts task to investigate how students stored combinations of numbers and whether they are able to access them automatically, without purposive calculation procedures. The study also included the number ordering task to assess the semantic representation of numbers by means of quantity comparisons and subtasks for numerical knowledge such as: number comparisons which requires both an understanding of the sematic numbers and the ability to read numbers; transcribing digits which assessed student's ability to elaborate the syntactic structure of numbers that governs the relationship between the digits the numbers contain.

Subtests of the TEMI-PM. Bryant et al. (2008) and Bryan et al. (2014) study used the four subtests composing the *Texas Early Mathematics Inventory-Progress Monitoring* (TEMI-PM). This measure assessed Magnitude Comparisons to assess a child's ability to differentiate the bigger or smaller of two numbers that are shown side by side within a box; Number Sequences to assess a child's ability to identify a missing number from a sequence of three numbers; Place Value to assess first and second graders knowledge of place value and Addition/Subtraction Combinations to assess first and second graders ability to correctly write the answers to addition and subtraction facts (sums ranging from 0 to 18).

Computer assisted measures. The study by Rouselle and Noel (2008) used the E-Prime 1.1 software on a personal computer screen with the aim of encouraging children to evaluate the plausibility of the proposed sum instead of rigidly engaging in a fixed calculation process. Leh and Jitendra (2012) on the other hand used the GO Solve Word Problems computer software program, (Tom Synder Productions, 2005) for the computer-mediated instruction. Nonetheless, they also used the Solving Math Word Problems: Teaching Students with Learning Disabilities Using Schema-Based Instruction curriculum (Jitendra, 2007) for the teacher-mediated instruction. These measures were used because the word problem interventions are grounded in schema theories of cognitive psychology, with instruction focusing explicitly on the underlying problem structure that has shown to be effective in improving student learning. Furthermore, Fuchs et al. (2006) used a measure of arithmetic number combination skill and a transfer measure of arithmetic story problems to examine the computer-assisted instruction effects and a measure on spelling accuracy using FLASH words and on three transfer measures—spelling accuracy with non-FLASH, high-frequency words; reading word identification accuracy; and passage reading fluency to examine the effects of computer-assisted instruction in spelling.

Swanson, Orosco and Lussier (2014) conducted their study using the Norn-referenced measure prior to intervention to assess fluid intelligence (Raven Colored Progressive Matrices; Raven, 1976), calculation (WRAT-3; Wilkinson, 1993), reading comprehension (TORC; Brown et al., 1995), and story problems (CMAT; Hresko et al., 2003). Furthermore, three working memory measures that captured executive processing (i.e., Conceptual Span, Updating, and Digit/Sentence) and two that captured visual-spatial working memory (i.e., Mapping & Directions, Visual Matrix) were used. This study also administered alternate forms of story problems from the Test of Mathematical Abilities (TOMA-2; Brown, Cronin, & McIntire, 1994) and WRAT-3 (Wilkinson, 1993) at pretest and posttest.

Powell et al. (2010) used the Arithmetic subtest of the Wide Range Achievement Test - 3 (WRAT, Wilkinson, 1993), where students had 10 min to complete calculation problems of increasing difficulty as the calculations screening measure. They also used the word-problem screening measure, the Iowa Test of Basic Skills: Problem Solving and Data Interpretation (Iowa; Hoover, Hieronymous, Dunbar & Frisbie, 1993), where students solve 22 word problems; data in tables and use graphs to solve items. In addition, they also used the reading screening measure WRAT (Wilkinson, 1993), where students read aloud letters and words until a ceiling is reached. The IQ screening measure nonetheless was the 2-subtest Wechsler Abbreviated Scales of Intelligence (WASI, Wechsler, 1999).

Fuchs et al. (2008) conducted their study using the Tier 1 General Education (and Control) Instruction which was guided using the *Math Advantage* (Burton & Maletsky, 1999). This measure relies on teacher-guided problem-solution instruction, with variations in problem cover stories where instruction addresses the same problem types, with one problem type addressed at a time.

Faramarzi and Sandri (2014) used the Wechsler Intelligence Scale for children (WISC-III-R), Keymath test, math academic performance test and clinical interviews were used for their study. Moreover, Swanson et al. (2013) also used subtests from the KeyMath (Connolly, 1998) and Comprehensive Mathematical Abilities Test (CMAT; Hresko, Schlieve, Herron, Sawain & Sherbenou, 2003) were used as criterion measures in this study.

Table 4.2 *Data extraction*

Author and Year	Journal	Source	Study Design	Population/ Sample	Geographic Location	Instruments	Data Analysis
Faramarzi and Sadri (2014)	Neuropsychiatria i Neuropsychologia	Academic Search Complete	quasi-experimental design with pretest, posttest and a control group	Dyscalculia girl students (8-9 years old) in the second grade of elementary school.	Isfahan city of Iran	Wechsler Intelligence Scale for Children-III (WISC-III-R) and Keymath test	Statistical criteria of average, variance, standard deviation and covariance analysis by making use of SPSS software.
Re et al. (2014)	Exceptional Children	Sage Journals Online	Experimental design.	54 students attending the second to fifth years of elementary school.	Italy	AC-MT battery to assess calculation ability and the ABCA battery used for the assessment of mathematical ability and provides a specific profile identifying each child's calculation components to assess the students' mathematical skills	Group (experimental vs. control group) by time (pre- vs. post-training) analysis of variance (ANOVA), separately for DYSC and MD groups

Table 4.2 *Continued*

Author and Year	Journal	Source	Study Design	Population/ Sample	Geographic Location	Instruments	Data Analysis
Bryant et al. (2008)	Remedial and Special Education	Sage Journals Online	Regression discontinuity design	126 (Tier 2, n = 26) first graders and 140 (Tier 2, n = 25) second graders who were identified as having mathematical difficulties.	Central Texas, USA	Four subtests composing the *Texas Early Mathematics Inventory-Progress Monitoring* (TEMI-PM)	Regression Discontinuity analysis
Rousselle and Noel (2008)	Journal of Learning Disabilities	Sage Journals Online	Experimental design	18 third-grade children with mathematics learning disabilities, 22 third grade children with normal achievement in mathematics, and 21 second-grade children with no known difficulties in mathematics	Louvain-la-Neuve, Belgium	E-Prime 1.1 software on a personal computer screen	RT analysis

Table 4.2 *Continued*

Author and Year	Journal	Source	Study Design	Population/ Sample	Geographic Location	Instruments	Data Analysis
Bryant et al. (2014)	Journal of Learning Disabilities	Sage Journals Online	Multiple-baseline design	Twelve second grade students (3 boys and 9 girls) from three schools	Texas	Four subtests composing the *Texas Early Mathematics Inventory-Progress Monitoring* (TEMI-PM)	Regression Discontinuity analysis
Fuchs et al. (2006)	Journal of Learning Disabilities	Sage Journals Online	Computer instruction software design	33 students drawn from nine first grade classrooms in three Title 1 schools	Metropolitan school, USA	Relied on a measure of arithmetic number combination skill and a transfer measure of arithmetic story problems	One-way analyses of variance, with treatment condition as the between-subjects factor.
Leh and Jitendra (2012)	Learning Disability Quarterly	Sage Journals Online	Not stated	25 third-grade students attending six classes in a suburban public elementary school	Northeast United States, Texas	GO Solve Word Problems computer software program	Not stated

Table 4.2 *Continued*

Author and Year	Journal	Source	Study Design	Population/ Sample	Geographic Location	Instruments	Data Analysis
Swanson, Lussier and Orosco, (2013)	Journal of Learning Disabilities	Sage Journals Online	Sage Journals Online	192 children from Grades 2 and 3 from a large south western public school district with MD	South western public school district	*Colored Progressive Matrices* (Raven, 1976).; *KeyMath* (Connolly, 1998); Reading subtest of the WRAT	Mixed ANCOVA model
Swanson, Orosco and Lussier (2014)	Exceptional Children	Sage Journals Online	Exploratory	One hundred and ninety-three children from Grade 3	Southern California public school district	Norn-referenced measures to assess fluid intelligence, calculation, reading comprehension, and story problems. Three working memory measures that captured executive processing and two that captured visual-spatial working memory. Test of Mathematical Abilities (TOMA-2; Brown, Cronin, & McIntire, 1994) and WRAT-3 (Wilkinson, 1993) at pretest and posttest.	HLM regression model

Table 4.2 *Continued*

Author and Year	Journal	Source	Study Design	Population/ Sample	Geographic Location	Instruments	Data Analysis
Fuchs et al. (2008)	Exceptional Children	Sage Journals Online	Randomized control trial	42 students with documented math and reading difficulties.	Schools in a south eastern urban district	Tier 1 General Education (and Control) Instruction which was guided using the *Math Advantage* (Burton & Maletsky, 1999)	one-way ANOVA
Powell et al. (2010)	Learning and Individual Differences 2	Science Direct	Experimental design	The 180 students (90 at each site) represented 45 classrooms in Nashville and 39 classrooms in Houston.	Nashville and Houston	Arithmetic subtest of the Wide Range Achievement Test - 3 (WRAT, Wilkinson, 1993)	Distributional exploration via statistical and graphical means.

4.5 Descriptive meta-synthesis

This section of Chapter 4 provides a descriptive meta-synthesis of the studies reviewed in this systematic review. The section provides a detailed description of the interventions of the studies reviewed in the study. It further provides a table (Table 4.3) that indicates the aims of the studies, the interventions as well as well as the intervention/program descriptions of the reviewed studies.

4.5.1 Interventions

This Systematic Review assessed intervention studies. The QAT assessed interventions based on the theoretical orientation of the interventions, the development of the interventions as well as the implementation of the programs. However, this section presents the interventions reported in the studies reviews, the scope and nature of the reviewed intervention studies.

Individual Administered Interventions. These interventions assessed students' mathematical learning individually in a quiet room either at the school or at the centre for the experimental conditions.

Re et al. (2014) study implemented the "Specific individualized training" in a quiet room at a centre to enable the students to achieve a sufficient level of accuracy as well as to improve their speed of response. The training was assessed in relation to the gains in the following fundamental calculation skills: Concept of number (numerical knowledge), automaticity in retrieving and using arithmetical facts, mental calculation and written calculation.

Computer aided interventions. One strategy for encouraging the development of number combination skills involves computers, which can provide routine and strategic designed practise in a logistically feasible manner. The following interventions used computer strategies for children at risk and presenting with mathematical disabilities.

Fuchs et al. (2006) study aimed at examining the "Computer-Assisted Instruction (CAI)" effects in math on number combination skill. This intervention which was referred to as

FLASH, briefly presented a stimulus (a number combination for math FLASH; a word for spelling FLASH) on the computer screen of which the duration that the stimulus remained on the screen corresponded to the student's performance during the session, with higher accuracy associated with shorter durations to maintain appropriate levels of challenge and pressure on working memory. The CAI software design of the intervention was based on the following assumption: Repeated pairing of a problem stem with its answer in short-term memory should help children to commit the corresponding number combination to long-term memory for automatic retrieval.

In a study conducted by Leh and Jitendra (2013), a similar intervention to the CAI was used known as the "Computer-mediated instruction (CMI) and the Teacher-mediated instruction (TMI) on the word problem solving performance". However, this intervention differs from CAI in that even though the computer provided all instruction, the teacher operated the software and facilitated implementation of that instruction in CMI. The intervention integrated cognitive modeling to identify the problem structure with critical instructional elements (e.g., explicit instruction, providing immediate and corrective feedback) specifically targeting the needs of at-risk students. It further examined the maintenance of the word problem-solving skills across time (on a retention test) and the transfer of the learned skills to a school administered, standardized mathematics achievement test.

The "Adaptive use of approximate calculation" used in Rousselle and Noel's (2008) study on the other hand was examined using a verification task. The aim of the intervention was to encourage children to evaluate the plausibility of the proposed sum instead of rigidly engaging in a fixed calculation process hence children were tested individually in a quiet room in their school. Stimuli were presented with the E-Prime 1.1 software on a personal computer screen which consisted of 60 addition problems presented with either a correct or an incorrect answer and the 104 verification problems were presented twice in two separate sessions for a total of 208 trials.

Instructional Content Interventions. Effective instructional procedures for teaching struggling students with a compelling evidence to focus on foundation skills in early mathematics instruction are mandatory. As such, this section stipulates identified evidence-based principles of explicit, systematic instruction that should frame intervention work for struggling students in maths.

Bryant et al. (2008) study focused on the development and implementation of booster lessons of the “Tier 2 intervention” program whereas then study by Bryan et al. (2014) implemented the “Tier 3 (tertiary) intervention”. The intent of these interventions was to “boost” student learning in the area of number, operation, and quantitative reasoning by providing systematic, explicit intervention in small groups during the school day. These lessons were supplemental to core mathematics instruction, which ranged from 45 min to 60 min of instruction on the designated skill areas (e.g., measurement, problem solving) for the week. Content for the booster lessons was based on the number, operation, and quantitative-reasoning skills and concepts from the Texas Essential Knowledge and Skills (TEKS) standards. Furthermore, the study by Bryant et al. (2014) further incorporated activities (e.g., number families, part–part–whole relationships) that were designed to help students develop a conceptual understanding of addition and related subtraction facts and the mathematical properties that can be used to solve these facts along; fluency-building activities were also contained as part of the total intervention.

Strategy Instruction Interventions. For each of the intervention described below, each strategy training session involved explicit practice and feedback related to strategy use and performance.

Strategy instructions by Swanson, Lussier and Orosco (2013) “Strategy instruction and working memory capacity (WMC) on word problem solving accuracy” and Swanson, Orosco and Lussier’s (2014) “Mathematics Strategy Instruction” involved explicit instructions regarding verbal strategies that direct children to identify (e.g., via underlining, circling) relevant or key propositions within the problems, visual strategies that require children to place numbers into diagrams, and a combined strategy condition that combines both verbal and visual strategies. The cognitive intervention sessions in Swanson, Lussier and Orosco’s (2013) instruction focused on directing children’s attention to the relevant propositions within word problems related to accessing numerical, relational, and question information, as well as accessing the appropriate operations and algorithms for obtaining a solution. Instructions to focus on relevant information for solution accuracy in the context of increasing distractions related number of irrelevant propositions (sentences) within word problems were embedded within lessons. Whereas, warm-up activities related to calculation were found effective in problem-solving interventions in the mathematics strategy instruction (Swanson, Orosco & Lussier, 2014).

Contrary to the above, Fuchs et al. (2008) study implemented a “schema-based strategy instruction” which relied in schema theory. This intervention took place by means of receiving secondary preventative tutoring 3 times per week, 30 min per session, for 12 weeks. The Schema-broadening tutoring taught students to (a) focus on the mathematical structure of 3 problem types; (b) recognize problems as belonging to those 3 problem-type schemas; (c) solve the 3 word-problem types; and (d) transfer solution methods to problems that include irrelevant information, 2-digit operands, missing information in the first or second positions in the algebraic equation, or relevant information in charts, graphs, and pictures. Also, students were taught to perform the calculation and algebraic skills foundational for problem solving.

Powel et al. (2010) study aimed to assess the effects of strategic counting instruction, with and without deliberate practice with those counting strategies, on Number Combination (NC) skill among students with mathematics difficulties. This study involved teaching students the efficient counting procedures (i.e., min for addition; missing addend for subtraction). Furthermore, in this study, a no-tutoring control group against two variants of strategic counting instruction were contrasted of which both were embedded in word-problem remediation. However, in one variant, the focus on NCs was limited to a single lesson that simply taught the counting strategies (i.e., strategic counting instruction without deliberate practice) whereas in the other variant, students were taught counting strategies in the same single lesson, but then also practiced strategic counting for answering NCs for 4–6 min each.

Neuropsychological Intervention. The aim of the study by Faramarzi and Sadri (2014) was to investigate the effectiveness of basic neuropsychological interventions in improving mathematics performance of girl students (8-9 years old) with dyscalculia (mathematics learning disabilities). This intervention involved reinforcing active memory (auditory and visual memory) by doing practise with meaningless words, numbers, and recalling them. Furthermore, reinforcing attention, training executive functions such as planning and organizing, developing and reinforcing visuo-spatial perception by doing exercise associated with reinforcing eye-hand coordination as well as reinforcing the skills related to speech and language were part of the aspects in the intervention.

Table 4.3 *Data extraction*

Author and Year	Study aims	Intervention	Program description
Faramarzi and Sadri (2014)	To investigate the effectiveness of basic neuropsychological interventions in improving mathematics performance	Neuropsychological interventions	The intervention involved reinforcing active memory (auditory and visual memory) by doing practise with meaningless words, numbers, and recalling them. Reinforcing attention, training executive functions such as planning and organizing, developing and reinforcing visuo-spatial perception by doing exercise associated with reinforcing eye-hand coordination as well as reinforcing the skills related to speech and language were part of the aspects in the intervention
Re et al. (2014)	To determine the efficacy of specific, individualized training for students with different levels of mathematical difficulties	Individualized training.	The training was assessed in relation to the gains in the following fundamental calculation skills: Concept of number (numerical knowledge), automaticity in retrieving and using arithmetical facts, mental calculation and written calculation.

Table 4.3 *continued*

Author and Year	Study aims	Intervention	Program description
Bryant et al. (2008)	To examine the effects of Tier 2 intervention in a multi-tiered model on the performance of first- and second grade students who were identified as having mathematics difficulties	"Tier 2 intervention" program	To "boost" student learning in the area of number, operation, and quantitative reasoning by providing systematic, explicit intervention in small groups during the school day.
Rousselle and Noel (2008)	To examine the adaptive use of approximate calculation using a verification task with children with mathematical disabilities.	The Adaptive Use of Approximate Calculation in an Addition Verification Task	Stimuli were presented with the E-Prime 1.1 software on a personal computer screen which consisted of 60 addition problems presented with either a correct or an incorrect answer and the 104 verification problems were presented twice in two separate sessions for a total of 208 trials.
Bryant et al. (2014)	To determine the effectiveness of a systematic, explicit, intensive Tier 3 (tertiary) intervention on the mathematics performance of students	Tier 3 (tertiary) intervention	The intervention involved reinforcing active memory (auditory and visual memory) by doing practise with meaningless words, numbers, and recalling them. Reinforcing attention, training executive functions such as planning and organizing, developing and reinforcing visuo-spatial perception by doing exercise associated with reinforcing eye-hand coordination as well as reinforcing the skills related to speech and language were part of the aspects in the intervention.

Table 4.3 *continued*

Author and Year	Study aims	Intervention	Program description
Fuchs et al. (2006)	To assess the potential for computer-assisted instruction (CAI) to enhance number combination skill among children with concurrent risk for math disability and reading disability	Computer-Assisted Instruction	Intervention was referred to as FLASH, briefly presented a stimulus (a number combination for math FLASH; a word for spelling FLASH) on the computer screen of which the duration that the stimulus remained on the screen corresponded to the student's performance during the session, with higher accuracy associated with shorter durations to maintain appropriate levels of challenge and pressure on working memory
Leh and Jitendra (2012)	To evaluate the effectiveness of CMI and TMI on the word problem-solving performance of third-grade students struggling in mathematics while controlling and balancing the key instructional features (e.g., priming the problem structure, use of visual representations) deemed critical to successful word problem-solving performance across conditions. In addition, we examined the maintenance of the word problem-solving skills across time (on a retention test) and the transfer of the learned skills to a school administered, standardized mathematics achievement test.	Computer-mediated instruction (CMI) and Teacher-mediated instruction (TMI)	These measures were used because the word problem interventions are grounded in schema theories of cognitive psychology, with instruction focusing explicitly on the underlying problem structure that has shown to be effective in improving student learning

Table 4.3 *continued*

Author and Year	Study aims	Intervention	Program description
Swanson, Lussier and Orosco, (2013)	To investigate the role of WMC in strategy training in children with MD.	Strategy instruction and working memory capacity (WMC) on word problem solving accuracy	Focused on directing children's attention to the relevant propositions within word problems related to accessing numerical, relational, and question information, as well as accessing the appropriate operations and algorithms for obtaining a solution. Instructions to focus on relevant information for solution accuracy in the context of increasing distractions related number of irrelevant propositions (sentences) within
Swanson, Orosco and Lussier (2014)	To investigate the role of strategy instruction on solution accuracy in children with and without serious math difficulties (MD) in problem solving performance.	Mathematics Strategy Instruction	Warm-up activities related to calculation were found effective in problem-solving interventions in the mathematics strategy instruction

Table 4.3 *continued*

Author and Year	Study aims	Intervention	Program description
Fuchs et al. (2008)	To assess the efficacy of a secondary preventative tutoring protocol addressing math word problems at third grade.	Schema Broadening Tutoring	The Schema-broadening tutoring taught students to (a) focus on the mathematical structure of 3 problem types; (b) recognize problems as belonging to those 3 problem-type schemas; (c) solve the 3 word-problem types; and (d) transfer solution methods to problems that include irrelevant information, 2-digit operands, missing information in the first or second positions in the algebraic equation, or relevant information in charts, graphs, and pictures. Also, students were taught to perform the calculation and algebraic skills foundational for problem solving.
Powell et al. (2010)	To assess the effects of strategic counting instruction (in which students are taught the min strategy for addition and the missing addend strategy for subtraction), with and without deliberate practice with those counting strategies, on NC fluency among students with MD	Strategic Counting Instruction	This study involved teaching students the efficient counting procedures (i.e., min for addition; missing addend for subtraction). Furthermore, in this study, a no-tutoring control group against two variants of strategic counting instruction were contrasted of which both were embedded in word-problem remediation. However, in one variant, the focus on NCs was limited to a single lesson that simply taught the counting strategies (i.e., strategic counting instruction without deliberate practice) whereas in the other variant, students were taught counting strategies in the same single lesson, but then also practiced strategic counting for answering NCs for 4–6 min each

4.6. RE-AIM Framework analysis

The RE-AIM framework proposed by Dzewaltowski et al. (2004) structures the results of the study in terms of the Reach, Efficacy, Adoption, Implementation and Maintenance of the studies in the review. This is a useful tool to facilitate as well as translate research into practise by promoting the development, delivery and evaluation of interventions (Matthews, Kirk, MacMillan & Mutrie, 2014). A summary of the findings is provided in Table 6.

4.6.1 Reach

This systematic review reports on the examination of the reach of the interventions in the included studies. In doing so, it considered the percentage of potentially eligible participants that took part in the studies and their representativeness to the entire population. The study further considered the characteristics of participants.

Findings by Bryant et al. (2008), Bryant et al. (2014), Fuchs et al. (2006), Leh and Jihendra (2013), Swanson, Lussier and Orosco (2013), Re et al. (2014), Swanson, Orosco and Lusier (2014), Fuchs et al. (2008), Rousselle and Noel (2008) and Powell et al. (2010) can be generalized to the whole population as the studies used a considerable sample size of study. Furthermore, these studies were conducted in different settings with diverse cultures and backgrounds such as suburban settings, combined urban and suburban areas, and rural areas as well as with different ethnic representations such as Anglo, Hispanic, Asian, Native American Asian, and Mixed. However, there was attrition in the study by Leh and Jitendra (2013) in which one student moved during the school year and therefore did not complete the intervention. The study by Faramarzi and Sadri (2014) used a sample with predominately girl students presenting with dyscalculia thus limiting its representativeness in both gender groups; hence the findings in this study can only be generalized and may only be relevant to the sample studied.

4.6.2 Efficacy

This section reports on the effectiveness of the intervention based on the findings in the studies in achieving the desired positive outcomes. Individual administered intervention, computer use interventions, instructional content interventions, strategy instruction interventions and neuropsychological interventions efficacy are reported below.

Individual Administered Intervention. Re et al. (2014) findings in assessing the efficacy of specific training for school children with different levels of mathematical difficulty highlighted that students in the individualized training condition (both with dyscalculia and with mild math difficulties) outperformed the control groups after the training and at a later follow-up in almost all math components. As a result, this study supports the feasibility of treating both severe and mild mathematical accuracy and fluency difficulties with specific, customized training.

Computer Aid Interventions. Fuchs et al. (2006) demonstrated that the CAI was effective in promoting addition but not subtraction number combination skill and that transfer to arithmetic story problems did not occur. Spelling CAI effects however were reliable on acquisition and transfer spelling measures, with small to moderate effect sizes on transfer to reading measures. On the other hand, the findings of Leh and Jitendra (2013) suggest that word problem-solving instruction that incorporates essential instructional elements (e.g., priming the mathematical structure, using schematic diagrams) is effective and feasible for schools to implement using computers or teachers. These findings converge with prior findings that the quality of instruction rather than the learning environment is more important (Chang, Sung, & Lin, 2006; Gleason et al., 1990). As a result, findings in this study did not support the benefits of computer mediated instruction over teacher mediated instruction when controlling for critical instructional variables, rather students in both conditions performed comparably on the word problem-solving measure immediately following the intervention and 4 weeks later.

Rousselle and Noel (2008) study examined the adaptive use of approximate calculation using a verification task. The findings in the study demonstrate that children with mathematics disabilities were unaffected by answer plausibility on simple addition problems, processed implausible and correct sums with equal speed on complex problems, and exhibited a smaller reduction of the complexity effect on implausible problems. They also made more errors on implausible problems, whereas typically achieving groups were sensitive to answer plausibility on simple problems, were faster at rejecting extremely incorrect results than at accepting correct answers on complex addition problems, and showed a reduction of the complexity effect on implausible problems, attesting to the use of approximate calculation.

Instructional Content Interventions. The findings by Bryant et al. (2008) showed differential effects by grade level in the Tier 2 intervention which delivered booster lessons. For first-grade Tier 2 students (i.e students that are in need of supplemental intervention, that fall below the expected levels of accomplishment and are at some risk of academic failure), the regression discontinuity analysis did not reveal a program effect, whereas for second-grade Tier 2 students, regression discontinuity analyses showed a significant main effect, indicating a positive program effect. However, the findings from second grade are encouraging regarding Tier 2 students' ability to improve their performance with number-sense tasks, place value, and arithmetic combinations. Lessons specifically on number sense tasks (e.g., number concepts) and fluency building with arithmetic combinations apparently provided students the added "boost" they needed to become more proficient in these areas.

Bryant et al. (2014) results indicated that even the most struggling students can benefit from small group intervention that is intensive, strategic, and explicit. Results further showed significantly improved mathematics performance for most of the students, thus making them eligible to exit the Tier 3 intervention (consists of children who are at high risk of failure and in need of special education).

Strategy Instruction Interventions. The goal of the study by Swanson, Lussier and Orosco (2013) was to investigate whether working memory capacity moderates the effects of strategy training for children who have difficulty solving word problems. The findings thus indicated that children with mathematical difficulty performed significantly better under visual-only strategy conditions and children without mathematical difficulty performed better under verbal + visual conditions when compared to control conditions. Moreover, Swanson, Orosco and Lussier (2014) study demonstrated that strategy conditions did not improve the problem-solving performance in children without mathematical difficulty. However, general and specific strategy conditions allowed children with mathematical difficulty in problem solving to exceed their peers in problem-solving accuracy. These results also suggest that different processes are accessed across strategies, some drawing extensively on working memory capacity whereas others drawing less on those processes.

Fuchs et al. (2008) findings suggest the potential usefulness of schema based strategy instruction beyond students with specific math difficulty to students with substantial deficits in math as well as reading. Furthermore, they also suggest that explicit schema-broadening instruction may strengthen mathematical problem solving beyond representative populations of third graders again to students with substantial math and reading deficits. The possibility that schema-broadening instruction may be useful for students with substantial math and reading deficits is notable given that students with learning disabilities, who typically have similarly low reading and math skills, are at particular risk for difficulty with word problems.

Powell et al. (2010) study assessed the effects of strategic counting instruction with and without deliberate practice among students with Mathematical difficulties. In this study, findings indicate that strategic counting without deliberate practice produced superior number combination fluency compared to control; however, strategic counting with deliberate practice effected superior number combination fluency and transfer to procedural calculations compared with both competing conditions. Also, the efficacy of Pirate Math word problem tutoring was replicated.

Neuropsychological Interventions. Findings in Faramarzi and Sadri (2014) study indicate that the auxiliary variable, neuropsychological interventions (reinforcing attention, executive functions in planning and organizing level, working memory, language skills and visuo-spatial processing) had an effect on augmentation and mathematics performance improvement of elementary students with mathematics learning disability. The efficacy therefore of neuropsychological interventions in mathematics academic performance of children with mathematics learning disabilities reported that the performance of elementary school children with mathematics learning disabilities in neuropsychological tests (executive functions, attention, memory and visuo-spatial processing) is drastically weaker than normal children.

4.6.3 Adoption

This review further assessed the adoption of the interventions in the studies which reports the proportion and representativeness of settings. Furthermore, for assessing intervention adoption, the number of partners who were engaged in the intervention was also used as the indicator.

In the study conducted by Faramarzi and Sadri (2014), parents were included as additional program administrators for administering other exercises pertaining to the intervention. Such exercises included sports like bowling for reinforcing the child’s attention, playing hula hoop and tire for reinforcing spatial perception, playing with dolls and attention to detail for reinforcing visual precision, preparing an audiotape for reinforcing auditory precision and storytelling were introduced which were all in line with the intervention program. However, Bryant et al. (2008), Swanson, Lussier and Orosco (2013), Swanson, Orosco and Lussier (2014), Powell et al. (2010) and Fuchs et al. (2008) studies report on having tutors conduct the interventions. These tutors ranged from being teachers or educators and students. Moreover, these tutors were randomly evaluated by independent observers (a postdoctoral student, a doctoral student, or the project director). Re et al. (2014) study on the other hand reports having psychologists specializing in learning disorders as participants adopting the intervention.

Rousselle and Noel (2008), Bryant et al. (2014), Fuchs et al. (2006) and Leh and Jitendra (2013) however, did not report on any additional parties involved in implementing the program. The settings of all these intervention studies were clearly stated and described.

4.6.4 Implementation

The review also assessed the implementation of the programs. Hence this section reports on the on the consistency and skill with which various program elements are delivered as well as whether an intervention was delivered as intended in relation to fidelity, attendance, attrition.

Fidelity to intervention protocols was high but reported in only seven articles. Intervention fidelity was measured by a variety of methods including: the maintenance of a daily journal of activities undertaken in sessions (Re et al. 2014); written records of observations (Bryant et al. (2014); expert trainers/project coordinators (Bryant et al. (2008); familiarity of programs prior to intervention, random evaluation by independent observers (i.e., a post-doctoral student, a non-tutoring graduate student, the project director) (Leh & Jitendra, 2013; Swanson, Orosco & Lussier, 2014); audio tapes (Fuchs et al. 2008; Powell et al. 2010). However, there was no information provided regarding the cost of intervention implementation.

4.6.5 Maintenance

This section reports on the extent to which individual participants maintain behavior change long term and, at the setting level, the degree to which the program is sustained over time within the organizations delivering it.

From the included intervention studies, 9 studies do not report on the maintenance of the interventions both at the setting level as well as at the maintenance of behaviour change. However, the study by Re et al. (2014) indicates that the results of the follow-up assessment on a sample of the students given individualized training showed that the positive results seen after the training, were durable in most cases. Furthermore, Rouselle and Noel (2006) showed that from a longitudinal perspective, the children with mathematical dyscalculia in their sample, who had been selected 1 year earlier for their number-processing and arithmetical disabilities, are still struggling with arithmetic a year later.

Table 4.4: Summary of the findings according to the RE-AIM framework.

Re-Aim Framework

Component	Definition	Application to the Review
Reach	Proportion of the target population	There is a definite evidence that interventions for children presenting with dyscalculia are generalizable as study participants represented different ethnic groups.
Efficacy	Success rate of the intervention defined by positive outcomes	Individual administered; computer use; instructional content; strategy instruction and neuropsychological interventions supported the probability of treating children presenting with dyscalculia.
Adoption	Proportion of settings, practices and plans that will adopt this intervention	In the reviewed studies, additional participants were included in the studies to assist with the administration of the interventions such as parents, teachers, and psychologists specialized in learning disorders.
Implementation	Extent to which the intervention is implemented as intended in the real world	Fidelity to intervention protocols was high but reported in only seven articles. Cost implications regarding the implementation of the interventions was not reported in all studies.
Maintenance	Extent to which a program is sustained over time	Studies do not report on the maintenance of the interventions both at the setting level as well as at the maintenance of behaviour change.

CHAPTER 5

DISCUSSION, LIMITATIONS AND CONCLUSION

5.1 Discussion

The aim of the systematic review was to provide an evidence base of filtered information assessed for methodological quality on interventions for children presenting with dyscalculia in primary schools. These interventions are bound to be effective at maintaining and preventing dyscalculia as well as raising a public awareness about dyscalculia in the school environment. Accordingly, studies that offered customized training individually to children with mathematical difficulties assessed students' mathematical learning in relation to the gains in numerical knowledge, automaticity in retrieving and using arithmetical facts, mental calculation and written calculation (Re et al. (2014). This type of intervention has been seen as feasible in treating both severe and mild mathematical accuracy and fluency difficulties in children. However, the strategy instruction interventions in these studies provided students with mathematical difficulties the tools and techniques that they can use in order to understand and learn new materials or skills (Swanson, Lussier & Orosco, 2013; Swanson, Orosco & Lussier's, 2014; Fuchs et al., 2008; Powel et al.. 2010). One can argue that such interventions are appropriate, effective and powerful student-centered approach to teaching based on the findings of the studies. Moreover, the use of technology to enhance learning has also been seen as an effective approach for many children with learning difficulties (Lermer & Johns, 2014). Additionally, these children often experience greater success when they are allowed to use their abilities (strengths) to work around their disabilities. As a result, computer-assisted instruction interventions (Fuchs et al., 2006; Leh & Jitendra, 2013; Rousselle & Noel's, 2008) encouraged the development of number combination skills in the intervention studies, which suggested that the quality of instruction is more important as compared to the learning environment. However, even though the computers provided routine and strategic practices, the intervention study by Leh and Jitendra (2012) indicated that the computer aided instruction used teachers to operate, facilitate and implement the instructions software. Small group interventions are also of great necessity with children presenting with dyscalculia in primary school, as the instructional content interventions provided the necessary enhancement needed for the children in order for them to become more proficient in the areas such as building fluency in arithmetic combinations (Bryant et al., 2008; Bryant et al., 2014). Moreover, the neurological intervention study revealed that neurological interventions showed that reinforcing active memory (auditory and visual memory) by doing practise with words, numbers, and recalling them had an effect on mathematics performance improvement of elementary students with mathematics learning disability (Faramarzi & Sadri, 2014).

5.2. Limitation of this systematic review

The limitation of this review was on the retrieval of articles as only studies that were not in English language were excluded from the review. Additionally, due to time constraints, reference list of articles was not searched for additional studies. Furthermore, differentiating terms such as primary school and elementary school was a challenge in getting articles as some studies were regarded as primary schools starting from grade 1 whereas those that were regarded as elementary schools had their education system starting from grade R.

5.3. Conclusion

The review provided an evidence base of filtered information assessed for methodological quality using the quality appraisal tool on interventions for children presenting with dyscalculia in primary schools. Studies were comprehensively located and synthesized using organized, transparent procedures through a process of identification, screening for eligibility and inclusiveness of articles in order to minimize bias in drawing conclusions. It is in this regard that articles included at the final stage of the review have been thoroughly assessed for methodological quality on interventions for children presenting with dyscalculia in primary schools. The findings in the studies provide a base of effective interventions that can be used in the school setting in different domains and levels such as individually, holistically or through various instructions. However, more studies still need to be done with regards to the topic of dyscalculia in order to inform policy in school and enhance the development of interventions and its implementation.

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Appendix A

Title Reading Tool

Author	Date	Title and Source	Database	Location where stored	OUTCOME: Exclude/Include

Appendix B

Abstract Reading Tool

Type of Design	Study population	Instrument used	Outcomes	Quality or results of study analysis

Appendix C

Quality assessment tool for a systematic review

Bibliographic Details	Author	Title	Source

Description of Intervention Study/programme		Year

Purpose	Yes (1)	No (0)
1. Is there evidence that literature has been consulted in providing context or background?	☐	☐
2. Is a clear problem statement?	☐	☐
3. Is a clear rationale provided for the study?	☐	☐
4. Are the aims of the study clearly stated?	☐	☐
5. Are the aims explicitly related to the problem statement?	☐	☐
Total points for this section	/5	
	Yes	**No**

Study	**(1)**	**(0)**
1. Is this an intervention study?	☐	☐
2. Is the theoretical orientation of the interventions reported and described?	☐	☐
3. Was the theoretical orientation described in detail?	☐	☐
4. Did the authors report on the development of the intervention?	☐	☐
5. Were the elements of the programme reported on?	☐	☐
6. Did the authors report on the implementation of the programme?	☐	☐
7. Is there a description of fidelity to the implementation of the programme?	☐	☐
8. What is the relationship of the study to the area of the topic reviewed?		
a. Minimal to no relevance (0) ☐		
b. moderate relevance (1) ☐		
c. Highly relevant (2) ☐		
Total points for this section		/9
	Yes	**No**

Sample	**(1)**	**(0)**
1. Was the source population clearly identified?	☐	☐
2. Were the inclusion/ exclusion criteria specified?	☐	☐
3. Did the authors make a distinction between probability and non-probability in sampling?	☐	☐
Did every eligible person have an equal chance of being included in the study?	☐	☐
4. Was the sampling choice motivated?	☐	☐
5. Was the sampling frame identified?	☐	☐
6. Was the sampling method appropriate?	☐	☐
7. How were subjects allocated to the groups?		
a. Pre-existing (1) ☐		
b. Random assignment (2) ☐		
8. How was the size of the study sample determined?		
a. Not reported (0) ☐		
b. Using threshold numbers (1) ☐		
c. Formulas (2) ☐		
d. Statistical requirements (3) ☐		
9. What techniques were used to ensure optimal sample size?		
a. None (0) ☐		
b. Mortality follow up (1) ☐	/20	
c. Incentivization (2) ☐		
d. Oversampling (3) ☐		
Total points for this section		

Ethics	Yes (1)	No (0)
1. Was ethics approval obtained from an identifiable committee?	☐	☐
2. Did the authors report on obtaining access from principals, school governing bodies and education departments?	☐	☐
3. Was informed consent obtained from the participants of the study?	☐	☐
4. Have ethical issues been reported on:		
a. Confidentiality?	☐	☐
b. Anonymity?	☐	☐
c. Withdrawal	☐	☐
d. informed consent?	☐	☐
Total points for this section	/7	

Instruments	Yes (1)	No (0)
1. Were instruments clearly identified with full references?	☐	☐
2. Were specific outcomes identified?	☐	☐
3. Were instruments appropriate for the outcomes identified?	☐	☐
4. Which of the following psychometric properties were reported on:	☐	☐
a. Did they report on the psychometric properties?	☐	☐
b. Did they report on psychometric properties of the scale for this sample?	☐	☐
c. Did the authors report on the type of data produced by the instruments?	☐	☐
d. Did the instruments produce data that supported the proposed analysis?		
Total points for this section	/7	

Data Analysis	Yes (1)	No (0)
1. Was the method of analysis made explicit? 2. Was the method of analysis motivated? 3. Was the method of analysis appropriate relative to the research question? 4. Were the conclusions drawn appropriate and supported by the data? 5. Were the inferences drawn sup ported by the type of sampling?	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
Total points for this section	/5	

Results	Yes (1)	No (0)
1. Were alpha levels reported? 2. Were results correctly interpreted? 3. Were the results clearly linked to the research questions? 4. Were the results presented in a tabular form?	☐ ☐ ☐ ☐	☐ ☐ ☐ ☐
Total points for this section	/4	

Conclusion	Yes (1)	No (0)
1. Was a clear conclusion drawn? 2. Was the conclusion supported by the findings? 3. Were relevant recommendations made based on the findings? 4. Were limitations identified?	☐ ☐ ☐ ☐	☐ ☐ ☐ ☐
Total points for this section	/ 4	
Total score/Score (%):	**Score (61)**	**Score (%)**
Weak ☐ **(<40%)** ☐ **Moderate** ☐ **(41-60%) Strong(61-80%) Excellent (>80)** ☐ **(Studies will be excluded from the systematic review if the quality of evidence was rated as weak (<50%) and if the combatting of health risk behaviour was not used as an outcome of the intervention.)**		
Overall Appraisal: ☐ **Include** **Exclude** ☐ **Seek further info** ☐		

Appendix D

Synthesis Tool

Author/Title/ Journal/Source	Intervention	Study aims	Study design	Population/ sample	Setting and context	Program/ intervention description	Duration	Outcome measures	Reach	Efficacy	Adoption	Implementation	Maintenance