Teacher-directed play as a tool to develop emergent mathematics concepts – a neuro-psychological perspective

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DECLARATION

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I declare that "Teacher directed play as a tool to develop emergent mathematics concepts – a neuro-psychological perspective" is my own work, that it has not been submitted for any degree or examination in any other university, and that all the sources I have used or quoted have been indicated and acknowledged by means of complete references.

Erika Helmbold November 2014

Signed ……………………………………

ABSTRACT

TEACHER-DIRECTED PLAY AS A TOOL TO DEVELOP EMERGENT MATHEMATICS CONCEPTS – A NEURO-PSYCHOLOGICAL PERSPECTIVE

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Recent research has elucidated the sustained benefits of early mathematics instruction. With growing concern about the performance of South Africa's senior learners in mathematics, it is imperative to look at long-term solutions within the education process.

One such solution may be to focus on improved mathematics instruction as early as preprimary school. However, children at this young age are not typically suited to formal teaching. Alternative methods of mathematics instruction must be considered for maximum and effective impact.

The study was conducted to test the notion that not all early methods of mathematics instruction are equal. During the empirical research approximately 200 preprimary school children in three different socio-economic environments (urban higher SES, township and rural) were tested after experiencing a teacher-guided play-based mathematics teaching intervention, or after experiencing a worksheet-based or free-flow play-based curriculum. The test performance of the participants was primarily compared to find relations between teaching methods and early mathematics performance. The study found that a teacher-guided play-based curriculum is superior to other curriculums in the instruction of mathematics in all educational settings, regardless of socio-economic background.

KEYWORDS

Mathematics, preschool, preprimary school, early childhood, adult-guided play, teacher directed play, free-flow play, worksheets, teaching methods, emergent mathematics, play

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CHAPTER ONE

INTRODUCTORY ORIENTATION

1.1 Background

Both internationally and nationally, mathematics is recognised as a pivotal learning area from the youngest grades of schooling. According to the South African Grade R mathematics curriculum document, mathematics instruction in the foundation phase creates the link between the child's preprimary school life and life outside of school, as well as to abstract mathematics of the later grades (DoE, 2011:11). In an extensive research undertaking by Duncan and colleagues, the researchers conclude that mathematical abilities demonstrated in early years predict later learning ability, even more so with mathematics than with literacy skills and attention skills (Duncan *et al*., 2007:1428). Another noteworthy finding of the same research project is that early mathematics is a more powerful predictor of later reading achievement than early reading is of later mathematics achievement (Duncan *et al.*, 2007:1443).

Mathematics therefore remains a vital universal language that requires the attention, involvement and development of all early childhood practitioners, but can often be neglected in the exciting and more "visible" wake of literacy and language programmes (Lee & Ginsburg, 2009:40). Early childhood educators have been reported to feel more comfortable teaching reading and language than they do teaching mathematics (Copley, 2004) and often regard teaching early literacy as more important (Stipek, 2013:433).

What many teachers fail to realise is that preprimary school-age children find their own mathematical development both an exciting and enjoyable experience (Ginsburg *et al*., 2006 in Cross *et al.*, 2009:12). Spontaneous interest in mathematical actions has been noted in the lives of children as young as 1 to 3 years of age (Sinclair, 1990:28) and young children have been described as "predisposed, perhaps innately, to attend to mathematical situations and problems" (Lee & Ginsburg 2009:38).

In a preprimary school environment, it can be argued that a child should be left to self-discover and self-acquire mathematical knowledge through self-initiated play and an incidental exploration of the environment. Indeed, self-directed play can be an excellent context for the reinforcement of mathematical abilities in the child (Cross *et al.*, 2009:250). However, Ginsburg, Lee and Boyd (2008:7) propound that the self-initiated mathematical activities of children that create "teachable moments" for intentional support by teachers are unlikely to lead to an effective and comprehensive preprimary school mathematics programme on their own.

Mathematics begins with the manipulation of concrete materials, but overt mathematical experiences are also essential (De Witt, 2011:184). This idea is not a novel one, and has been proposed in literature for decades. The 1960's teacher and writer Virginia Beard stated: "not enough incidental mathematics experiences arise in kindergarten… planned mathematical experiences should occur" (Beard, 1962:22).

A child benefits more from mathematical activities if teachers are directly and intentionally interacting with the child, or if the teacher gives sufficient support to the child (e.g. through concept development, feedback and mathematical language modelling) prior to the onset of an activity (Cross *et al*., 2009:237). There is, therefore, a call for early childhood teachers to deliberately and actively assume their role in teaching mathematics to young children (Lee & Ginsburg, 2009:40).

It seems that mathematics instruction to the young child more often requires the marriage of adult direction through the elucidation of concepts and the process of a child independently and actively constructing his/her own self-knowledge. This is, in essence, embodies the constructivist approach to mathematical development (Woolfolk, 2010:311), incorporating the Vygotskian notion of adult intervention, where the adult acts as mediator who encourages and directs the child to achieve potential beyond what the child would be able to do independently (Troutman & Lichtenberg, 2003:16).

Unfortunately, the positive aspects of such adult intervention are lost if they are presented through teaching methods that are harmful or are perceived negatively by the fun-loving nature of the child. In her research, Susan Stodolsky (1985:132) explains how the choice of mathematics instruction in school affects the manner in which adults approach mathematical tasks, avoid mathematics, or believe that ability alone is the determiner of mathematics achievement. The child's early impressions of mathematics, influenced by a typically limited variety of instructional conditions, may later establish negative attitudes, expectations and conceptions of mathematics learning (Stodolsky, 1985:125). In contrast, De Sanchez (2010:132) describes how mathematical skills positively established and optimally developed in the early years of a child, determines a child's willingness to believe in the value of mathematics for everyday life and problem solving later on. The Committee on Early Childhood Mathematics of the US National Research Council (Cross *et al.,* 2009:12) state that the preprimary school period, particularly age 3 to 6, is critical for maintaining and enhancing the child's desire to learn mathematics.

The same committee also underscores the importance of early mathematical experiences for children from disadvantaged backgrounds, helping to create a more level footing between these students and their advantaged peers. Research has indicated that preprimary school children from lower socio-economic groups are not receiving a broad base of intentional mathematical instruction and are therefore entering school less prepared than their middle class peers, which translates into negative implications for their later mathematics achievement (Starkley & Klein, 2000:662).

A well-planned and adult-guided play-based preprimary school mathematics programme could be instrumental in the level of mathematical success experienced by a primary school child. The development of number sense during preprimary school has been proven to predict mathematics achievement in Grade 1 fairly well. In their longitudinal research, Jordan and his colleges demonstrate that number sense and number sense growth in preprimary school account for 66% of the variance in mathematical performance in Grade 1 (Jordan *et al*., 2007:37).
In another research project investigating the potential of early intervention and screening in mathematics, Locuniak and Jordan (2008:451) conclude that number sense in preprimary school further predicts mathematical ability throughout Grade 2 as well.

The purpose of this research study can be described as an exploration of the notion that mathematics is naturally fun for the child and lends itself to a structured and shared play experience between himself/herself and the adult, particularly if the adult has been trained in this regard. It is appropriate and actually necessary that the teacher and the child repetitively, enthusiastically and practically “play” mathematics together in all Grade R classrooms, and that new mathematical concepts are introduced in a playful way. The purpose of the Grade R mathematical curriculum should include the playful introduction of pre-numeracy skills that will lay a solid foundation for the cognitive understanding of the child. This approach is possible within the mire of challenges facing South Africa’s preprimary school children, regardless of their diverse and unique socio-economic backgrounds, urban or rural settings and extreme diversity within these settings.

1.2 Problem analysis

The following section contains an analysis of the problem. It begins with an explanation of current concerns in the field of South African mathematics and elaborates on the context of this study. It includes an exposition, exploration and formal statement of the problem.

1.2.1 Exposition of the problem

When considering South Africa’s performance as a whole in the area of mathematics, the results over the past few years have been most discouraging. In a recent World Economic Forum Report, South Africa was ranked 143rd out of a possible 144 countries for its quality of mathematics and science education (Bilbao-Osorio *et al*., 2013:261). South Africa’s performance in TIMMS (Trends in International Mathematics and Science Study) 2011 was also quite alarming. The country’s scores for Grade 8 mathematics ranked among the bottom six countries assessed, and fell considerably below the low-performance benchmark (HSRC, 2011:4). The same report describes how the most competent of South African pupils were only average when compared in their performance to pupils from Singapore, Chinese Taipei, the Republic of Korea, Japan, Finland, Slovenia and the Russian Federation (HSRC, 2011:5).

Glancing back over the last three years, in 2011, the mathematics pass rate in matric dropped more than a percentage from 2010 to 2011 and a Business Day report on the matter describes the Department of Education as “remaining concerned” about mathematics matriculation results (Anon., 2012). Similarly, the results of the 2012 National Senior Certificate examinations were disconcerting, with only 35.7% of learners who wrote mathematics achieving 40% and above (DoE, 2013a:120), and according to the 2014 diagnostic report (DoE, 2014a:125), only 40.5% of students achieved 40% or above in their 2013 matric mathematic results. Although this is an improvement on the previous two years, the results still translate into worrying figures for the country as a whole.

Although the overall matric pass rates have been promising over the past three years, mathematics is one of the subjects that South Africa cannot boast about. This may lead one to question the overall value of our general matriculation scores. University of Free State vice-chancellor and rector, Jonathan Jansen, is quoted in an article in the Times (Anon.,2014e), as expressing his concern at reports describing overall positive matriculation results, as he believes these results contradict the reality of the performance of South African students in the international arena, particularly in the area of mathematics and science. This imbalance, he believes, is creating scepticism about the value of using matric pass rates in measuring South Africa’s success in secondary education.

A further concerning trend in matriculant mathematic results is the decline in the actual number of students sitting to write the mathematics paper (DoE, 2014a:125). The figures in this regard have dropped from 263 034 in 2010 to 241 509 in 2013. An article in the Mail and Guardian (Campbell & Prew, 2014) expresses concern over the issue and describes how owing to the decrease in numbers of learners who are sitting for mathematics examinations, fewer learners will be able to enter critically needed mathematics-related tertiary fields of study.
This trend is also reflected in the number of students who are opting to replace Mathematics for the so-called easier subject of Mathematics Literacy, the popularity of which is growing dramatically, as can been seen in the increase in the number of students sitting – an increase of 43 261 from 2010 to 2013 (DoE, 2014a:159).

According to a newspaper report by Carien Kruger (2012b), international test results reveal that the average national mathematics results of South African pupils in Grades 3, 4, 6 and 8 is found to be between 30% and 40%. The same article highlights the fact that, unlike other subjects where results can be improved on through time, these results are more permanent. The journalist proposes that grass roots changes are required as young as Grade R for these results to show a significant shift. It is mentioned in the same article that in an international test administered in 2012 by the Southern and Eastern African Consortium for Monitoring Educational Quality (SACMEQ), even South Africa's top students are being bested by students from other countries in Africa.

In a similar article (Kruger, 2012c) Jurg Basson, a former lecturer at Rand University and a mathematics specialist who was consulted for the article in his professional capacity, attested that the mathematics syllabus needs to be more challenging for South African pupils. This is essential to create an internationally comparable standard. Aarnout Brombacher, a second consultant in the article, believes that attention should also be given to making mathematics meaningful and focused on problem solving, rather than the memorisation of facts, rules, formulas and procedures.

According to the South African Education Department's reported findings regarding the Annual National Assessments, the average percentage scores of South African Grade 3 pupils for 2011 mathematics stood at 28% (DoE, 2012b:20). In 2012, this figure improved significantly to 41%, but it is still far below "adequate" expectations for the subject at this level (DoE, 2013b:23-24). This report on 2012 assessments showed a decline in learner performance in the subject in Grade 6 from an average of 30% in 2011, to 27% in 2012 and a "worryingly low" performance of 13% at a Grade 9 level in 2012.

Annual National Assessment mathematics figures have shown some increases in the foundation phase grades in 2013 (DoE, 2014b:3), yet the higher grades still produced worrying results, levelling off at the disturbing average of 14% in Grade 9 in 2013.

1.2.2 Preliminary exploration of the problem

Although there is sufficient evidence that South Africa is in a crisis regarding mathematics performance in the higher grades, the Department of Education is, satisfied that it is on track with strengthening mathematics performance in the younger grades based on comparative ANA findings.

The 2014 departmental report on the Annual National Assessments (ANAs) of 2013 claims that due to recent efforts made by the Department of Education to "strengthen basic skills at the foundation phase" there are signs that these interventions are having an overall positive impact, which the department views as encouraging (DoE, 2014b:4).

The credit, therefore, apparently goes to the attention that the Department is giving to mathematics education for the younger grades in recent years, and the believed pay-offs are beginning to reflect in the upward trend of Annual National Assessment (ANA) scores in the foundation phase. However, results of these ANA scores have come under some scathing criticism recently.

In an article in *Teacher's Monthly*, Dr Malcolm Venter describes the comparisons based on ANAs and the advances suggested by these comparisons as "largely meaningless" (Venter, 2013:2). He cites a variety of reasons for his argument, some of the most compelling being that the ANA tests were written in completely different times of the school year between 2011 and 2012, and that the reliability of the ANA tests is questionable due to the lack of an independent external verification processes, with teachers administering and marking their own tests. In addition to this, if the Department's claimed improvements in the younger grades are pitched against TIMMS, Grade 3 pupils in South Africa have managed to improve more in a single year than Columbian pupils have accomplished in twelve years. If one keeps in mind that Columbia is the fastest improving country in the TIMMS study 1995-2007 (Venter, 2013:3), the South African improvement in the ANA scores in the younger grades is virtually impossible.

The Department itself acknowledges the limitations of different ANAs being administered each year, making comparisons in performances from year to year quite difficult (DoE, 2014b:28). Further arguments against the accuracy of ANA findings for the foundation phase are cited by economists Van der Berg and Spaull (John, 2012). According to these economists, the improvements in ANA scores for the younger grades are not plausible, both locally and internationally.

Mary Metcalfe, former higher education director general and MEC for Education in Gauteng, has warned that we need to exercise caution in examining the ANA results, first establishing their credibility before using them as a foundation for system improvement (Venter, 2013:5).

An earlier and arguably more accurate South African benchmark of mathematical performance in the foundation phase can be found in the research conducted through the University of Stellenbosch in their National School Effectiveness Study (NSES). In this project, data were collected between 2007 and 2009 on a nationally representative sample of schools in South Africa. The study concluded that in 2007, the mean achievement for numeracy in Grade 3 was 28.42% (Taylor, 2011:9). This figure is a far cry from the proposed Grade 3 figures of the ANAs for 2013 – even when taking plausible educational growth rates into consideration. Again, it is unlikely that South Africa is improving at this phenomenally fast rate, meaning the accuracy of the 2013 Grade 3 ANA scores is in doubt (Spaull, 2013).

In light of these arguments, great caution is exercised in using the ANA scores as an accurate indicator of the so-called healthy status of mathematics performance in the foundation phases of South Africa's schools. Even if one is to believe that the Department's attention to early mathematics education is paying off, there seems to be very little to no research available on the performance of our Grade R pupils in the area of mathematics. There is also very little documented research into the most effective didactic approach to teaching mathematics in South African schools in the year prior to formal schooling. Preliminary qualitative investigation into this question reveals that approaches to teaching mathematics at a preprimary school level varies from incidental (no structured teaching) to exceptionally formal (workbook-type work).

As the Department does not yet recognise Grade R as a compulsory schooling year and will more than likely not do so until 2019 (Louw, 2013), there is little controlled enforcement of the prescribed CAPS mathematics syllabus in South African preprimary schools, which effectively translates into vast differences in the approaches of schools and teachers to the teaching of the subject in this reception year.

Based on the above arguments, it would therefore be premature to attribute the so-called upward mathematical trends in the early Grades (ANA findings) to mathematics instruction through CAPS implementation in Grade R, as this implementation is extremely varied and unmonitored. This leaves one to further argue that research needs to be undertaken into the best possible approach to teaching mathematics in this vulnerable year of schooling.

Another facet of the overall problem that needs investigation is the fact that South African teachers are ill-equipped to teach mathematics to their pupils from Grade R upwards. Nicholas Spaull, a researcher in economics at the University of Stellenbosch, believes that this particular fact is one of the biggest challenges facing education in South Africa today (Kruger, 2012a). While describing South Africa's poor teacher performance, he isolates three particular problems that need attention, namely the challenge of laying a solid foundation, ironing out inequalities and improving accountability.

The same article suggests that less than 40% of South African teachers know the correct answer to questions on Grade 6 mathematics question papers. There are, however, quite diverse results for teacher performances in Grade 6 mathematics papers between schools in higher socio-economic categories compared to schools from poorer areas. This underlines the importance of teacher competence and training, particularly in the area of mathematics, and even more so in rural or less-advantaged areas.

In his article for the Volksblad entitled "Wiskunde op skool kan beter" [Mathematics at school can be better] (Jansen, 2012), Jonathan Jansen proposes that instead of testing pupils through Annual National Assessments, teachers should be tested to determine their competence in teaching mathematics to their pupils. In addition to this rather radical proposal, he makes several other contentious suggestions, including an annual month-long intensive teacher training programme preparing teachers to tackle the content as well as the pedagogical aspects of mathematical instruction. He proposes that this approach should be closely monitored, possibly by competent mathematics mentors, to ensure that teachers are applying principles acquired through training.

This idea of tackling teacher incompetence is further expounded by Nan Yeld, the dean of the Centre for Higher Education Development at the University of Cape Town (Yeld, 2012). Yeld states that “the major underlying problem (is) many teachers’ lack of knowledge about what they teach.” She describes how mathematics education systematically builds from one grade level to the next and highlights that there is a dire need for increased teacher knowledge, rather than quick fix approaches like workbooks or test item exemplars. She also attests to the fact that national benchmark test results reveal a consistent picture of low academic performance in South African pupils, and the “situation in respect of mathematics is the most dire”.

These expressed concerns demand the attention of educators and clearly demonstrate the problem educators face in improving the mathematical standard from the foundation phase upwards. Our children deserve the best we can give them, and this may require rethinking the presentation of subject material, especially at the introductory level of Grade R. If high correlations between mathematics skills at school entry and academic success in later grades have unequivocally been established (Bodovski & Farkas, 2007; Duncan *et al*., 2007; Jordan *et al*., 2009), it stands to reason that poor results in the later grades, and ultimately the poor mathematics matriculation results of South African pupils, could be remedied with a serious overhaul and improvement of the performance of pupils in mathematics at school entry level. In their work on the feasibility of a rigorous preprimary school mathematics curriculum, Chard and his researchers state that “another contributor to later mathematics difficulties may simply be a missed opportunity to develop young children’s mathematical understanding early” (Chard, 2008:12).

In the school environment, mathematics instruction is often taught with a “drill-and-kill” strategy. This, together with the fact that many preprimary school teachers are phobic regarding mathematics instruction, results in the avoidance of mathematics teaching altogether, or the use of very ineffective teaching methods (Stipek, 2013:433). Observation and general discussion with practitioners in the field brings one to the conclusion that the general approach to mathematics education in South African Grade R settings is either to ignore the subject completely and rely on the child's ability to self-construct their knowledge through child-initiated play, or to expect the child to grasp mathematical concepts through static, two dimensional worksheet-type or workbook work.

When considering the worksheet approach, Professor Sue Grossman (1997:1-4) from Eastern Michigan University describes how this approach is developmentally inappropriate for young children and does not encourage children to feel competent at taking risks in problem solving. She believes that a child's ability to complete a worksheet task does not signify the child's ability to comprehend a mathematical concept. She further describes how worksheet-type work can have detrimental consequences to a young child's emotional, social and physical well-being, in contrast to a variety of alternative and more interesting ways for children to understand mathematics and numbers. Ultimately, Dr Grossman proposes that there are two fundamental problems with worksheet-type work, namely that young children are not learning from them as parents believe they do, and that children are not spending their time with endeavours that would serve to benefit them more.

The argument against a worksheet-type approach is also explored by Van de Walle (2011, cited in De Sanchez, 2010:130), who explains how number understanding cannot easily be acquired through the completion of worksheets. He also confirms how worksheet-type work does little for the development of new ideas, concepts or skills.

The idea of worksheet type work being "developmentally inappropriate" is confirmed by De Sanchez (2010:133). Mathematical worksheets at a young age are not taking the child's own symbolic representation of mathematical ideas into account. De Sanchez argues (2010:135) that worksheets are the incorrect way of providing a context for children to print numbers, and do not signify a child's ability to abstract or understand number concepts. De Sanchez subsequently postulates that worksheet-type work does not facilitate mathematical development in the young child.

The worksheet or workbook approach for Grade R is, however, advocated by the Department of Education in the official CAPS document. It is stated herein that "in order to reinforce learning, written work (work book, work sheet examples, work cards etc.) should form part of the group session where possible. Learners should have writing materials (class work books, etc.) available for problem-solving activities" (DoE, 2011:12). The workbook and graded worksheet idea is further promoted in the CAPS document as one of the first alternatives a preprimary school teacher should use when selecting an independent mathematical learning activity (DoE, 2011:13).

Regardless of the didactics of teaching advocated, be it the worksheet approach or play-based approach, one has to acknowledge that the content and skill expectations for mathematics outlined in the CAPS document for Grade R is both impressive and extensive. CAPS does not ignore the idea of a physical and concrete introduction to mathematics instruction, as seen in its proposed daily lesson plans, but it remains questionable if the truly playful/games aspect of mathematics is captured by these lesson proposals. In addition, many teachers are still at a loss as to how to teach these concepts in an enjoyable and appealing way that will lead to optimal mathematical competence in the Grade R child.

Is the child-initiated free-play approach, or alternatively, the formal "worksheet/workbook approach" predominant in many South African preprimary schools truly the most idyllic and fruitful foundation for mathematical development for our children? And how are we to equip teachers to introduce a more play-based yet adult-guided approach?

1.2.3 Research question

After examining the research problem through a preliminary research study, it became apparent that an examination into the pedagogics of early foundation mathematics instruction in South Africa is required. It is evident that South Africa is facing an overall crisis within the area of mathematics instruction and that there is insufficient research into the performance of our preprimary school children in mathematics or the impact of preprimary school mathematics teaching on the academic success of South African students in later grades.

Thus, the research question for this study is formulated as follows:

Will the introduction and implementation of an adult-guided play-based mathematics curriculum in Grade R significantly improve the South African preprimary school child's understanding of foundational mathematical concepts at their time of entry into Grade 1?

The global hypothesis states:
There will be a statistically significant difference between the averages (means) of the test scores of South African preprimary school children when tested on their understanding of foundational mathematics concepts at the time of entry into Grade 1, between children who have been taught using an adult-guided play-based mathematics curriculum and children who have had no formal mathematics instruction or only workbook-type instruction in Grade R.

1.3 Aim and objectives of the study

The primary purpose of the research is to determine if an adult-guided and structured play-based mathematical programme, focusing on developmentally appropriate pre-numeracy skills, significantly improves the preprimary school child's understanding of mathematical concepts upon entry into Grade 1.

The overarching aim of the study can be subdivided into the following specific research questions:

- Is the outcome of the primary research question significant for specific regions in South Africa?
- Can we gain insight into the child's understanding of mathematics concepts as a whole through reviewing previous studies and literature?
- What is the ideal pedagogical and developmentally appropriate approach to teaching Grade R children mathematics in South Africa, and can this be determined by means of a literature study, qualitative research and an empirical study?
- What are the benefits of a workshop-type training approach for pre-school teachers in South Africa?

- What are the feelings and thoughts of teachers who are attempting different approaches to teaching Grade R mathematics?
- In which ways can we equip and inspire teachers to re-examine their teaching methods and to make the necessary adjustments to meet the mathematical needs of the young child in different communities?
- Which particular areas in pre-mathematics are most impacted by the intervention programme?

1.4 Research design and method

The research design of this study is based on a combination of macro-methodologies. Firstly, a descriptive/interpretive method is employed in that the researcher seeks to describe, analyse and interpret the current circumstances, relationships and needs related to the problem by using a small sample size and doing an in-depth analysis through teacher interviews (Basit, 2010:14).

A second methodology is employed in the use of a positivist/experimental method. The researcher will establish the influence of the changes in the independent variable (in this case, the implementation of an adult-guided play-based mathematical curriculum), on the dependent variable (the performance of Grade R learners in a mathematical test once an intervention programme has been completed) (McMillan & Schumacher, 2010:21). Control and test groups are selected from similar geographical areas and backgrounds.

Overall therefore, the research follows a mixed method design, combining qualitative and quantitative data for a more enriched and elaborate understanding of the research phenomenon (McMillan & Schumacher, 2010:395). Within this mixed-method approach, both a sequential explanatory design and a concurrent triangulation design are considered, as data obtained from teacher interviews are utilised for elaborating and enriching quantitative research findings. This also allows the researcher to infer more credible conclusions – as data originate from two different research methods (McMillan & Schumacher, 2010:401-403).

Within the specific experimental research design, a quasi-experimental quantitative design is selected, which approximates a true experimental design, but does not utilise a random assignment of subjects, as subjects are already assigned to specific classes and schools (McMillan & Schumacher, 2010:22).

1.4.1 Literature study

According to Mouton (2001:87) a literature review should focus the researcher on finding out what has already been done in the field of study, learning how other scholars have theorised and conceptualised issues, their empirical findings, their choice of instrumentation and to what effect these have been used. Mouton further describes it as an attempt to uncover the most recent, credible and relevant scholarship in one's field of study.

The literature study included as part of this study strives to uncover the most ideal approach to teaching mathematics to young children and the types of mathematical skills which can be regarded as essential in the foundation of early mathematical understanding. Many sources, including published books, journal articles and electronic sources available on the Internet, were utilised to obtain an understanding of the nature and meaning of the problem stated.

1.4.1.1 Empirical research

The empirical study is conducted through a pen-and-paper standardised test, intended to determine if the introduction and implementation of an adult-guided play-based mathematics curriculum in Grade R significantly improves the preprimary school child's understanding of basic pre-mathematical concepts at their time of entry into Grade 1, compared to control group participants who have no such curriculum exposure.

1.4.1.2 Qualitative research

For the qualitative aspect of the study, data are gathered through teacher interviews designed to collect hitherto unexplored information on the issue of a Grade R teacher's emotional and cognitive knowledge regarding mathematics teaching and to highlight certain phenomena by means of this tool (Basit, 2010:100).

1.4.1.3 Ethical measures

Ethical clearance was obtained from the ethical clearance committee of the University of South Africa (see addendum A).

It was of extreme importance that the well-being of participating teachers and pupils be respected throughout the research project. Measures were taken to ensure children and teachers involved in the study were exposed to minimum risks. Participants were informed verbally and in writing that their participation is voluntary and they could exercise their right to withdraw at any time without penalty.

1.4.1.4 Voluntary informed consent

Teachers participating in the study were required to do so only after signed voluntary consent was obtained. School principals were also asked to provide signed voluntary permission for research to be undertaken in their schools.

Parents of the test and control groups were informed about the intended study through letters. In the letter, the nature, duration and risks associated with the research undertaking were clearly elucidated. Parents were asked to give their signed, voluntary consent for children to participate in the research. Children were required to indicate their consent to the study on forms presented to them before testing commenced. These forms, explaining the testing procedure in child-oriented language, were read to the children and they were invited to choose to participate through a simple crossing of a block on the form.

Parents and any other interested parties were invited to review the research programme and findings at any time if interested.

1.4.1.5 Confidentiality

Individual research findings of children are treated with confidentiality and anonymity in the publication of research findings. Access to individual results was provided to the principals, teachers and parents of the child. Only the individual results of children within a particular school were given to the principal and teacher of that school, and not individual results of learners from other schools. Research results on the mean comparative performance of a particular school were made available to the school, but the names of all other participating schools was kept confidential in the findings.

Potential use of interview data captured was explained to the teachers. Personal comments were kept strictly confidential and were not disclosed at all to principals, parents or pupils. Measures were in place during data processing and publication to protect the identification of participants.

1.4.1.6 Measures to ensure reliability/ validity and trustworthiness

Within the quantitative aspect of the research, the following factors were taken into consideration regarding reliability and validity:

- Construct validity: McMillan and Schumacher (2010:115) propose three particular threats to construct validity, namely the inadequate preoperational explication of constructs, the mono-operation bias and the mono-method bias.

  In terms of the explication of constructs, pedagogical approaches advocated by the proposed study, as well as the concepts falling within the scope of the study, were clearly defined. The collection of data were limited to the definitions provided in the literature review.

  The mono-method bias was compensated for with the mixed-method design, combining quantitative data with qualitative data obtained.

- Test situation: the children in test groups and control groups were subject to similar, standardised test environments.

With regard to both the qualitative and quantitative research, the following factors were considered to strengthen the internal validity of the research (McMillan & Schumacher, 2010:115):

- The composition of the control group and the test groups were similar with regard to their socio-economic status, geographical location and availability,
- Contained intervention was followed in that the control group had no known exposure and carried no known knowledge similar to the participants of the intervention programme.
- As no pre-test was administered, the possible negative bias created through pre-test administration was avoided.
- On a small scale, maturation effects were accounted for in that the test administered was broken down into 20 minute intervals with 5 minute breaks to ensure optimal concentration. On a larger scale, both the control group and test group subjects experienced growth and change, therefore these influences should not have affected data, as collection was conducted within the same time-span between control and test groups (i.e. the same day or within the same week).
- Subject effects were minimised due to the use of a local interpreter and the presence of the child's teacher during testing. Interviews were conducted in naturalistic settings, allowing subjects to feel quite relaxed in their participation.

The external validity (McMillan & Schumacher, 2010:116) of the study was considered in that the overall average population of South African preprimary school children (age and general socio-economic variables) was taken into consideration and the sample taken for research closely matched this general population.

1.4.1.7 Method

The following methods were used to obtain necessary data for the study:

- **Sampling**

According to Children Count South Africa, approximately 70% of South Africa's children live in the poorest 40% of households (Hall & Meintjies, 2013). Based on these findings, approximately 70% of the research sample in this study was taken from known underprivileged geographical areas, so that the research findings can be generalised more accurately to the overall Grade R population of South Africa.

For the quantitative aspect of the research, a sample size of approximately100 (test group children) and 100 (control group children) was selected. The teachers of these children constituted the smaller sample for the qualitative research.

Purposive and proportional stratified sampling was employed, allowing subgroup comparisons (McMillan & Schumacher 2010: 139) in that approximately 30% of the overall sample of 200 children was selected from schools in an urbanised township region (Kwa Thema). 40% of the overall sample was selected from schools in a rural region (Limpopo, Bolebedu South, Fobeni Village). The remaining 30% of the sample was selected from schools in an urbanised city (Kempton Park region). Schools from these regions had recently implemented an adult-guided play-based curriculum in their schools in 2014, after undergoing extensive workshop-based training in this regard. A list of these schools was provided to the researcher (information provided by the workshop facilitator). The number of schools that had undergone training conveniently fell within the proportionate quota sampling scope, in that the percentages of schools represented matched the pre-selected percentages for representation of rural, urban and urbanised township regions. These schools formed the core of the test group sample.

Sampling was also purposive as subjects had to have certain characteristics (McMillan & Schumacher 2010: 138). These characteristics were determined through introductory interviews and preliminary investigations confirming that the schools in the test group were indeed implementing an adult-guided play-based Grade R mathematics curriculum.

For the control group, sample schools were selected from schools that do not follow the above-mentioned curriculum. Snowball sampling was used to gather control group schools from the same regions as test group schools (McMillan & Schumacher, 2010: 327).

- **Data collection**

For the quantitative aspect of the study, data were collected through a standardised pen-and-paper test administered to research subjects at the end of the third school term of 2014. Both control group and test group participants were subjected to the same test. An ANOVA test was used to determine the statistical differences between the sample means of the test and control groups.

Qualitative data were obtained through prepared interviews for participating teachers based on a set of predetermined questions used as a guideline to glean relevant information for the topic (see chapter 3).

- **Data analysis**

The process of qualitative data analysis should result in the presentation of objective findings, initially summarising what is found without interpretation or discussion (McMillan & Schumacher, 2010:29). Qualitative data are analysed through two broad processes, namely data preparation through editing, coding and data capturing, and then data summation and reduction through tabulation (Tustin *et al*., 2005:451).

Quantitative data analysis was undertaken through ANOVA tests to determine the level of statistical significance of the differences between the means of the control and experimental groups from various regions.

1.5 Elucidation of concepts

To ensure common understanding in the discussion, concepts are defined below before commencing with the literature study.

1.5.1 Grade R

The year before formal schooling in South Africa, also known as the reception year. The Department of Education recognises a Grade R pupil as a child of four years, turning five or older by 30 June (DoE, 2014c).

1.5.2 Language Modelling

This refers to a practice by adults when they converse with children. They ask open-ended questions, repeat or extend children's responses and use a variety of words, including more advanced language. It is also a process of building on words the children already know (Cross *et al*., 2009:353).

1.5.3 Developmentally Appropriate Practice (DAP)

Educational practice based on guidelines provided by the US National Association for the Education of Young Children (NAEYC) on appropriate educational practice for young children ages birth through age eight, relative to their current and future development (Charlesworth, 1998:274).

1.5.4 Structured play

Structured play refers to play in which the resources are planned by the adult with specific intended learning outcomes in mind based on assessment of the learning needs of children (Duncan & Lockwood, 2008:88). For the purposes of this research project, guided play has been used synonymously with structured play, yet a distinction is often made by various authors in that guided play is even more adult-directed. Duncan and Lockwood (2008:89) further define guided play as play in which "the activity is chosen by the adults with very specific activity and learning outcomes in mind; the child is given a goal."

1.5.5 Free play

Duncan and Lockwood (2008:87) term free play as free-flow play. They describe it as "activity (that) is self-initiated, freely chosen, free from any external imperatives, is intrinsically worthwhile, is flexible following entirely the player's agenda, a process that is open-ended, with no predetermined outcomes, involves active engagement and is enjoyable for the individual."

1.5.6 National Curriculum Statement (DoE, 2011)

As of 2012, the National Curriculum Statement is a policy statement for learning and teaching in South African schools and comprises the Curriculum and Assessment Policy

Statements (CAPS) for all approved subjects and the national policy pertaining to the programme and promotion requirements of the National Curriculum Statement Grades R-12 and the National Protocol for Assessment Grade R-12.

1.5.7 Active learning

A broad term referring to a variety of instruction models that focus the responsibility of learning on learners (Anon, 2013a). Characteristics include the active involvement and engagement of students; less emphasis on information transmission and more on skills development; more utilisation of higher-order thinking skills; engagement in activities and more emphasis on exploring attitudes and values. Students do things and think about what they are doing (Bonwell & Eison, 1991:2).

1.6 Demarcation of the study

This study entails both a qualitative and quantitative investigation into the impact of an adult-guided play-based mathematics curriculum in Grade R, on the preprimary school child's understanding of foundational mathematical concepts at their time of entry into formal schooling. The research is undertaken in schools in Kempton Park and Kwa Thema in Gauteng Province and Bolebedu South, Fobeni Village in the Limpopo Province. A broad sample of learners in Grade R is investigated and a small sample of Grade R teachers is involved in the study.

1.7 The research layout

Chapter one provides an introduction and overview of the study, including the statement of the research problem, an elucidation of the main concepts and a brief discussion on research methodology.

Chapter two provides an understanding of the conceptual framework guiding the research in this study.

Chapter three presents a literature review of the pedagogical approaches to teaching Grade R mathematics and recent research into the field. It includes an overview of:

- Pre-mathematics concepts,
- Neurology and the effect of early stimulation on developing mathematical concepts,
- Which approaches to teaching mathematics in preprimary school are regarded as ideal by researchers in the field,
- Why should we begin mathematics education as early as preprimary school?
- What content should be included in a so-called pre-mathematics syllabus?

Chapter 4 presents the research design and methodology.

Chapter 5 presents results and discussion of study findings.

Chapter 6 presents a summary of the study and conclusions, recommendations and possible limitations.

1.8 Conclusion

This chapter provided a background to the study. It presented the research problem and expanded on the study's aims and objectives. Certain terms used in the dissertation were defined, and the research methodology was briefly introduced. The chapter concluded with a study layout. The chapter to follow incorporates a conceptual framework employed as a platform for the study.

CHAPTER TWO

CONCEPTUAL FRAMEWORK

2.1 Introduction

According to McMillan and Schumacher (2010:74), research should be placed into a general conceptual framework or theoretical orientation. This provides justification for the subjects, variables and design of the research, and provides a basis for the interpretation of research results since it is seen in light of a particular theory. A conceptual framework also provides the logical link between research questions and methodology.

Should a study draw on a theoretical framework, this framework needs discussion and clarification as to its relevance to the research (Basit, 2010:207). Furthermore, this theoretical framework needs to guide the researcher, act as a structure, scaffolding and a frame for research (Merriam 1998:45-46, cited in Basit 2010:40).

2.2 Theories and models guiding educational research

There are multiple theoretical arguments surrounding teaching and learning that are constantly being debated and utilised by educational researchers (Basit, 2010:38). These theories are often argued, modified, developed and refuted through further quality research.

For the purposes of this research study, the discussion of the theoretical framework has been limited to theories regarded as pertinent and relevant to the specific research problem:

Will the introduction and implementation of an adult-guided play-based mathematics curriculum in Grade R significantly improve the preprimary school child's understanding of foundational mathematical concepts at their time of entry into Grade 1?

2.2.1 Constructivism

Constructivism is a theoretical approach rooted in the view that meaning is constructed by the learner (O'Donnell, 2012:61). This approach primarily centres on the work of Piaget, Vygotsky, Bartlett, Bruner, Rogoff and Dewey (Woolfolk, 2010:310).

Constructivism is a broad, umbrella term encompassing a variety of specific theories, the commonalities of which rest on the following basic ideas (Woolfolk, 2010:311; O'Donnell 2012:61; Bohlin *et al.*, 2012:368):

- Learners are active and central in constructing their own knowledge.
- Social interactions are important in knowledge construction, and the community plays an important role in learning.
- Authentic tasks and tools are used to support learning (scaffolding).
- Knowledge is constructed by the learner and influenced by the learner's previous experiences.
- Teaching methods are considered student-centred.

2.2.2.1 Piaget's theory of cognitive development/Theory of genetic epistemology

Perhaps one of the loudest voices resonating through the annals of educational theory is that of Swiss psychologist Jean Piaget.

Piaget devised a model describing how humans make sense of their worlds through the gathering and organising of information (Woolfolk, 2010:31). According to Piaget's theory, a child's cognitive processing differs significantly from that of an adult. These processes change as the child matures and strives to make sense of the world. With increased learning and maturation, thinking grows more differentiated and specialised in various domains (Sternberg, 1999:436).

Piaget's theory incorporates the interaction of both nature and nurture in the development of human knowledge (Bohlin *et al*., 2012:119).

According to Woolfolk (2010:32) and Bohlin *et al*. (2012:119), Piaget identified four factors that interact to influence changes in the thinking process, namely biological maturation, activity, social experiences and equilibration.

<u>Biological maturation (nature)</u>

This refers to the unfolding of biological changes that are genetically programmed (Woolfolk, 2010:32) and is regarded by Piaget as one of the primary influences on the way we make sense of our world. It implies a biological "readiness" to learn from social experiences and active exploration. This aspect is beyond the influence of teachers or parents, with the exception of the physical care and nourishment a child needs to remain healthy.

<u>Active exploration of the physical environment (nurture)</u>

As children matures their ability to act on the environment and to learn from these actions increases. The child explores, tests, observes and organises information through acting on the environment. Children also discover principles and alter their thinking processes through this active exploration.

<u>Social Transmission (nurture)</u>

Piaget believed that development occurs simultaneously with interactions between the child and the people in such a child's world. Cognitive development is influenced by social transmission and learning from others. Social transmission is, however, dependent on the child's stage of cognitive development. Piaget advocated that interaction that includes the exchange of ideas and cooperation between peers is more effective than the social transmission that occurs between adults and children (Bohlin *et al*., 2012:120).

Equilibration or self-regulation

This refers to the notion that there is an inherent search for balance within a person while that person organises or adapts to the information received from the environment. The adequacy of thinking processes is constantly being tested to obtain a feeling of comfort or equilibrium.

Organisation

A child is born with an inherent tendency to organise thinking processes into psychological structures. These structures form systems for the child to understand and interact with the world. Simple structures are continually combined and coordinated to improve their sophistication and efficiency. Piaget refers to these structures as schemes, and he views them as the basic building blocks of thinking. Schemes are "organised systems of actions or thought that allow us to mentally represent or think about the objects and events in our world" (Woolfolk, 2010:32).

Schemes can vary in size from the small and specific e.g. "recognising-a-dog scheme" to large and general e.g. "pet care scheme". As thinking becomes more organised, more schemes develop and behaviour becomes more sophisticated and better suited to the environment.

If a person applies a scheme to an event or situation and the scheme works, then the person experiences a state of comfort (equilibrium). If the scheme does not work, the disequilibrium felt is uncomfortable and motivates the child to use the processes of assimilation or accommodation to change his or her thinking.

However, levels of disequilibrium have to be optimal to result in changes in thinking. Excessive disequilibrium creates discouragement and anxiety, both of which are not conducive to change, while too little disequilibrium results in disinterest, which does not motivate change either (Woolfolk, 2010:33).

Adaptation

Piaget believed that humans have a tendency to adapt to their environments through assimilation or through accommodation.

Assimilation occurs when a person uses their existing schemes to understand and make sense of their environment. It is a process of trying to understand something new by fitting it into something that is already known. In the world of a child, this may result in distorting new information in an attempt to make it fit into an existing scheme e.g. a child calling a squirrel a dog, as the child has a pre-existing "dog scheme" of an animal with four legs and a tail.

Accommodation occurs when the person must create a new scheme or change their existing scheme to respond to a new environmental situation. Thinking is adjusted to fit the new information instead of the other way around. Accommodation would occur for example when a child creates a completely new scheme for identifying squirrels.

<u>Piaget's four stages of cognitive development</u> (Woolfolk, 2010:33-39; Bohlin *et al*., 2012:120-124; Piaget, 1950).

Piaget hypothesises that human beings progress through four stages of cognitive development between birth and adulthood – three of which particularly fall under the scrutiny of the early childhood researcher. All humans pass through all four stages in exactly the same order, and these stages can be associated with specific ages, although they are believed to be guidelines and not labels for all children of a certain age.

Piaget agrees that certain individuals may spend greater lengths of time transitioning from one stage to another and that humans can show the characteristics of one stage in one situation, but the characteristics of a higher or lower stage in another situation. For the purposes of this study, we will focus on the stages of cognitive development relevant to early childhood. Although the sensorimotor and preoperational stages fall within the age criterion of a preprimary school child, Piaget's concrete operational stage is specifically addressed as part of the study, as the research is concerned with the pupil's preparation for this particular stage (Woolfolk, 2010: 35).

Stage	Characteristics
Sensorimotor stage Approximately 0 – 1½ or 2 years	• Child's thinking involves largely the senses and motor actions. • Infants develop object permanence during this stage, which lays a foundation for the child's ability to construct mental representations. • Beginning of logical goal-directed actions. Separate lower order schemes are combined to form higher-level schemes to achieve goals.

	• Reverse actions are achieved – but not reverse thinking, i.e. reverse actions are limited to the field of the subjects own action. • Infants cannot distinguish existence as separate from objects or people in the environment.
Preoperational stage Approximately 2 – 7/8 years.	• The first evidence of thinking that is separated from action is seen in the ability of the child to use symbols e.g. words, signs, gestures and images (semiotic function). • Schemes become general and less tied to specific actions. • There is rapid development of the symbolic system of language (particularly between the ages of 2 and 4 years). • Thinking remains limited to one direction (one-way logic) and reversible thinking is very difficult, e.g. the conservation principle whereby the amount of something remains the same even if the appearance or arrangement changes, as long as nothing is added or subtracted. Piaget experimented with two pellets of dough of the same shape and size. Children were unable to establish that the material, weight and volume remain constant if one pellet is modified. • Children struggle to focus on more than one aspect of a situation at a time (inability to decentre) e.g. the idea that decreased diameter compensates for increased height. Piaget refers to an experiment with two glasses filled with the same number of beads, but with different dimensions. • Children are predominantly egocentric, and struggle to view the world through another person’s perspective. This also coincides with the child’s belief that others share his feelings, reactions and perspectives.

Concrete operational stage Approximately 7 – 11/12 years	• Described as the stage of "hands-on" thinking when the child recognises the logical stability of the physical world (identity constancy). • An understanding that elements can be changed or transformed, yet conserve their original characteristics. • This understanding of conservation is guided by the development of three aspects of reasoning – identity, compensation and reversibility. Identity is an understanding that without something being added or taken away, material remains the same. Compensation is the understanding that apparent change in one direction can be compensated for by change in another direction. Reversibility refers to the understanding that changes to or actions on elements can be reversed. • Classification is mastered, i.e. the ability of the child to focus on a single characteristic of objects within a set, and to group objects according to this characteristic. • The child is capable of seriation – making an orderly arrangement from large to small or *vice versa* – and understanding sequential relationships between objects. • The child now possesses a complete and logical system of thinking. However, this system is still tied to physical reality.

Brief summary of criticisms of Piaget's theory

Many educational psychologists and experts in the field of education agree with Piaget's description of how children think. However, there have also been many criticisms directed at his theory, particularly regarding the "when" and the "why" of children's thinking.

- There is criticism against the notion that children's cognition can occur chiefly as an outcome of maturational processes (Sternberg, 1999:443). Piaget did allow for the processes of adaptation to the environment, but largely held that internal maturational processes determine the sequence of cognitive development. These ideas are challenged by evidence suggested in research conducted by Gelman and Baillargeon (1983).

- There is criticism against the fundamental assumption that development occurs in four separate stages of thought in a fixed sequence, regardless of task domains, tasks and contexts (Siegel, 1993; Brainerd, 1978). Many psychologists believe that cognitive development is a more continuous and gradual process (Sternberg, 1999:443; Woolfolk, 2010:41).
- Some critics believe that Piaget may have underestimated children's cognitive abilities (Woolfolk, 2010:41; Gopnik, 1996:221; Halford, 1989). There are scholars who suggest that preprimary school children know much more about number concept than what Piaget thought. Other factors, like aspects of the child's environment, the child's prior experiences with tasks and task materials, and the researcher's presentation of the task itself (language and complexity of instructions) may lead to questions regarding Piaget's experiments, proving the so-called limitations of children's cognitive abilities (Sternberg, 1999:444).
- Another point of criticism is aimed at the notion that the development of cognitive operations cannot be accelerated, as children need to be developmentally ready to learn. Much research has been undertaken to prove that certain concepts, e.g. conservation, can be taught with effective instruction and that children do not have to naturally discover these ways of thinking (Woolfolk, 2010:42).

2.2.2.2 Lev Vygotsky's sociocultural theory

Lev Vygotsky was a Russian psychologist who proposed that to understand the cognitive development of the child, we need to consider the social processes from which a child's thinking is derived (Papalia & Feldman, 2011:34). Cognitive development is the result of a complex interaction between heredity and the environment, called the natural and cultural lines of development (Bohlin *et al*., 2012:124). Vygotsky therefore maintained that higher mental processes, like problem solving, self-regulation and memory, are co-constructed during shared activities between children and other people. In this social context, processes are internalised and become part of the child's cognitive development (Woolfolk, 2010:43). Papalia and Feldman

(2011:34) further describe how Vygotsky's theory stresses the importance of interaction and engagement with the environment and the collaborative process of cognitive growth.

Vygotsky's theory utilizes a concept called the zone of proximal development (ZPD). This is defined as the gap between what children are already able to do and what children are not quite ready to accomplish by themselves (Papalia & Feldman, 2011:34). Children performing tasks in this zone can almost, but not quite, perform the task on their own. With the correct guidance, success can be obtained and the responsibility for learning gradually shifts from the adult to the child. The zone of proximal development is described as a dynamic, changing space as the student and teacher interact and understandings are exchanged (Woolfolk, 2010:47). Within this zone, children can develop new ways of thinking, internalise new skills and reach new levels of potential development. When this new level of thinking is obtained, this becomes their actual developmental level, and the cycle starts again (Bohlin *et al*., 2012:124).

<u>Vygotsky's mechanisms of cognitive change</u> (Bohlin *et al*., 2012:124-126)

Intersubjectivity

This refers to the co-construction of knowledge when two individuals who begin with different knowledge and perspectives come to a shared understanding as each person adjusts to the other person's perspective. Both the learner and the more cognitively advanced individual are active partners in co-constructing.

It is in the shared activities and social interaction between the child and the cognitively more advanced person that children internalise their society's ways of thinking and behaving (Papalia & Feldman, 2011:34).

Psychological and cultural tools

These are the means by which the more advanced and less advanced partners bridge the gap between their perspectives. Woolfolk (2010:44) describes how these tools could be material (e.g. paper or computers) or psychological (e.g. signs and symbols). Vygotsky maintains that higher-order mental processes are mediated through psychological tools. In the exchange of signs, symbols and explanations between an advanced peer and a less advanced learner, the learner acquires a "cultural tool kit" to make sense of their world. This transference of the "tool kit" involves a measure of transformation in that children transform the tools they are given as they construct their own representations, symbols, patterns and understandings. These understandings will change as children continue to be changed through social activities and strive to make sense of their worlds.

One of the most important tools in Vygotsky's theoretical "tool kit" is that of language. Vygotsky places an enormous amount of emphasis on the role of language in learning and cognitive development. Vygotsky also believes that language, particularly in the form of private speech, guides cognitive development.

Scaffolding

Similar to the temporary platforms used to steady and support the construction of a building, scaffolding refers to the temporary social support offered to children to help them accomplish a task. It is the support that parents, teachers or others give a child to do a task until the child is able to do the task alone (Papalia & Feldman, 2011:34).

Internalisation

This refers to the process through which children develop more cognitive responsibility for a task and scaffolding is gradually withdrawn. This implies a shift from performing tasks socially with others to performing tasks mentally by themselves.

2.2.2.3 Bruner's theory on constructivism and discovery learning (McLeod 2008)

American psychologist Jerome Bruner is one of the founding fathers of the constructivist theory (Seel, 2012:488). Bruner believes that an intelligent mind is creative and learning should allow a child to invent concepts, categories and problem-solving procedures. Education should facilitate thinking and the development of problem solving skills. Learners construct their own knowledge through organizing and categorizing information and using a coding system. This coding system should be discovered through learners constructing their own knowledge, categories and problem solving procedures for themselves (McLeod, 2012). Like Vygotsky, Bruner also maintains that language is paramount in bridging the gap between environmental stimuli and a child's response.

Education should create learners who are autonomous and who are able to learn how to learn. This is accomplished by scaffolding and by encouraging children to comprehend the structure of knowledge. Understanding the structure of a subject facilitates its understanding (Seel, 2012:489).

Bruner proposes specific ways to store and encode memories in cognitive development (Bruner 1964:2):

- Enactive representation (action-based). Largely muscle-memory related.
- Iconic representation (image-based).
- Symbolic representation (language-based).

Unlike Piaget's age-related stages, these so-called modes of representation are only loosely sequential and are not related in such a way that one mode has to presuppose the preceding one. One mode may dominate in usage, but all modes exist simultaneously.

A vitally important aspect of Bruner's theory that underpins these modes of representation is his belief that a learner can learn any material at a very young age, as long as the instruction of this material is structured appropriately (this contrasts strongly with Piaget's theory). Infants are intelligent and active problem solvers, with intellectual capacities similar to adults.

<u>Implications for education:</u> (McLeod 2008)

- Education should not focus on the impartation of knowledge, but on the facilitation of thinking and problem solving skills.
- Education should focus on developing symbolic thinking in children.
- Bruner opposes the Piagetian notion of "readiness" and matching the complexity of material to the child's cognitive stage of development. Bruner believes that teachers are holding children back in their misguided beliefs regarding cognitive maturity. Very young children are capable of grasping the structure of knowledge when solving problems and engaging in discovery learning (Seel, 2012:489).
- Any child at any age is able to understand complex information if taught appropriately. Although a child's cognitive structures develop over time, you can accelerate cognitive development without waiting for the child to be ready.
- Bruner proposes the idea of a spiral curriculum where complex information is taught at a simplified level initially and then re-taught at a more complex level later on. Subject

information must be taught in such a way that it gradually becomes more difficult and that new concepts are built on what was previously learned (Howard 2007:1).

- Teaching should lead to children solving problems independently. Intuitive and analytical thinking should be rewarded (Seel, 2012:489).
- Bruner strongly believes in discovery learning, where learners develop their own coding system to organise and categorise information, rather than taking on someone else's coding system.
- Interest in a subject is the best motivator for learning (Seel, 2012:489).
- Although agreeing with Piaget that children are active learners, Bruner sides more with Vygotsky's belief that adults and more knowledgeable peers are essential players in education. Teachers have to provide suitable learning tasks and materials that will enable learners to solve problems effectively. Teachers are important role players in the pre-structuring of problem situations (Seel, 2012:490).
- Cognitive development occurs continuously, and not through a series of predetermined stages.

2.2.3 Behavioural learning theories

The theories of behavioural learning can be divided into two basic camps: classical conditioning or operant conditioning. In spite of their differences, these two approaches have the following factors in common (Bohlin *et al*., 2012:159):

- Learning involves a change in behaviour.
- Behaviour is a result of experiences.
- Learning is the result of forming associations between a stimulus and a response.
- There should be a short time lapse between stimulus and response for learning to occur.
- Learning processes occur similarly across species.

Classical Conditioning (Bohlin *et al*., 2012:160; Woolfolk, 2010:200-201)

The theory of classical conditioning finds its roots in the 1920s in the work of Russian physiologist Ivan Pavlov and his infamous experiments with dogs. Pavlov's assistants would ring a bell or tuning fork before presenting dogs with food. Pavlov noticed that after a certain number of trials, ringing the bell would cause the dogs to salivate even without the presentation of food. Pavlov concluded that an unconditioned stimulus (presentation of food) and its unconditioned response (dogs salivating) can be paired with a previously neutral stimulus (bell or tuning fork), resulting in a conditioned response or a learned response (salivating to bell). In this case, the neutral stimulus becomes a conditioned stimulus.

Once learning has occurred, behaviour can be further altered, changed or even eliminated through processes like generalisation (conditioned learning expanding beyond specific stimulus to other similar stimuli), discrimination (learning to differentiate between similar, but different stimuli) and extinction (conditioned stimuli presented repeatedly without unconditioned stimulus).

Operant Conditioning (Bohlin *et al*., 2012:161-163; Woolfolk 2010:201-206)

Operant conditioning moves beyond pairing involuntary behaviours with a stimulus to pairing voluntary behaviours with a stimulus.

Operant conditioning originated in the work of Edward Thorndike and the law of effect. In essence, this law states that behaviours associated with satisfying consequences are more prone to re-occur than behaviours associated with annoying or adverse consequences.

This basic theory was expanded on by Skinner (1953), who postulated that an antecedent (A) occurs prior to a behaviour (B) and leads to a consequence (C). The antecedent and the consequence should occur in quick succession for learning to occur. The consequence of behaviour will either increase or decrease the likelihood of that behaviour occurring based on whether the consequence is viewed as a reinforcement or as a punishment. Positive reinforcement is achieved by adding something desirable for the individual. Negative reinforcement is the removal of something undesirable. Positive punishment occurs through the adding of an unpleasant stimulus to the individual, and negative punishment is achieved by removing something desirable for the individual. Reinforcements increase the likelihood of behaviours recurring and punishment decreases the likelihood of those behaviours recurring.

To firmly establish behaviour, consequences are initially needed every time a behaviour occurs. This is referred to as a continuous schedule. Once behaviour has been learned, reinforcement can occur intermittently through ratio schedules (reinforcement based on a fixed number of times a behaviour occurs), interval schedules (reinforcement based on fixed time intervals) or variable schedules (intermittent reinforcement and the most effective and efficient schedule in establishing long-term learned behaviours).

2.2.4 Theory of learning sets by Harold Harlow (Harlow, 1949)

Harold Harlow was an American Psychologist who is most significantly remembered for his controversial work on nonhuman primates in the early half of the 20th century.

In his work, Harlow discovered that the monkeys he worked with were able to develop strategies to solve his perception tests. Harlow labelled these strategies as "learning sets" and described them as a process of "learning to learn" (Anon, 2014c).

In translating the results he found with monkeys to human behaviour, Harlow concluded that learning behaviour in human beings is not the result of a single learning situation, but rather a culmination of several learning experiences with multiple, comparable, learning problems. Learning sets allow an organism to move beyond mere trial-and-error responses, to responses based on hypothesis and insights (Harlow, 1949:51). In other words, Harlow postulated moving beyond the conditioned response idea embedded in classical behaviourism theory, to the idea that learning is the result of reasonable rationalism (Harlow, 1949:52).

In his work with primates and learning sets, Harlow used object-quality discrimination learning problems. His data indicated that subjects progressively improved in their ability to learn the correct responses. Harlow concluded from multiple trials that the formation of learning sets, this so-called ability to learn from learning, is a highly predictable and orderly process.

What sets Harlow's work apart from the "trial-and-error" work of Thorndike years before, was the observed gradual increase in the rate of learning. By the end of 50 or so problems, Harlow's research demonstrated that animals were learning virtually all new problems in only one trial (Schrier, 1984:96-97).

Harlow's theory shows how apparently advanced types of behaviour or cognition can develop as a result of repetitive systematic experiences with a certain type of problem (Schrier, 1984:97).

2.2.5 Play theory by Froebel

Friedrich Wilhelm Froebel (1782-1852) is known as the "Father of the Kindergarten" because he coined the name "kindergarten" and for his passionate life work in creating a positive early childhood education system that would contradict his own unhappy childhood experiences (Gordon & Browne, 2011:12).

Froebel's theoretical approach strongly leans towards the child's right to play and have toys. He centred his theory on the need for the child to engage in self-activity and the importance of developing children's self-esteem and self-confidence (Gordon & Browne, 2011:12). He believed that children have a right to develop naturally and without compulsion, and that this natural development centres on play. Froebel viewed play as the most important way to give expression to experience (Verster, 1989:209).

Froebel designed his own educational toys and referred to them as "gifts" (Manning, 2005:373). He also developed "occupations" to guide learning. In today's terms, "occupations" would be the equivalent of "skills", beginning with perforating and moving on to sewing, tracing, freehand drawing, weaving, paper twisting, cutting, clay modelling etc.

Manning (2005:373) describes Froebel's basic three tenets of educational philosophy as unity, respect and play.

Froebel held a spiritual reverence for nature. Throughout his life he saw his ideas through the combined lens of God and nature. He essentially believed that nature provides humanity with ways to understand invisible mental processes, and that toys should have the basic attributes of patterns and forms in nature (Resnick, 1998:43). These "gifts" represent symbolic ideas in concrete form and emphasise progressive learning, as well as learning from the tangible to the abstract (Manning, 2005:373).

All original Froebel kindergartens were equipped with blocks, pets and finger plays. Froebel presented his "gifts" systematically, in accordance with a child's age. Beginning with coloured balls and expanding to complex construction blocks by age five. Froebel's gifts moved from simple to complex; from unity to variety; from the whole to its parts; from easy manipulation to more difficult manipulation (Osborn, 1991:49).

Froebel's theoretical approach emphasises language, numbers, forms, and eye-hand co-ordination (Osborn, 1991:44). This systematic presentation of concepts and skills allowed Froebel to experience the success with his kindergarten's that gained him international attention.

Froebel also believed in the child's right to be educated by trained teachers (Gordon & Browne, 2011:12). His theoretical orientation was influenced by Pestalozzi (whom he studied with) and the work of Comenius. In summary, Froebel's theoretical approach focuses on self-directed activity and play, the child's right to develop at their own pace, and the education process being one of delight, exploration and discovery.

2.2.6 Maria Montessori

Gordon and Browne (2011:13) describe how Maria Montessori was the first female physician in Italy at the turn of the 19^{th} century. In spite of her obvious qualifications and expertise, Montessori focussed her life's work on the poor and disabled slum children of Rome believing that their condition was a manifestation of their lack of proper motivation and a caring environment.

Montessori theory holds that infants are born incomplete and "neutral" (without inherent goodness or evil) and have to complete their own formation, a process lasting from birth to twenty-four years (Lillard & Jessen, 2003:3-5).

Selected aspects of Montessori's philosophy can be summarised in the following tenants:

- Education is more than the transmission of knowledge. It is the development of human potential (Montessori, 2012:2).
- The child has a mind that can absorb knowledge and instruct itself (Montessori, 2012:4). "Education is a natural process spontaneously carried out by the human individual" (Montessori, 2012:7).
- Although children pass through fixed stages of development, cognitive development is at its greatest in the first few years of life (Montessori, 2012:8). The ages 3 to 6 is particularly characterised by a period of great transformation (Montessori, 2012:25).
- Knowledge is gained through experience and using the hands, first through play and then through work (Montessori, 2012:36-37). Ideas and information should be given to the young child first in a concrete form that can be held, discovered and explored (Lillard & Jensen, 2003:5).
- All activities that teachers perform should be prepared, guided and lead to the illusion of teacher "inactivity" (Montessori, 2012:393). Teachers should not interfere unless asked, and should present new objects when the child has exhausted possibilities with old objects (Montessori, 2012:399).
- Learning progresses through sequential steps (Gordon & Browne, 2011:14). Almost any task can be learnt through breaking it down into a series of small steps.
- For effective learning to take place, activities presented to the child should be self-correcting (Gordon & Browne, 2011:14).
- Teachers should base their teaching on observation (Gordon & Browne 2011:14) and match the child's interests with certain activities.
- Focus should be placed on training the child's senses and providing guidance in practical life issues (Gordon & Browne, 2011:366) as seen in activities like sweeping, buttoning and washing.
- Learning is an individual experience and not a product of group instruction (Gordon & Browne, 2011:367).

Sensitive Periods and Windows of opportunity

It is Montessorian belief that, particularly in the early years, children pass through “sensitive periods”. These periods are times during which the child is ready to acquire certain skills and knowledge (Gordon & Browne, 2011:14). It is during these time frames that a child becomes focused in a particular area of development to the point where he ignores phenomena that were previously interesting to him (Lillard & Jensen, 2003:6). It is the responsibility of the teacher to recognise these sensitive periods and to provide the child with activities that will stimulate development in these particular areas.

The Montessori classroom environment

Montessori’s ideal classroom environment has the following components:

- An environment where children are free to select their own materials and activities (Gordon & Browne, 2011:366). These materials and activities are defined by some as “work”.
- Materials in the classroom are made out of wood, are self-correcting and are appealing to the senses (Gordon & Browne, 2011:367).
- Equipment and furniture is child-sized and displayed in an orderly fashion. Children must accomplish one task before starting another (Gordon & Browne, 2011:367).

It has been claimed that Montessori’s philosophy has influenced nearly every early childhood education programme in existence today (Gordon & Browne, 2011:367).

2.3 How theories, methods and models were used for this study

An eclectic combination of theories, methods and models are used in this particular study for the selection of the mathematical intervention programme under investigation.

The intervention programme in the empirical study is an adult-directed play-based mathematical curriculum administered by teachers in 7 different classroom settings over a period of approximately 30 weeks or for the duration of three school terms.

2.3.1 Constructivism

The study uses the conceptual idea that children can be actively involved in constructing their own knowledge by engaging in tasks designed to create personal meaning (Gordon & Browne, 2011:120). In the life-world of a preprimary school child, play is regarded as exceptionally meaningful, and is essential for his or her social, emotional, cognitive and physical well-being (Milteer *et al*., 2012:204). Play offers children a platform to develop creativity and imagination while strengthening their physical, cognitive and emotional skills (Milteer *et al*., 2012: 205). Engaging in playful mathematical interactions with adults inspires the child to be central in constructing rules about mathematics, game-playing and social interaction as a whole. Children are challenged through games to actively develop new cognitive skills and apply their knowledge to win, have fun or to obtain a worthwhile reward.

As constructivists advocate social interaction as an important aspect of constructing knowledge, teachers are viewed as a very real and dynamic part of the child's social world in this play-based study. The programme used by the experimental group is designed around two daily sessions of intense playful and social interaction between the teacher and the children. One such session entails half an hour of small group interaction, and the other session involves forty minutes of large group interaction.

The small group sessions allow for more intimate and personal social interaction between the teacher and her pupils, allowing the teacher to adapt her interaction and playful instruction to the pace of the group and the needs of the individual learner. This is a constructivist student-centred approach, with each small group session having a distinctly different "flavour" (pace and approach), based on the needs of the learners in the group.

2.3.1.1 Piaget's theory of cognitive development

The following ideas from Piaget's theory are noticeably used in the intervening adult-guided play-based maths programme:

<u>The importance of active exploration of the physical environment in cognitive development</u>

Piaget attests that children learn through acting on the environment. This action allows children to discover certain principles (Bohlin *et al.*, 2012:120). By allowing children to handle manipulatives and mathematical equipment and tools in a non-threatening and relaxed environment, children are free to explore and actively acquire knowledge. The mathematics programme investigated in the research study utilises a very large variety of interesting and stimulating tools to encourage children to explore mathematical principles and concepts e.g. decorative posters, hula hoops, strings, abacuses, blocks, Frisbees, see-saws, cups, paper plates, sorting boxes, match sticks, buttons etc.

<u>Equilibration</u>

The programme used in this study is designed to constantly place children in a state of disequilibrium (Bohlin 2012:120), making assimilation and accommodation a daily necessity. Children are challenged through games and playful interaction to structure the new information they learn through creating mathematical schemes, and to adapt these schemes in the face of new possibilities and problems.

<u>Piaget's four stages of cognitive development</u> (Woolfolk 2010:33-39; Bohlin *et al*. 2012:120-124)

The study recognises that the children participating in the research fall within what Piaget classifies a pre-operational stage. That being said, the study also takes into consideration the work of Gelman and Baillargeon (1983) and Sternberg (1999) and concludes that many of the characteristics of the concrete operational stage are possibly attained younger than what Piaget initially theorised. The intervention programme under investigation seeks to create a so-called Vygotskian zone of proximal development (Woolfolk, 2010:47), encouraging children, with the necessary support, to master the cognitive procedures characteristic of the early concrete operational stage. Within the programme, hands-on thinking, conservation, seriation and classification are considered appropriate Piagetian concrete-operational topics to engage in, provided that the children are adequately supported with physical manipulatives and teacher involvement (scaffolding). The programme begins in the first term with a focus on the pre-operational concept of the symbolic representation of numbers. That being said, more weight is given in the study to the constructivist notion that cognitive development can be accelerated, unlike Piaget's belief that the process has to unfold naturally.

2.3.1.2 Lev Vygotsky's sociocultural theory

Much emphasis is given to the sociocultural theory of Vygotsky in the intervention programme under scrutiny in this study. The entire mathematics programme is based on the understanding that the social context of playful interaction between a cognitively superior and a cognitively inferior individual will result in an environment conducive to cognitive development (Papalia & Feldman, 2011:34). It is only in the context of this collaborative approach that the envisaged goal of education is optimally obtained. The fact that teachers have to actively engage with the children in a playful manner in small groups every day allows for this recommended state for socio-cultural and cognitive transmission.

The programme also holds in high regard the notion of zones of proximal development. Children are not left to explore on their own and are not faced with worksheet and workbook challenges beyond their comprehension, but are placed in a learning situations where the teacher presents the learning tools and structures to the child and then encourages the child to use these structures in a way that is challenging, yet obtainable. Games within the study become increasingly more complex and are designed to build on previous knowledge. The cultural tool of language is strongly and repetitively emphasised, and teachers have been trained to speak to the children as much as possible while engaging in mathematical games.

The process of teacher scaffolding is integrated with all of the mathematical games. Once learners have mastered a cognitive understanding of the principles behind the games, they are encouraged to use the tools and games at their leisure without this necessary adult scaffolding.

2.3.1.3 Bruner's theory on constructivism and discovery learning (McLeod, 2008)

The lessons in the programme that deal with word sums, pegboards and sorting trays are based on Bruner's belief in providing challenging problems for learners to solve. Learners are encouraged to explain how they obtained the solutions to the problems posed in these activities, particularly using active and iconic representations.

The programme also makes use of a spiral curriculum as proposed by Bruner (Howard 2007:1), whereby lessons at the beginning of the programme are more simple and re-visited several times during the programme, increasing in complexity.

The Bruner notion that any child at any age is able to understand complex information if taught appropriately (McLeod, 2008) is practically utilised in the study. The programme was introduced to a relatively large sample of children of different ages (4 to 6 years) from diverse socio-economic and geographic backgrounds. As a result, it would be difficult to wait for each child's so-called "readiness". Rather, we assume that cognitive development can be stimulated and even accelerated (Seel 2012:489) and that very young children are capable of complex cognitive thinking and tasks.

2.3.2 Harold Harlow and learning sets

Most lessons in the curriculum of the schools incorporated in the study use similar learning problems presented in different ways (learning sets). The belief is that by presenting these problems repetitively, the children will develop the necessary learning structures to apply their knowledge more quickly with each new problem.

The following tables provide a brief overview of the programme used by test group schools in the study, clearly demonstrating both the spiral curriculum approach and lessons requiring self-discovery and problem solving (Bruner), as well as the repetitive learning set approach by Harlow.

Dates and weeks	TOPICS FOR SMALL GROUP MATHS (1/2 hour per day)	TOPICS FOR CLASS MATHS (40 minutes per day including calendar work and counting games)
15 Jan – 17 Jan		Maths songs
20 Jan –24 Jan Week 1	Sequencing with paper plates	Folding Symmetry Sorting Directionality P.T. Measurement
27 Jan –31 Jan Week 2	The story of Number 1	Pegboards Sorting Working memory Shapes
3 Feb – 7 Feb Week 3	The story of Number 2	Folding Tangram Symmetry Conservation and sets Working memory
10 Feb – 14 Feb Week 4	The story of Number 3	Pegboards Symmetry Directionality P.T. Working memory Shapes
17 Feb – 21 Feb Week 5	The story of Number 4	Sorting Tangram Working memory Conservation and sets Folding
24 Feb – 28 Feb Week 6	The story of Number 5 and 6	Pegboards Symmetry Word sums Working memory Shapes

3 March – 7 March Week 7	The story of Number 7	Folding Tangram Directionality P.T. Working memory Conservation and sets
10 March – 14 March Week 8	The story of Number 8	Pegbaords Sorting Word sums Working memory Shapes
17 March –20 March Week 9	The story of Number 9	Folding Tangram Word sums Working memory Measurement
24 March – 28 March Week 10	Recap/ revision	Pegbaords Directionality P.T. Word sums Working memory Measurement

Dates and weeks	TOPICS FOR SMALL GROUP MATHS (1/2 hour per day)	TOPICS FOR CLASS MATHS (40 minutes per day including calendar work and counting games)
7 April - 11 April WEEK 1	Recap games on numbers from term 1	Working memory Symmetry Sorting Word sums
14 April – 17 April WEEK 2	Shapes board game	Folding Symmetry Pegboards Directionality P.T.
22 April – 25 April WEEK 3	Number ordering with bottles, stacking towers and rods	Working memory Tangram Word sums Measurement
28 April – 2 May	HOLIDAY	
5 May - 9 May WEEK 4	Number ordering – tongue depressor game	Folding Sorting Directionality P.T. Maths art
12 May – 16 May WEEK 5	Number ordering - carpet swamp hop	Working memory Symmetry Pegboards Word sums
19 May – 23 May WEEK 6	Mass and more/ less game with blindfolds	Folding Tangram Measurement Shapes
26 May – 30 May WEEK 7	Number ordering with Erika's abacus	Working memory Symmetry Word sums Maths art

2 June – 6 June WEEK 8	Number ordering with stuck in the mud	Folding Sorting Pegboards Shapes
9 June – 13 June WEEK 9	Patterns and sequences with buttons	Working memory Symmetry Tangram Maths art
17 June – 20 June WEEK 10	Number fun – conservation paper plates and odd/even bugs	Folding Word sums Directionality P.T. Conservation
23 June – 27 June WEEK 11	Number ordering board game	Working memory Pegboards Tangram

Dates and weeks	TOPICS FOR SMALL GROUP MATHS (1/2 hour per day)	TOPICS FOR CLASS MATHS (40 minutes per day including calendar work and counting games)
21 July - 25 July WEEK 1	Bonds – balls, milk lids and egg cartons	Working memory Symmetry Sorting Word sums
28 July – 1 August WEEK 2	Bonds – Erika's abacus	Folding Symmetry Pegboards Directionality P.T.
4 August – 8 August WEEK 3	Bonds – fishing game	Working memory Tangram Word sums Measurement
11 August – 15 August WEEK 4	Sequencing and patterns with buttons	Folding Sorting Directionality P.T. Maths art
18 August – 22 August WEEK 5	Bonds – spoon game	Working memory Symmetry Pegboards Word sums
25 August – 29 August WEEK 6	Measurement and Frisbees	Folding Tangram Class bonds and paper plates Shapes
1 Sep – 5 Sep WEEK 7	Bonds – Bingo and snakes and ladders	Working memory Symmetry Word sums Maths art
8 Sep – 12 Sep WEEK 8	Money with lids	Folding Sorting Pegboards Shapes

15 Sep – 19 Sep WEEK 9	Bonds – hula hoops and dominoes	Working memory Symmetry Tangram Maths art
22 Sep – 26 Sep WEEK 10	Bonds – sneaking up	Folding Word sums Directionality P.T. Conservation
29 Sep – 3 Oct WEEK 11	Double and half – Mr Double Trouble and Mr Halver	Working memory Pegboards Tangram

2.3.3 **Behavioural learning theories** (Bohlin *et al*. 2012:161-163; Woolfolk, 2010:201 - 206)

The study departs from the belief that if mathematical thinking and participation in mathematical tasks is appropriately rewarded with positive consequences, this thinking and participation will prevail in more complex tasks and through later years. The following positive consequences or reinforcers are utilised in the intervention programme:

- Undivided attention of an adult
- Emotional excitement and joy experienced in play and games

During the application of the programme it became clear that these consequences are highly motivating for the child and reinforce the likelihood that the emotion of joy is associated with mathematics at a young age. These motivators are in fact an intrinsic part of the curriculum, following a regular, repetitive interval pattern in a more noticeable way than what would be prevalent in a work-sheet based or work-book based curriculum. Recent research suggests that mathematics anxiety is a very real and crippling problem among students (Geist, 2010:24). Geist proposes that even before a child can add or even count, they are constructing affective ideas about mathematics from their environments through their interaction with adults.

Maloney and Beilock (2012:406) claim that maths anxiety has been found in children much younger than what was previously believed. This is attributed to social factors and the student's level of competency, where their deficiencies may cause them to pick up on negative environmental cues about mathematics. Affective factors therefore play an important role in mathematics performance.

As proposed by the theory of classical conditioning (Woolfolk, 2010:201), the mathematics programme couples a previously neutral stimulus (mathematics reasoning) with an unconditioned response (emotional fun experienced through play), resulting in a positive affective state when faced with future mathematical challenges (conditioned response).

In the same way, using the theory of operant conditioning (Woolfolk, 2010:203), positive emotional reinforcement experienced through fun, play and games (positive consequence) will result in a certain form of behaviour (mathematics reasoning) to be repeated in future.

2.3.4 Froebel and Montessori

Both the work of Froebel and Montessori was considered and utilised in the programme. The use of a variety of interesting and visually stimulating tools and "gifts" was incorporated, allowing concepts to first be explored in the concrete form before the abstract (Lillard & Jensen 2003:5). The diversity of manipulative materials used in the study, similar to equipment presented in Froebel and Montessori kindergartens, allows for children to naturally develop mathematical concepts like number, size and shape (Resnick, 1998:43).

All aspects of the programme considered the life-world of the child, allowing for full accessibility to equipment and designing activities around the child (Gordon & Browne, 2011:14). The "play" focus of the programme confirms Froebel's theoretical stance that play is the right of the child (Gordon & Browne, 2011:12).

Like the Montessori idea of breaking down complex tasks into smaller steps, all seemingly large mathematical concepts are broken down into smaller sequential steps through simpler games that become increasingly difficult.

Froebel's idea of educating through "occupations" (Manning, 2005:375) has been incorporated into several "mathematical art" pieces in the programme. Participating teachers are also encouraged to use these "occupations" as often as possible to incorporate mathematical ideas in a creative way in the classroom.

Certain Montessori concepts have deliberately been avoided in the curriculum in question due to the extent and nature of the research. Concepts like matching activities with the child's sensitive period were not attempted, as most of the schools participating in the study have a whole-class instruction approach and are not of a Montessori orientation. Therefore, the Montessori idea of developing children at their own pace (similar to the theory of Piaget), was replaced in the curriculum with the constructivist idea of accelerating cognitive development through combined and active structure formation between the adult and the child.

That being said, grouping children into cognitively similar smaller groups of 6 for the small group activities, allows for some measure of adaptability to the games and "occupations" presented, giving the teacher the opportunity to consider the child's zone of proximal development and to scaffold learning accordingly.

2.4 Hypothesis

The null hypothesis (H_0) and alternative hypothesis (H_1) on the global significance of implementing an adult-guided play-based mathematics curriculum in Grade R comparing control and experimental groups are as follows:

H_0: There is no significant difference between the mathematical reasoning of the subjects in the control and experimental groups.

H_1: There is a significant difference between the mathematical reasoning of the subjects in the control and experimental groups.

A hypothesis can be deduced that states that the programme that has been developed based on the broad principles of the constructivist theory, learning set theory, behaviourist theory and play-based theory, is one that will provide positive results and proves to have had a great impact on the mathematical reasoning of Grade R children upon entry into Grade 1 and to have aided in their stimulation over the 30-week intervention process.

2.5 Conclusion

This chapter considered the theories behind the development of the intervention programme under investigation, and referred to various historical models, theories, methods and concepts of early childhood development. A brief overview of the intervention programme in the form of a 30-week intervention schedule was provided as well.

CHAPTER THREE

LITERATURE STUDY AND ARGUMENTATION

3.1 Introduction

Before embarking in any field of research, one must first investigate what has already been accomplished in one's particular field of study by doing a thorough review of literature in the field (Mouton, 2001:6). Once literature has been searched, it must be read and recorded in a critical and evaluative way within the framework of the proposed research (Basit, 2010:45).

This chapter is a recording of literature pertinent to the research topic of an adult-guided play-based mathematics curriculum for Grade R.

3.2 How should mathematics be taught in early childhood education settings?

3.2.1 The argument for play

"Learners will develop reasoning abilities by considering thought-provoking questions which can be presented to them through games and other activities involving concrete materials and real problems" (De Witt, 2011:184-185). This playful and realistic approach is promoted by most Grade R experts today, but little research has been undertaken to actually prove that these activities will effectively extend successfully to the context of teaching mathematics in the South African Grade R classroom.

The inquiry regarding the most ideal approach to mathematics instruction for young children has been on the table, yet unresolved, since the 1960's (Stipek, 2013:432). The advantages of child-initiated and child-directed education over structured teaching has been thrashed out in lively debate by educators and researchers alike.

The relatively recent trend of implementing a "play-based developmentally appropriate curriculum" in preprimary school leads us to the question of what constitutes "play" in this context. The literature study reveals that the simple, child-like activity of play is not so "simple" to categorise and even harder to define.

3.2.1.1 A recent view of children's play

It is a vogue and widely accepted fact that the natural act of play is a vital and positive aspect of a child's education and development (Almon, 2003; Freeman & Brown, 2004:10). In educational contexts, play helps children to be guided actively in their learning, allowing children to bring together what they know in a connected and whole way (Bruce, 2011:4). Play improves a child's content knowledge, competencies and disposition to learn (Wood & Attfield, 2005 cited in Martlew *et al*., 2011:72).

This modern notion of play was rooted in educational thinking as early as the seventeenth and eighteenth centuries when children were first viewed as beings with a "right to happiness" (Verster, 1992:95), but really came to the fore in the work of educationalists like Froebel and Pestalozzi, who focused on the benefits of playful and creative activities in educating the child. It is Froebel especially who emphasised learning by doing, and the value of motor expression, self-activity and creativity, particularly accomplished through play (Verster, 1992:149) (see "Play theory by Froebel" par 2.2.5). This view dramatically impacted the way preprimary school education was conducted in its day, and its rippling effects still felt in the 21st century.

In the early 1900's, another influential advocate of the excellence of play came to the fore in the life work of Maria Montessori (see "Maria Montessori" par 2.2.6). Montessori pursued the ideal that children could playfully self-direct their learning through a carefully organised environment. She emphasised that young children are "sensorial explorers" and require concrete apparatus to explore and construct their own understanding of the world (Lillard & Jessen, 2003:7). Montessori viewed play as "the work of the child" and as the means through which children make choices and practice actions to mastery (Child Development Institute, 2011). Montessori's results with her children were so extensive and impressive, that the international community were compelled to stand up and take notice, and to acknowledge the possible value of her play-based curriculum (Gordon & Browne, 2011:13).

Today, play is viewed through multiple lenses. Although the importance of play for healthy cognitive, social, emotional and physical development is uncontested, the actual process of obtaining this utopian state is under scrutiny. In a world of increasing academic pressure and global exponential intellectual development, the academic demands of the education system are being placed on the shoulders of the very young. Many are defending the right of the child to play, yet how can one combine this ideal with the increasing academic demands of curricula for young children? In light of this question, not all play is viewed as equal, and "early childhood educators need to improve the quality of play in order to justify its place in the curriculum" (Wood & Bennett, 1997:27).

3.2.1.2 The multiple definitions of play

It only takes a short discussion with a gathering of preprimary school teachers to conclude that play has a multitude of definitions. According to the Collins Concise Dictionary (1999, s.v. "play"), there are 32 possible understandings of the word "play". The primary definition given is that play is an act of occupying oneself in a sport or diversion.

The concept of play "subsumes a wide variety of behaviours, activities and experiences which may serve a variety of different purposes according to a child's age and development level" (Wood, 1997:30).

Several authors in the historical psychology journals of the later 19th century (e.g. "Child Life" and "The Paidologist") describe play as a prelude to adult work and a preparation for adult life (Makman, 2004:6-7). Yet Makman goes on to describe how, at the same time, a new definition of play emerged, namely an activity for its own sake.

Supporting the Montessori notion of play, play has often been defined as "the work of children" (Freeman & Brown, 2004:10) and a "tool for learning" (Moyles 1994:6). It has conversely been described as "a self-initiated and open-ended process with internal motivators that provide positive emotions and allow children to solve self-imposed problems" (Patterson, 2004:112). A Vygotskian approach would be to see play as an activity "to facilitate the interaction between and among students and teachers and lead to the development of new skills and/or understandings" (Rodgers, 2012:15) (see "Lev Vygotsky's Sociocultural Theory" par 2.3.1.2.).

Perhaps a better way to define play is to see it as a description of an activity rather than the definition of an activity in itself. This is a notion expounded by Piaget (1962:147), who describes play as the general orientation of a behaviour, or the "pole" of an activity, rather than one particular type of activity or behaviour. In his work *Play, Dreams and Imitation in Childhood* (1962) Piaget systematically argues against the popular criterion for defining play and emphasises that primarily, play is an act or process of assimilation and accommodation, a way of a child cognitively constructing his/her own realities, rather than a definition of an actual activity (Piaget, 1962:147-150).

Whatever one's chosen definition, the human propensity to play in childhood is undeniable. Children are simply designed to play (Gray, 2011:443).

3.2.1.3 The two camps of play

Although the definition of play seems to be elusive, the general perception of how play should occur in a kindergarten or preprimary school classroom can be divided into two basic schools of thought. On the one hand, there is the belief that play should be child-directed. Advocates of this approach defend the child's right to choice and the child's innate ability to acquire knowledge through self-directed discovery, child-centred and child-initiated learning activities (Stipek, 2013:432). Proponents of this approach often argue that children will develop on their own, at their own pace and that adult intervention is an unnecessary interference in the natural order and development of the child.

This form of play is often called “free-play” or “free-flow play”, as children have the freedom to choose what they want to do, how they want to do it and when to stop doing it (Santer, *et al.*, 2007: xii). This form of play is an active process, often without a product and is seen as intrinsically motivated (Lewis, 2011). Several proponents of this approach to play argue that providing children with an academic focus through direction, rather than allowing unstructured play to naturally unfold, undermines the young child’s self-confidence, natural curiosity and intrinsic motivation to learn (Stipek, 2013:432).

Piaget was an exponent of “free play” or the child-directed approach to play. In his discussion of Piaget’s view on play and cognitive development, Grossman (2004:92-93) describes that an ideal Piagetian play experience would be one in which children have the freedom to explore in a free play atmosphere, where they can learn for themselves about the physical world (see “Piaget’s Theory of Cognitive Development” par 2.2.2.1.c.). The teacher’s role would be to create opportunities for exploration and to provide materials for play, but children’s construction of structure and meaning develop out of their spontaneous and free interaction with this physical and social world. Grossman (2004:93) further believes that Piaget would say “What’s the hurry? Children will get there on their own,” if he was confronted with the modern notion of accelerating a child’s intellectual development at a young age through adult guidance and scaffolding.

Piaget also proposes that spontaneous play that incorporates cooperative play is the ideal environment for social interaction between peers (see “Piaget’s Theory of Cognitive Development” par 2.2.2.1.d). This interaction creates appropriate cognitive disequilibrium and allows children to learn through accommodating and assimilating information, changing their way of seeing things around them (Grossman, 2004:92).

An academic advantage to the “free-flow play” approach is that children develop familiarity with objects and toys, which allows them to use these tools in creative and flexible ways for solving problems. This idea was theorised and proven in the 1970’s, when researchers observed the behaviour of children who had first been exposed to certain toys before being presented with a problem in which the creative use of the toys would make the solution more accessible. Unlike those with prior exposure, children with no prior exposure to the toys were unable to solve the problem presented by the researchers. The researchers also noted how children who had previously been allowed to freely play with the toys were more tenacious in their problem-solving skills in this particular context (Sylva *et al*., 1976 in Sylva, 1984:172-173).

It has, however, been argued that preprimary school programmes devoted entirely to free play experiences are unsuccessful in assisting disadvantaged children, as many of these children are unfamiliar and untrained in playing in a sustained or rich, creative manner (Sylva, 1984:174-175).

The second school of thought is that play should be adult-guided or adult-directed. This form of play is often referred to as "structured" or "guided" play and finds its roots in Froebel's traditional kindergarten approach (Samuelsson & Pramling, 2013:1) (see "Play Theory by Froebel" par 2.2.5). Advocates of this approach argue that in guided play an adult initiates the learning process, constrains the learning goals and keeps the focus on these goals as the child guides his own discovery (Weisberg *et al*., 2013:105). In other words, adults guide play, but children are intensely involved through their own active efforts (Sylva, 1984:180). This view suggests that the child's development can be enhanced and even accelerated through guided adult activities, through giving commentary while children are playing, co-playing alongside children, encouraging children to explore materials in new ways and asking children open-ended questions (Weisberg *et al*., 2013:105).

One example of a certain type of "guided" or "structured" play can be seen in the Weikart curriculum, now referred to as the High/Scope curriculum. In a Weikart classroom teachers assist children in making deliberate choices in their play, carrying out their play plans and in sharing their play experiences with their peers (Sylva, 1984:175).

No mention of a High/Scope approach in research would be complete without some reference to the now famously dubbed "High/Scope Perry preprimary school study" (Schweinhart & Weikart, 1990). This research project was one of the largest and longest research projects in early childhood education, beginning in 1962, examining the long-term effects on children being exposed to the High/Scope preprimary school environment (adult-guided play) versus children not exposed to any preprimary school environment (presumably a free-flow play environment). Compared to the no-preprimary school group, the group exposed to the High/Scope curriculum had higher rates of employment and self-support, lower welfare rates, fewer acts of serious misconduct and a lower arrest rates as adults. It is arguable what exact component of the High/Scope programme made such a dramatic impact on the lives of the research participants, but it "*is* known, however, that guided play - rather than free play - was central to the experiences of the children" in the High/Scope research programme (Sylva, 1984:179).

In an effort to determine the superior view out of the two camps of play, an empirical study was undertaken in Oxfordshire and Miami in 1980 by Sylva, Roy and Painter. These researchers observed 240 children engaged in play activities. Children were unobtrusively observed to determine if all play was truly equally valuable in terms of "stretching the mind, nurturing concentration, problem solving and imagination" (Sylva, 1984:179). Researchers concluded that not all play is equal, and that high on the list of "mind stretching" play activities are art, puzzles, games and construction activities. Much lower on the list are playing with sand, dough and dressing up (free-flow play activities). The most dramatic research findings in their categorisation of sustained and rich play experiences were their results obtained through observations of children playing *with adults*. Sylva concluded that "play partners" (guiding adults) enriched play and also encouraged children to talk and reflect on their experiences (Sylva, 1984:179).

In another research study conducted by Jowett and Sylva in 1986 (Sylva, 1993:29-30), the researchers considered two groups of 45 children entering the reception class. One group came from local authority nursery classes, following a "guided play" philosophy, and the other group from playgroups, following a "free play" philosophy. Research findings were that children coming from guided play environments were more engaged in purposeful and creative play activities than playgroup children. They spent more time completing work-cards and one of their favourite activities was self-initiated writing. They adapted better to the routine of schooling and were more inclined towards independent functioning. They were also less inclined to ask for assistance when meeting with a problem or obstacle in their work or play, and demonstrated tenacity and persistence in tasks. Sylva describes how children experiencing guided play concentrated better, played richer and were more prepared for school than the "free play" subjects in the study.

Another leading protagonists in the second "camp" of adult-guided play, would be the cognitive psychologist Jerome Bruner (see "Bruner's Theory on constructivism and discovery learning" par 2.2.2.3). Bruner proposed that a great deal of problem solving skills in children could be developed through the assistance and guidance of adults (Wood *et al*., 1976:89). Together with his associates, he argued that problem solving and skill acquisition would not exclusively occur through leaving the learner unassisted, but that it more often than not required the process of "scaffolding" (Wood *et al*., 1976:90).

This idea of "scaffolding" was first implied in the work of Russian psychologist Lev Vygotsky, particularly as part of his concept of teaching in the zone of proximal development (see "Lev Vygotsky's sociocultural theory" par 2.2.2.2). Vygotsky held that all human activity occurs within a cultural setting, and that human activity cannot be understood apart from these social settings. Guided play would create the ideal inter-psychological setting to allow the child to construct knowledge by interacting with a person with more advanced thinking skills than himself (Woolfolk, 2010:43).

A further argument in favour of the social dynamic of guided play is presented in the work of Saxe, Gearhart and Guberman (1991:155). These researchers describe how the understanding of a mathematical concept like number development in a mother-child setting requires an analysis of three distinct aspects. Firstly, the understanding of the teacher (in this case the mother) with regard to the goal of the activity. Secondly, the goal structure that the child imposes on the activity, and thirdly, an analysis of how the teacher/mother participates in the child's construction of the goals in the activity.

The conclusions of their research demonstrate that children conceptualise a mathematical task quite differently to adults and that their solution strategies are quite different to those of adults. As such, the goal structure of numerical activities is described as an *emergent* phenomenon, occurring *through social interactions*. The goal structure of numerical activities is not located in the mental ability of the teacher/mother, or the child, but in the *interaction* between the two. It is the result of a merging of the child's understanding together with the teacher/mother's cultural transmission aimed at the child.

Hancock investigated and compared the relative effectiveness of spontaneous play versus teacher-directed play in enhancing the preprimary schooler's cognitive skills. Research was undertaken with two classes, one of which only engaged in spontaneous play, the other of which engaged in teacher-directed play. Her research findings concluded that the teacher-directed play method proved superior (Hancock, 1981). This may lead one to consider if the notion of adult-directed play can co-exist with the modern ideal of developmentally appropriate practice (DAP) in preprimary school. Galen Harlene (1994:21-22) argues that teachers who use DAP are in fact "in control" and do "teach" rather than simply allowing an exclusively "free-flow play" experience. She describes how DAP teachers should use guided play as a learning strategy, and argues that in DAP, teachers should assist children in the emergence of literacy and mathematical thinking, but that having fun is a vital part of learning. The teacher is viewed as the coach rather than the drill instructor. This idea is supported in more recent literature where developmentally appropriate teaching is described as "purposeful" and "intentional" and not a process of leaving education up to chance (Copple & Bredekamp, 2006:7).

When investigating structured and guided play versus free play, the arguments for both camps of thought are compelling and thought-provoking. The proponents of free play list the advantages of such play as invaluable for the social, emotional, cognitive and language development of the child (Singer *et al*., 2003:45). These authors also describe how children learn to become flexible, control their impulsivity and enact their feelings through unguided play (Singer *et al*., 2003:43-44).

Evidence suggests that a decline in free-flow play leads to a decline in the mental health of children and adolescents and that free-flow play allows children to develop intrinsic interests, competencies, make decisions, solve problems, exert self-control and follow rules (Gray, 2011:443).

When observing preprimary schoolers in a free-play situation, it is apparent that free-play enhances their creativity, their physical activity, their language usage and importantly, their overall enjoyment of the learning environment.

However, once again, in the work of researchers like Hancock (1981) and Wood *et al*. (1976) there is a strong argument for the importance of cognitive development in children through adult-directed play. In adult-directed play the child's current level of development can be ascertained and matched. The child's attention can be directed to relevant information and the adult can help children to break down complex tasks into smaller, more manageable steps. The adult can then assist the child in sequencing these steps correctly (Smith, 1994:24). This would be particularly appropriate in the context of mathematics instruction.

It would seem that certain cognitive, social and emotional skills can only be developed and enhanced through adult intervention and adult direction, yet other vital skills are constructed and honed through free play.

The problem of the "two camps" of play and the argument for and against the pedagogical and cognitive value of each camp is further confounded by the fact that various types of play, as mentioned earlier, are not as clearly distinguishable within these two camps. It comes back to the idea that what constitutes play is in actual fact a "notoriously difficult" concept (Smith *et al*., 1985:25). These two camps can be broken down into smaller, complex categories, as seen in the work of researchers like Smilansky (1968) and Parten (1932).

3.2.1.4 A resolution between two opposites

Instead of dividing play into two camps, David Weikart and his colleagues propose a two axis model for defining certain types of play (Sylva, 1993:26-27). In his model, two continuums cross each other perpendicularly, creating four quadrants of possible play activities stretching from total adult dominance to a *laissez-faire* approach, and total child initiation to a child responding approach. Free play and structured play can be placed onto this continuum with varying degrees of adult intervention, and varying positive developmental gains. Arguably, a healthy preprimary school environment would encompass a balance between the types of play on this continuum.

In conclusion to the discussion concerning "adult-guided" versus "child-initiated" play, a slightly alternative approach could be considered when exploring a large research project recently undertaken by Walsh and her associates in Northern Ireland (Walsh *et al.,* 2011). These researchers conducted an eight–year-long evaluation of an innovative, play-based informal curriculum called "Enriched Curriculum" introduced in Northern Ireland in over 100 primary schools (children aged four to six) between 2000 and 2002. This curriculum's focus was *playfulness*, rather than simply play. Playfulness is "a characteristic of the interaction between adult and child and not just characteristic of child-initiated versus adult-initiated activities, or of play-time versus task-time" (Walsh *et al*., 2011:107). Walsh and her associates refer to this pedagogic alternative as "playful structure".

In their explanation of this approach the researchers attest that high-quality pedagogy of the early years requires a balance between child- and adult-initiated activities. A key concept in "playful structure" lies in the ability of the teacher *to be playful* and in the fact that "all classroom activity, not only free play, can assume playful characteristics" (Walsh *et al*., 2011:110). They propose that the way forward is through blending structure in the curriculum with the notion of *playfulness*. Play is viewed as a valuable mode of learning in itself, but playfulness is the key that should unlock every learning activity (Walsh *et al*., 2011:110), encompassing outgoing, light-hearted and spontaneous interactions between teachers and children (Walsh *et al*., 2011:112). This playfulness in adult-directed classroom activities facilitates learning through high levels of engagement and good teacher-pupil relations (Walsh *et al*., 2011:113).

In the conclusion of their paper, Walsh *et al*. describe how, previously, play may have been associated with child-initiated activities and work with adult-directed activities, but "playful structure" implies an infusion of playfulness throughout the day and as a normal part of the adult-child interaction. This also implies that structured activities (like mathematical instruction) need not necessarily mean formal activities, but can be presented in a playful manner that enhances learning and scaffolding within the classroom. "We suggest that the image of playful structure is a novel way of bridging previously held divisions between formal and informal, work and play, child-initiated and adult-led activities in early years classrooms" (Walsh *et al*., 2011:117) .

Therefore, the problem of defining or "proving the best" approach to play as a cognitive activity does not rest in minutely defining the play activity as "adult-guided" or "free-flow/child-initiated", but rather in delineating the playfulness of any type of activity (Howard *et al.*, 2002). The distinction between a "play-based" curriculum and a "play-structured" or "playful" curriculum is often overlooked by enthusiastic researchers and educators alike, yet it has been suggested that the "playfulness" brought into an activity is the magical ingredient that truly makes the contribution to a child's development, particularly in an intellectual context. Howard and his associates suggest that to maximise and exploit the perceived playfulness of an activity for the child, a teacher should consider the following (Howard *et al.*, 2002):

- Use different locations for activities (not binding an activity to a table)
- Have frequent adult involvement in play and activities
- Create a positive atmosphere in classroom activities through a playful approach
- Emphasise process over product
- Create feelings of choice and control in the child

3.2.2 Playing games and mathematics

In addition to the playful presentation of mathematics concepts, the desirability of playing actual games as a primary tool for the teaching of mathematics is explored in the work of Ernest (1986). Ernest explains that playing mathematics games is particularly advantageous for the child in four particular areas: the reinforcement and practicing of skills; the acquisition and development of concepts, the development of problem solving strategies and the provision of motivation (Ernest, 1986:3-5).

He expounds how mathematical games encourage children to become actively involved and receptive in their learning (Ernest, 1986:3). He does, however, warn that games should be selected on the basis of one's teaching objectives, and should be incorporated into a teaching programme – rather than a haphazard collection of activities whose primary purpose is entertainment or to fill up teaching time (Ernest, 1986:5).

The advantages of games and teaching mathematics in a "game-based" fashion is further endorsed in the work of researchers Moeller *et al*. (2012:261), who add that playing games allows concepts to be accessible for the child's own experience. It is an emotionally fun experience for children and “by using games to lead your child to the discovery of mathematics, one can ensure that the child will associate maths with pleasant experiences” (Maree, 1994:21) (see “Behavioural learning theories” par 2.2.3.). A further advantage to playing games in mathematics is that it provides a multicultural platform for problem-solving (Charlesworth, 2012:48).

Although research into game playing and mathematics was popular in the latter years of the 20th century, the idea has continued to gain momentum and “the topic is trending in the past decade” (Hernandez, 2013:112). Research by Ramani and colleagues concludes that playing number board games in small groups with low-income children can promote the development of a multitude of mathematical concepts like number line estimation, magnitude comparison, numeral identification and counting (Ramani *et al*., 2012).

However, Ainley cautions that it would be misleading to assume that all children will learn equally well through playing mathematical games. Nevertheless, she highlights an important advantage of playing games in its ability to discourage mere rote learning and in allowing children to exercise mathematical principles for a pre-determined and entertaining purpose (the game’s objectives) and not to merely complete exercises set by another person, which has less bearing on the life-world of the child (Ainley, 1990:85-91). In this context, games are a catalyst for the acquisition of mathematical knowledge as they provide known situations and authentic activities and transactions within the child’s physical and social world (Aubrey, 1993:30).

Ainley equates the use of mathematical skills in mathematical games to the reading of comics in the onset of literacy skills in life of the young child (Ainley, 1990:86). She also elucidates how mathematical games are excellent tools for teaching skills like predicting and testing, conjecturing, generalising and checking and justifying (Ainley, 1990:87-90).

Teachers stand to gain from the game experience as well. In her reference to the Primary Mathematics Project led by Professor Richard Skemp at Warwick University, focusing on the inclusion of games in a mathematics curriculum for young children, Ainley describes how teachers began to enjoy the “quality time” spent with children. In playing mathematical games with small groups of children, teachers could access their pupil's thinking strategies in an easy and natural way, without the intimidation of an obvious assessment environment (Ainley, 1990:90-91).

In conclusion, the Committee on Early Childhood Mathematics of the US National Research Council provides a list of the advantageous features of mathematical "play" or games (Cross *et al*., 2009:251):

1. It is solver-centred with the solver being in charge of the process
2. It uses the solver's current knowledge
3. It develops links between the solver's current schemes while the play is occurring
4. These links will reinforce current knowledge
5. It will assist in future problem solving/mathematical activity as it enhances future access to knowledge
6. It is applicable to all ages

3.2.3 The manipulation of concrete apparatus

In addition to games as an ideal method for teaching mathematics, the Committee on Early Childhood Mathematics of the US National Research Council also advocates the use of concrete materials and manipulatives in the teaching of mathematics. "Concrete materials are needed for preschoolers to learn non-verbal and counting strategies for addition and subtraction" (Cross *et al*., 2009:252). It is proposed that by counting manipulates, children develop meaningful understanding of a number as an adjective e.g. 5 cats, rather than the abstract idea of number as a noun. Concrete apparatus allow children to represent written or verbal symbols, avoid retrieval errors and understand decompositions (Mix *et al*., 2002:111-112). The committee hastens to add that manipulates should be seen as thoughtful stepping stones rather than a prerequisite for mathematical learning, and as such, children should progress to solving tasks without them (Cross *et al*., 2009:252). In other words, the use of manipulatives may act as "a sort of crib sheet" for children until they have internalised the ordinal meanings of numbers or memorised number facts (Mix *et al*., 2002:111-112).

The idea of using materials and activities that are real, concrete and relevant in the field of South African early mathematics is also strongly promoted by Botha *et al*. (2005:703). They refer to the work of Piaget and his ideal of a stimulating learning environment (see “Piaget’s Theory of Cognitive Development” par 2.2.2.1.c). The preoperational child should use concrete referents when developing mathematics concepts, as, according to Piaget, even a child as old as 11 years is still not fluent in logical abstract thought (Woolfolk, 2010:34) (see “Piaget’s Theory of Cognitive Development” par 2.2.2.1.f). The idea that the environment should be a stimulating field to develop cognitive skills is supported not only Piaget’s work, but also in the work of Vygotsky and Feuerstein (Botha *et al*., 2005:701).

In her work on the reasoning and achievement correlation scores for Grade R to Grade 3 pupils, Virginia Silliphant (1983:293) suggests that children who are underdeveloped in their mathematical reasoning skills need manipulatives to assist them, e.g. providing children with rods to understand arithmetic equations. It would also appear that the use of manipulatives correlates with the working experience of teachers (Raphael & Wahlstrom, 1989:173), an idea which could indicate that it is a time-tried and proven effective method.

Moyer (2001:194) cautions, however, that the use of manipulatives is not merely a “magic wand”. The effectiveness of the use of manipulatives can only be considered in terms of how they connect and relate with other features in a mathematics lesson. It has also been suggested that teachers should minimise the use of manipulatives that are too rich in perceptual detail or highly familiar to children in a non-school contexts, as this may distract the focus of the learners, leading to less depth in learning or making dual representations more challenging for the child (McNeil & Jarvin, 2007:314).

3.2.4 Movement as a means of teaching maths

Although overall, a physically-based pedagogical approach to teaching young children is beneficial for their health, the relationship between physical activity and academic achievement has been debated over the years. Mathematical learning appears to correlate to the overall physical development of the child, beginning with sensory and kinaesthetic movement and progressing to concrete learning (three dimensional) and ultimately abstract learning (two dimensional) (Charlesworth & Lind, 2012:3). Motor development and cognitive development may be fundamentally neurologically intertwined (Diamond, 2000).

Gallahue and Donnelly (2003:103) claim an undeniable link between motor development and cognitive concept learning in the early years of a child's life. They attest that research has proven that the movement activities experienced by children are a means of reinforcing concepts learnt in the classroom in subjects like mathematics. Movement is a way for children to grasp concepts that are normally taught only two-dimensionally or auditory-visually through the use of additional sensory modalities (Gallahue & Donnelly, 2003:110-111).

Fedewa and Ahn (2011) considered a synthesis of 59 studies on the topic dated from 1947 to 2009 and conclude that physical activity has a significantly positive impact on children's cognitive outcomes and academic achievement in school. Similar results were found in a second analysis undertaken by Erwin and his associates who, through systematically reviewing, published studies on the topic of classroom-based physical activity interventions from 1990 to 2010, conclude that incorporating physical activity into the school day is an inexpensive and successful intervention for improving outcomes for students (Erwin *et al*., 2012a:32).

However, there are research findings that do not support the above claims. In a study investigating the relationship between cognitive and motor performance in children aged 5 to 6 (independent of the confounding variable of attention) global relations between cognitive and motor performance could not be significantly established, but conversely, relations between specific cognitive tasks and motor performance were positively established (Wassenberg *et al*., 2005:1100).

Similarly, inconclusive results were found by Keeley and Fox, who found insufficient evidence in their examination of research in the field in the last decade to confidently confirm the hypothesis that an increase in physical activity directly translates into an increase in academic achievement. An interesting aspect of their findings, however, was that replacing academic time in a curriculum with physical activity time appears to have no *detrimental* effects on a child's academic achievements (Keeley & Fox, 2009:210).

For the purposes of this study, it is postulated that regardless of the somewhat conflicting research findings linking cognitive outcomes directly with physical activity, and regardless of the limited prior research proving physical movement as being beneficial to the structure of teaching mathematics, a playful teacher-directed approach incorporating physical movement will have the advantage of keeping young children interested and enjoyment levels high, which will translate into a better overall learning experience in the mathematics context (Bryan & Bryan, 1991:490) and a decrease in mathematics anxiety (Vukovic *et al*., 2013:9).

A preprimary school teacher should try and integrate physical movement into academic lessons and academic lessons into physical movement as *"*physical education context presents plentiful opportunities to challenge students to employ critical thinking strategies*"* (Gallahue *et al.*, 2003:671). By providing physical education activities that children would not normally pursue on their own, experiences are created that positively impact perceptual-motor and cognitive concept learning (Gallahue *et al*., 2003:118). At a practical level, however, even if mathematics lessons incorporating movement are not possible, allotting short physical activity breaks to students during the day can significantly improve their reading and mathematics scores (Erwin *et al*., 2012b).

3.2.5 The learning set approach (see "Theory of learning sets" par 2.2.4.)

The idea of a "learning set" was first postulated by Harold Harlow (Harlow, 1949) after his work with primates seemed to indicate that through repetitive and numerous examples of learning experiences, learning improved dramatically and the principles learned could be generalised more effectively. This method has also been described as a readiness or predisposition to learn based on previous learning experiences, and the ability of the organism to solve each successive problem (of equal or increasing difficulty) in fewer trials (Anon., 2013). Pasnak and his associates (1991:6) employed this approach of using a large number of problems involving a broad variety of concrete objects. They explain that although the problems may differ quite broadly in details, they can all be solved by the same principle, which is gained inductively and repetitively (Pasnak *et al*., 1991:6). In other words, when applied to a mathematical context in preprimary school, a learning set can be seen as a variety of games and concrete experiences applied over and over again, teaching the same mathematical principle, allowing children to repetitively experience this principle, increasing the likelihood of their internalising and generalising it.

The “learning set” approach is also supported by neurological evidence suggesting that practice in a particular skill results in long-lasting structural changes in the brain (Gaser & Schlaug, 2003:9240). Butterworth states that by practicing a skill, the number of neurons the brain assigns to that skill increases on a relatively permanent basis (Butterworth, 1999a:313). He also advocates that improving mathematics abilities is simply a matter of more deliberate practice (Butterworth, 1999a:314).

3.3 Why begin at preprimary school?

Between the ages of 5 and 7, children are comfortable and ready to begin mathematical idea representation through a variety of media and symbols (Botha *et al*., 2005:699). This idea is also expressed in the statement, “the cognitive sciences have helped us understand that in the course of development, quantity and number become solidly interconnected in a child’s thought around the age of 5, providing a foundation for number sense and for successful learning of arithmetic” (Griffin, 2004:42).

There is ample evidence to support the claim that a child’s mathematical performance in preprimary school is a strong predictor or their mathematics achievement in later schooling (Jordan *et al*., 2009; Morgan *et al*., 2009; Mazzocco & Thompson, 2005; Locuniak *et al.*, 2008; La Paro *et al*., 2000).

In their large longitudinal research project in 2007, Duncan *et al*. investigated the links between school readiness and later school mathematics and reading achievement. They concluded that the strongest predictor of later achievement is school-entry level math, reading and attention skills. A meta-analysis of these results reveal that early math skills have the greatest predictive power overall. Their concluding remarks state, “particularly impressive is the predictive power of early math skills, which supports the wisdom of experimental evaluations of promising early math interventions" (Duncan *et al.*, 2007:1444).

3.3.1 A brief look at the preprimary schooler's brain

The first years of a child's brain development are defined as the stage of high plasticity (Berk, 2013:188). In addition to high plasticity the brain is also described as "sponge-like" during the child's first few years, allowing the easy acquisition of new skills (Berk, 2013:191).

Human beings are born with approximately 100 billion neurons and a maze of synaptic connections between these neurons. Within the first few years of a child's life the body begins a process of retracting synapses called "synaptic pruning". During this process, more active synapses tend to be strengthened and less active ones are weakened or even eliminated, a discovery accredited to Peter Huttenlocher in 1979 (Anon, 2014f). This pruning process culminates near the age of 6 (Nelson *et al*., 2008:24). Thus the brain uses a "use it or lose it" principle. If a connection is not consistently used it is eliminated to allow other connections to become stronger (Edie & Schmid, 2007:1). The preprimary school years are therefore the time during which the brain begins to maximise efficiency by determining which connections to keep and which to eliminate (Edie & Schmid, 2007:1).

In the process of making a neurological argument for an early approach to teaching mathematics, the discussion now briefly diverges into a neurological defence of a play-based approach to teaching mathematics. Neurologically, a link has been established between cognitive changes and structural brain changes (Casey *et al*., 2008:115). Within the white matter of the human brain lies the limbic system, functionally and anatomically interconnected nuclei and cortical structures that control functions necessary for self-preservation, as well as moderating the body's level of arousal and motivation (Swenson, 2006). These emotional responses are curtailed by the controlling functions of the prefrontal cortical regions of the brain (Sousa, 2008:100; Casey *et al*., 2008:112). Studies in human brain growth suggest that the brain's phylogenetically older cortical areas (including the limbic system situated in the white matter of the brain) develop faster in childhood than the newer prefrontal cortical regions (Lenroot & Giedd, 2006:726; Gogtay *et al*., 2004:8177). Development thus follows the sequence of milestones in cognitive and functional development.

The limbic area reaches full maturity at about 10 to 12 years, but the frontal lobes only mature closer to 24 years of age (Sousa, 2008:100). This translates into the fact that younger children are guided more quickly by emotional responses than rational thought (Sousa, 2008:101). Within the context of learning, a young child's *emotions* will direct their attention to a mathematics lesson, rather than a deliberate decision-making process to do so. Teachers should therefore strive to make an emotional connection with their pupils during lessons to ensure that they pay attention and see its real-life application (Sousa, 2008:101). Play will capture the child's emotional interest quickly, arousing the attention levels in the brain of a child and allowing for an optimal learning experience.

3.3.2 Preprimary school is the time to start scaffolding executive function

Executive function (EF) can broadly be defined as high level cognitive functions like attention, planning, problem solving, inhibition, working memory and decision making. They are the set of cognitive operations and strategies necessary for self-initiated, purposeful behaviour in relatively novel or challenging situations (Berk, 2013:281).

Research confirms that the cognitive processes involved in executive function are likely to play a role in knowledge acquisition in early mathematics (Blair & Razza, 2007:649). EF is more important than intelligence quotient (IQ) in determining school readiness, and EF predicts math competence throughout schooling (Diamond & Lee, 2011:959).

Early childhood is a vital time for laying the foundations for EF (Berk, 2013:282). Preprimary school is a time for making strides in focusing attention, inhibiting inappropriate responses and thinking flexibly. This parallels rapid synapse formation and synaptic pruning in the pre-frontal cortex (Berk, 2013:282).

EF can be improved as early as 4-5 years of age by the training of teachers in better teaching approaches. School curricula hold much potential for affecting EF broadly and getting children on a "positive trajectory from the start" (Diamond & Lee, 2011:963).

3.3.3 If infants can do maths, preprimary schoolers can too!

Another argument in favour of the notion that preprimary school is not a too-early start for a quality mathematics programme lies in research concerning the mathematical ability of infants. It has been postulated that core systems of numerical representations are present in babies (Feigenson *et al*., 2004:307) and that even 9-month-old infants are capable of large-number addition and subtraction (McCrink & Wynn, 2004). The idea that babies can master certain aspects of the number concept and number knowledge is believed and researched by many experts, and was a particularly vogue subject of research in the latter years of the 20th century (Starkey & Cooper, 1980; Antell & Keating, 1983; Simon *et al*., 1995; Koechlin, 1997).

3.3.4 Sensitive periods

A sensitive period refers to a time when the effect of experience on the brain is particularly strong, and where certain capacities are readily shaped or altered by experience. The experience must be of a particular kind and occur within a certain period if the behaviour is to develop normally (Knudsen, 2004:1412).

Maria Montessori (see "Maria Montessori" par 2.2.6) is well-known for her belief and work on "sensitive periods" of development in the child. According to Montessori, particularly before the age of 6, children go through these well-defined periods of interest in certain particular areas of development (Lillard & Jessen, 2003:6). Montessori's career with normal children began in 1907 in the *Casa dei Bambini* house where she worked with more than 50 children between the ages of two and five (Gordon & Brown, 2011:13). Montessori was acutely aware of these children's natural interest in learning, and she introduced complex and abstract mathematical concepts to her pupils at a young age based on her understanding of their interest and sensitive periods. The methods of mathematical computation used by very young children in modern Montessori classrooms are startling and unmatched in most normal schools, let alone pre-primary schools (Shute, 2002:70). Montessori children often accomplish rational counting by as young as 4 years (Montessori, 1961:136-137) and Montessori herself noticed that presenting certain mathematical concepts to older children (7 years+) resulted in a luke-warm response, yet younger children were extremely enthusiastic when introduced to the same principles (Montessori, 1961:137), providing evidence for the “sensitive period” hypothesis. This idea has been criticised by some, even sometimes creating a sense of disgust in visitors seeing young Montessori children handling large arithmetic problems (Montessori, 1961:137).

The discussion on the reasons for teaching mathematics at a preprimary school age is concluded with a quote from Botha *et al.*, who claims that “one could probably safely say that it is essential for learners to acquire a sound background in mathematics from an early age onwards in order to stand a chance of achieving satisfactory results in mathematics in later years…” (Botha *et al.*, 2005:698).

3.4 What should be taught in a preprimary school mathematics programme?

By the time the child enters formal schooling, mathematics concept formation should have already been established (De Witt, 2011:184). These essential mathematics concepts taught in preprimary school necessary for formal schooling can be referred to as “pre-mathematics skills” (Anon, 2013d), and include skills like counting numbers, sequencing of numbers, shapes and relative sizing. These pre-mathematics skills are further intertwined with the development of the learner’s language competence (De Witt, 2011:185).

The following essential mathematical concepts should be taught in a preprimary school programme (De Witt, 2011:186): Classification, ordering, comparing, measurement, counting, graphing, addition and subtraction, shape, conservation and the concept of retention, sequencing, money, patterning, cardinal numbers and ordinal numbers.

According to the Department of Education’s Curriculum and Assessment Policy Statement (DoE, 2011:9-11), Grade R mathematics content is divided into five specific areas, namely: numbers, operations and relationships; patterns, functions and algebra; space and shape; measurement and data handling.

Although the list of possible pre-mathematical skills that should be taught is exhaustive, for the purposes of this investigation only a few prominent pre-mathematics skills that are pre-eminent in current research trends and literature will be considered.

As mathematics is closely related to verbal development, our point of departure is that a good foundation in the language of mathematics is essential, and that acquiring mathematical language opens the door to mathematical thinking and complex skills (Mix *et al*., 2002:135).

3.4.1 Mathematics vocabulary and language

The one important influence on arithmetic that varies between cultures and the home and school contexts, is that of mathematical language (Dowker, 2005:207). If mathematical language is not clearly explained or deduced by the child, mathematics will be "full of incomprehensible mumbo-jumbo" (Dowker, 2005:207). It would therefore seem that the importance of mathematical language and language acquisition for young learners is one of the most critical factors to include in a young learner's mathematics programme (Botha *et al*., 2005:706).

The dialogue that specifically takes place between the child and the adult during the imparting of mathematical knowledge is referred to as Mathematical Mediated Language (MML), which is the framework in which mathematics and language structures become integrated through the social construction of knowledge (Moseley, 2005:386).

Rabel and Wooldrigde concur that high quality dialogue is recognised as an essential component in achieving mathematical understanding (Rabel & Wooldridge, 2013:15). In their action research study with 33 Grade 4 students in a mathematics class, they conclude that children should be encouraged to engage in exploratory talk during mathematics lessons as this has been proven particularly beneficial for medium-ability mathematics learners (Rabel & Wooldridge, 2013:21).

Providing children with guidance and practice in how to use language for reasoning will enable them to use language more effectively as a tool for working on mathematics problems together, and will also improve their individual learning and understanding of mathematics (Mercer & Sams, 2006:525). It would appear that the quality of dialogue between teachers and learners, and among learners, is of great importance if it is to have a significant influence on learning and educational attainment (Mercer & Sams, 2006:525).

The idea of researching the quality of mathematics instruction as it relates to MML is not a new one. Reeves (1990:446) refers to an Australian action research project undertaken in Perth metropolitan schools in conjunction with Curtin University. Teachers and speech students documented young children's language usage, verbal reasoning and strategies in mathematical contexts. Their concluding discussions emphasise the importance that language modelling plays in the mathematics classroom. Language modelling was already described in the 90's as something of great importance for young children (Reeves, 1990:446).

Teachers generally demonstrate a lack of utilisation of higher level mathematical language (Rudd *et al.*, 2008). According to researchers, most mathematics-mediated language appears to centre on numbers and lower level thinking skills. Very little consideration appears to be given to seriation or ordering, shapes of objects, addition or subtraction or patterning. Rudd *et al.* also note an overall void of planned mathematical activities within the preprimary school classes they observed, leading to obvious heightened concern (Rudd *et al.*, 2008:79-80).

Learning mathematics has been equated with learning a new language (Pimm, 1987 cited in Dowker, 2005:97). Dowker (2005:98) postulates that translating between arithmetic problems presented concretely, verbally and numerically is crucial in a child's arithmetic development. The inability of children to translate between concrete and numerical formats will create a hindrance to the child's understanding of arithmetic. Other researchers concur that weak language proficiency interferes with the comprehension of mathematical problems (Sun Lee & Ginsburg, 2009:39). The most important mathematics language children learn in a stimulating mathematics programme is the language of thought, justification and proof, as this language is far superior to a language involving e.g. the remembering of simple bonds (Sun Lee & Ginsburg, 2009:40). Nevertheless, whether talking of bonds or advanced mathematical thought, we conclude the argument in favour of the importance of a MML-filled curriculum with a study by Klibanoff and her associates, who explain how their research demonstrates that the extent of a teacher's mathematics-related talk is significantly related to the growth of a preprimary schooler's mathematics knowledge over the course of the school year (Klibanoff *et al*., 2006:66).

3.4.2 Cardinal numbers, ordinal numbers and counting

The ability to count is a fundamental pre-mathematical principle, common to human behaviour for at least 50 000 years and the foundation of mathematical notation and numeral systems (Anon, 2013c). Counting is regarded by many as the very foundation for mathematics. This idea has, however, been challenged by Russian psychologist and educator Davydov, who adopted the position that the comparison of quantities within sets is more fundamental than counting numbers (Sophian, 2007:6). That being said, numerical information about collections of objects or events are encoded very early in life and form the foundation for further development in the mathematical arena (Sophian, 2007:6). At a young age, this numerical information is obtainable through actual counting or perceptual subsidising – which involves stating how many items are in a group without actually counting them (Charlesworth, 2012:85).

The concept of counting in early childhood has been assumed to encompass five basic principles, initially proposed by Gelman and Gallistel in 1978 (Tipps *et al*., 2011:168 ; Gelman & Gallistel, 1978):

- The one-to-one rule – counting objects individually by connecting one counting word to each object
- The stable order rule – counting words must be memorised in an unchanging order
- The cardinal rule – naming sets of objects by their total value or the last number counted
- The abstraction rule – dissimilar objects can be counted as a part of the whole group
- The order irrelevant principle – objects can be counted in any order

Building on the work of Gelman and Gallistel, Fuson (1988:98) explored possible errors that children make in counting. Errors were prevalent in young children who did not know the words corresponding to the set i.e. they had not learned by rote the numbers in sequence, or they experienced accuracy errors in one-to-one correspondence. There was little demonstration of errors in the cardinality principle. Fuson (1988:401) claims that in terms of counting, children understood quite early that counting required the use of a special list of counting words and that

these words had a standard order. Children as young as three seem to be able to see various entities as countable units.
It is truly amazing that very young children are able to display competence in counting, which is a complex activity, and children as young as 4 ½ years can demonstrate quite a high level of competency in this regard (Fuson, 1988:402).

In the context of preprimary school, the child should attain competence in two particular counting stages, namely that of rote counting and that of rational counting. Rote counting involves a child using the number names, but not necessarily incorporating the one-to-one rule or the correct number sequence (Reys *et al*., 2012:151). Rational counting involves giving the correct number name to objects counted in succession. It incorporates the one-to-one rule, as well as the cardinal rule of counting (Reys *et al*., 2012:151). This one-to-one correspondence should be the focal point in teaching children even at *pre*-kindergarten level and is one of the most fundamental components of the concept of number (Charlesworth, 2012:70).

It is believed that once rational counting has been achieved, the focus should shift to more efficient and sophisticated counting strategies like counting on, counting back and skip counting (Reys *et al*., 2012:152-154).

Counting on is defined as the process whereby the child can start counting at any number, and proceed counting using the correct number names (Reys *et al*., 2012:152).
Skip counting is defined as the counting of every n^{th} number in a series (Frank, 1989:15). Skip counting encourages speed and flexibility in counting and is connected to multiplication and division (Tipps *et al*., 2011:176). It is also useful skill in laying the foundation for money counting and telling the time (Frank, 1989:15). Counting back refers to the ability of the child to count backwards from any particular point, and this skill is important in laying a foundation for subtraction (Reys *et al.,* 2012:152).

Counting strategies in preprimary school programmes should also promote the introduction of ordinal numbers.

Piaget explains the concepts of cardinality and ordinality in counting in his description of counting a series of objects (e.g. 7 objects on a table). Counting these objects requires one to ignore the differences between objects and to count each element only once. The elements are only noted as different in the place they occupy in the counting sequence. The ordinal number of the last element in the sequence, in this case the 7th, represents the quantity in the set. As the last object is the 7th object (ordinal number) there are 7 (cardinal number) objects in total (Piaget, 1960, in Hamel, 1974:44).

The importance of counting as a preprimary school mathematical skill is emphasised by Thompson, who believes that young children will use counting skills for problem solving and mental calculations, and through counting will gradually develop greater mathematical cognition (Thompson, 1995:39). He also claims that counting is one of the basic components of a child's "problem solving armoury" and that children will creatively combine the counting skills they acquire in preprimary school with other acquired mathematical skills, facts and knowledge in problem-solving later on. "It is through the application of increasingly more efficient counting procedures that young children gradually discover or construct for themselves many of the basic number concepts" (Thompson, 1995:39). Arguably, Thomson's concluding stance is that counting, and its sub-skills, should take pre-eminence over all other "pre-number activities" in a preprimary school mathematics programme.

Match counting is a further important aspect of counting in a preprimary school syllabus. It is the understanding that the outcome of a count not only establishes the numerical value of a set, but also provides information about its numerical relation to other sets whose cardinal value is known (Sophian, 2007:35). Thompson states that there is a two-fold reason why matching activities appear so prominently in early childhood mathematics programmes, namely that they help children with the concepts "fewer" and "more", and that they prepare children for further counting, particularly according to Gelman's one-to-one correspondence principle (Thompson, 1995:38).

Accurate comparisons between sets seem to be very challenging concept for the young child. In a series of experiments conducted in 1987, Sophian noted that children struggled with sets that were separated spatially and arranged in different configurations (Sophian, 2007:35). This confirms the

Piagetian notion that in the pre-operational child, as long as optical correspondence lasts, equivalence is obvious, but once the first is changed, the second disappears (Piaget, 1950:132).

Ultimately, number counting in the preprimary school will culminate in developing a better understanding of number sense, and ideally a number-symbol correlation. Number-symbol correlation is believed to develop through looking and listening and, through play, develops when children imitate what they have seen and heard (Charlesworth, 2012:248). Gifford also believes that young children thoroughly enjoy recognising and representing numerals, and should be encouraged to do so, to enable the building of a repertoire of physical, visual and auditory images, including mathematical symbols (Gifford, 2005:18-19).

3.4.3 Ordering/seriation

Preoperational seriation involves ordering things from least to most, according to a quantitative dimension like height or width (Ciancio *et al*., 1999:193). It is the arrangement of objects based on gradual changes in an attribute (Tipps *et al.*, 2011:162). The ability to insert into a series implies "the ability to relate an item to others in an increasing or decreasing series and to insert the item in its proper place in that series" (Kidd *et al.*, 2008:166). Therefore the culmination of ordering and seriation in a preprimary school mathematics context will be the child's ability to order and insert numbers in a series, as seriation is a process of developing comparative vocabulary such as "bigger than" or "smaller than" (Tipps *et al.*, 2011:163).

Piaget (1952 cited in Butterworth 1999b:99) claims that understanding and organising numbers is closely connected with understanding inclusion (hierarchy of logical classes i.e. ordering of numbers) and qualitative seriations. The ability to seriate is, in turn, rooted in the child's ability to reason transitively. This implies an understanding that if A is bigger than B, and B is bigger than C, then A is bigger than C (Piaget, 1950:44). Classification and the ability to insert into a series are regarded by Kidd and her associates as the earliest forms of abstract thinking (Kidd *et al*., 2008:174) – an idea more associated with Piaget's concrete operational stage of thought (see "Piaget's theory of cognitive development" par 2.2.2.1.f).

As we have described, seriation implies a degree of conservation and transitive reasoning, in that the child must grasp that by moving objects around in a series, one is not adding or subtracting from their total numerical value, yet the placement of an object into a series will depend directly on the relationship that exists between that object and the object preceding and following it. Piaget believed that this level of cognitive reasoning was only possible once a child had obtained abstract reasoning skills (see "Piaget's theory of cognitive development" par 2.2.2.1.f). However, Kidd *et al*. (2008:196) counter-argues that by providing successful instruction (learning sets using the oddity principle, insertions into series and conservation) younger children can gain the early abstract thought required.

In one of the first published research projects in preprimary school seriation, Omotoso and Shapiro (1976) conclude that there was a significant correlation between seriation, classification and conservation and mathematics achievement in Nigerian children between the ages of 4 and 8. Seriation proved to be the strongest predictor (Omotoso, 1976:1335). In a research project conducted 7 years later, Silliphant (1983:293) concurred that reasoning in kindergarten, particularly in the areas of conservation, seriation and classification had a profound impact on achievement in early school grades.

If the importance of insertions into a series is not grasped as a pre-mathematics skill, a preprimary school child may face serious difficulties in their navigation of an early school mathematics curriculum (Kidd *et al*., 2008:166). Most preprimary schoolers are able, through maturation and experience, to form a series of objects. However, inserting a new item into an already existing series is a more complicated skill that 3-year-olds and 4-year-olds are unable to fully grasp yet (Kidd *et al*., 2008:169). Insertion into a series is a skill that allows a child to eventually also deal with concepts like ordinality and number lines.

Ciancio *et al*. (1999) argue that teaching seriation is often poorly guided by research and that very few preprimary school teachers understand the importance of this skill. In their study involving a large variety of games-based experiments, young children were strengthened in their abilities of classification and seriation, and were thereby better equipped to meet the cognitive demands of kindergarten and the primary grades.

In practice, Kidd *et al.* suggest that preprimary school teachers should spend as little as 10 minutes per day, three times a week playing games with children involving the oddity principle, seriation and classification principle to show significant gains in their children's reasoning abilities – which will in turn translate into other mathematical achievements (Kidd *et al*., 2008:193). These gains, taught in preprimary school, will also persist through to Grade 1 (Pasnak *et al*., 1996:87). It is suggested that the effect of this intervention is self-propagating, as well as lasting (Pasnak *et al*. 1996:92).

It is noticeable in the preprimary school classroom that one of the end results of seriation and ordering is the ability of the child to accurately estimate the place of a number on a number line. The skill of number-line estimation has been positively related to math achievement (Booth & Siegler, 2006:189).

3.4.4 Classification and the oddity principle

Classification is defined as putting things together that are alike and belong together, assisting children in the development of number concept (De Witt, 2011:186). This process incorporates the child's ability to match groups of objects that share common characteristics and attributes (Tipps *et al.*, 2011:161). Preoperational classification includes the concepts of sorting, understanding hierarchies and mastery of the oddity principle (Ciancio *et al*., 1999:193).
Pasnak *et al*. (1991:5) postulates that "the progressive development of concrete operational thought throughout the elementary school years involves many other abilities, but classification, seriation and conservation are probably the key mental operations at the outset".

The oddity principle can be described as the converse of classification in that it is defined as the ability to identify the only item in a group that differs from all others on some level (Kidd *et al.*, 2008:167). Utilisation of the oddity principle implies a process of comparing, which involves establishing a relation between two or more objects on the basis of their shared attribution (De Witt, 2011:186). This ability also marks the transition of thinking primarily from a perceptual perspective, and advancing into an abstract thought patterning (Kidd *et al*., 2008:167). Researchers believe that a child who cannot consistently solve oddity problems will be unable to separate relevant and irrelevant items in other learning situations in the classroom (Pasnak *et al*., 1996:87).

In their research, Kidd *et al*. (2008:168) discovered that when young children were initially exposed to a group of objects e.g. safety pins, and asked to identify the "unlike" object, children were slow to recognise the overall relation between objects and rather focused on absolute qualities like the "bigness" or "littleness" of the objects. The researchers also discovered that children required extensive practice in their understanding of the oddity rule before they could apply it to a variety of dimensions.

Pasnak and his associates discovered that teaching the oddity principle together with the principles of conservation and insertion into a series to 17 classrooms from 5 different schools produced significant gains on the Otis-Lennon School Ability Test (OLSAT), a standardised test of cognitive ability used as a predictor of school performance. This was followed 4 months later by significant gains in the Standford Early School Achievement Test (SESAT) in verbal comprehension and mathematics concepts (Pasnak *et al*., 1991:12).

Kidd *et al*. (2008) embarked on a research project where 26 children from an experimental group were instructed in the oddity principle, number conservation and insertion procedures. Instruction was undertaken using familiar, everyday objects. With regard to the oddity principle, children were presented with three objects that were similar and one that differed in one dimension. In the first 20 games, the object differed in form. In the next 20 games, the object differed in size. In the last set of games, the object differed in orientation. Research participants were assessed with the Woodcock-Johnson III Applied problems scale and the oddity scale from the Otis-Lennon Ability Test (OSLAT). The research results strongly supported the idea that cognitive functioning can be enhanced through instruction on classification, number conservation and insertion into series. Research results also indicated that experimental group participants performed better overall in numeracy tasks. Due to the cognitive instruction received, research participants in the experimental group demonstrated an approximate 3-month gain on a standardised scale of the development of early numeracy.

In their discussion on their findings, the researchers describe how "it is reasonable to conclude that the higher achievement (general) of the cognitive group is due to the cognitive intervention designed to promote the kindergarten student's reasoning ability" (Kidd *et al.*, 2008:192). It was further postulated that as the preprimary schooler's cognitive abilities were enhanced, their opportunity to learn from classroom instruction would most likely be increased.

In conclusion to their research, Kidd *et al*. advocate teaching the oddity principle, insertions into a series and conservation to kindergarten students as a "promising approach to promoting early abstract thought and mathematical achievement" (Kidd *et al*., 2008:196).

More recently, a similar research project was conducted in 2012, and results again confirmed that playful instruction in seriation and the oddity principle translated into improved cognitive abilities, which was accompanied by improvements in early numeracy (Kidd *et al*., 2012:916).

3.4.5 Problem solving

Problem solving is a major vehicle for learning in that children have to connect what they know to a new situation (Gifford, 2005:151). It is the focus of modern mathematics programmes (Charelsworth, 2012:40) and is vitally important for the developing of understanding, therefore should be ingrained in every mathematics lesson (Compton *et al*. 2007:79). Structured problem solving activities are ideal for learners entering the transition stage to concrete operations (Charlesworth, 2012:40).

Problem solving has been described as a motivation for learning in children, and a process of stimulating higher levels of thinking like analysis, synthesis and creativity (Gifford, 2005:151). Problem solving involves important cognitive learning processes (Gifford, 2005:151):

- Visualising solutions
- Checking for errors
- In a collaborative context – imitation, instruction, talking and reflecting

Charlesworth adds that problem solving engages heuristics – a process of learning by asking self-generated questions, challenging children to think about their thinking and manage it in an organised fashion (Charlesworth, 2012:42).

Problem solving is an instrument for emotional and social learning, and builds self-esteem in children (Gifford, 2005:151). Problem solving opportunities influences the depth and breadth of student's mathematical learning (Wall & Posamentier, 2007:80).

Successful problem solving strategies include (Gifford, 2005:153):

- Getting a holistic view of the problem
- Planning, preparing and estimating
- Monitoring progress towards a goal
- Systematically trying possibilities
- Trying alternative approaches and evaluating strategies
- Refining and improving solutions

Problem solving should involve problems that children understand (familiar contexts), where the outcomes matter to them, where they have control over the process and that use mathematics with which children are confident (Gifford 2005:155). Charlesworth further advocates that problem solving is best tackled with concrete materials and the drawing of explanations of solutions (Charlesworth, 2012:43).

It can be argued that the child's ability to solve mathematical problems, in addition to other supporting skills, rests heavily on an understanding of numbers and number sense. Although computational proficiency is essential, concepts of numbers and reasoning with numbers are critical to develop number sense and computational fluency (Tipps *et al.*, 2011:13). An inability to develop a clear understanding of a number is the key predictor of later mathematical difficulties (Chard *et al*., 2008:12). Number sense is defined as "a child's fluidity and flexibility in using and manipulating numbers… an ability to perform mental mathematics and look at the world and make what, in essence, boils down to quantitative comparisons without difficulty" (Chard *et al*., 2008:12). It is also seen as a broad term encompassing preparatory mathematical skills that lay the foundation for learning formal mathematics (Kroesbergen *et al*., 2012:295). Number sense makes the connection between quantities and counting, underlies the understanding of more and less, relative amounts, the relationship between space and quantity, and parts and wholes of quantities (Charlesworth 2012:85). Its definition can incorporate "Piagetian" aspects like conservation, classification, correspondation and seriation, as well as counting skills (Kroesbergen *et al*., 2012:295) (see "Piaget's theory of cognitive development" par 2.2.2.1.f.)

Children acquire the conceptual foundation for number sense at the age of 5 or 6, when their schemas for making global quantity comparisons and counting merge (Griffin, 2004:40). Griffin also believes that all higher-level mathematics learning is based on the acquisition of number sense at a preprimary school age. In her preprimary school mathematics programme called "Number World's Programme", number sense is promoted through three basic concepts: providing rich activities for making connections (games-based and focused on counting, quantities and formal symbols), exploring and discussing concepts and ensuring that concepts are taught in a sequence (Griffin, 2004:41).

This discussion concludes on number sense and problem solving with the following thought-provoking quote: "Unless students can solve problems, the facts, concepts, and procedures they know are of little use. The goal of school mathematics should be for all students to become increasingly able and willing to engage with and solve problems" (Wall & Posamentier, 2007:82).

3.4.6 Shapes, spatial awareness and geometry

Shape and space is one of the first aspects of mathematics that young children spontaneously survey and explore, and teaching should focus on this aspect (Frobisher *et al*., 2007:6). Children are naturally curious and interested in shapes and spatial ideas (Brown 2009:474), and expanding on their interest could nurture a child's enthusiasm for mathematics and provide a context for learning about numbers and other mathematical concepts (Brown, 2009:479). Geometry in early childhood mathematics is far more important than most people realise (Arnas & Aslan, 2007:83) and children fail to reach the descriptive level of geometry largely because they are offered insufficient geometric problems in their early years (Van Hiele, 1987 cited in Clements *et al*., 1999:208).

In his article, Brown emphasises the importance of play when introducing children to shapes and geometry, and the importance that the learning environment plays in providing opportunities for children to explore shapes, engage in geometrical play and construct their knowledge. Scaffolding children in their geometrical skills acquisition is a process involving the use of rich geometric language, as well as playing games with children (Brown, 2009:476-477). A variety of stimulating manipulatives like blocks and art materials should be used to facilitate the acquisition of geometrical knowledge, which in turn will aid overall language and cognitive development (Brown, 2009).

Study on childhood education and geometry would not be complete without some reference to the Van Hiele model of geometric thought. Van Hiele and his wife proposed that children progress through various levels of geometric reasoning, similar to the cognitive stages model of Piaget, and that achievement on one level is not possible without first passing through previous levels (Crowley, 1987:1). The level of most preprimary school children will begin at level 0, or "visualisation level", which is described as the level where students can judge shapes by their appearances (Van Hiele, 1999:311). It is proposed that a child at this level can learn geometric vocabulary, identify specific shapes and reproduce them (Crowley, 1987:2). At the next level, the "descriptive level", children identify figures as having certain properties. Language is important for describing shapes at this level, but properties of shapes are not necessarily logically ordered (Van Hiele, 1999:311). On the third level, called "informal deduction level", properties of shapes become logically ordered (Van Hiele, 1999:311). Students can establish interrelationships of properties within figures and among figures (Crowley, 1987:3).

According to the Van Hiele theory, children will be unable to ultimately proceed into the production and analysis of Euclidean geometric theory (formal deduction) unless the first levels of geometric thought have been well established (Van Hiele, 1999:311). He also postulates that the levels progress sequentially, are not age-dependent, but rather dependent on quality experiences and effective teaching (Frobisher, 2007:26). This in itself should be sufficient motivation for the inclusion of thorough geometric exploration in the preprimary school curriculum. Van Hiele proposes that geometric understanding in young children should begin with play and playful activities, involving things like mosaics, pattern blocks, design tiles or tangrams (Van Hiele, 1999:310), as well as paper folding, drawing and pattern blocks (Van Hiele, 1999:315). However, van Hiele cautions that instruction in geometry should begin with an exploratory phase and gradually build into concepts and related language, and culminate in a summary activity integrating new information with what students already know (Van Hiele, 1999:311). In his earlier work, he suggests five stages of instruction in geometry leading to higher levels of thought (Van Hiele, 1959:63):

- Inquiry (children use materials to explore and discover)
- Direct orientation (children are presented with tasks that will encourage geometric characteristics to be revealed)
- Explicitation (the teacher introduces terminology)
- Free orientation (tasks presented that can be solved in different ways)
- Integration (tasks integrating all knowledge learned e.g. the child designs own activities)

The initial ideas that van Hiele proposed can be found in almost all modern textbooks on geometry and have influenced most modern geometric curriculums. As suggested by Van Hiele, the role of guided play in developing spatial awareness and understanding, is vital (Frobisher *et al*., 2007:6).

It has been deduced that young children's shape knowledge is malleable and influenced by pedagogical experience (Fischer *et al*., 2013:1877). Researchers worked with 4- and 5-year-olds to determine which pedagogical approach to teaching shapes would be the most successful. It was concluded that guided play was the most superior method when compared to free play and didactic instruction. Guided play lead to more robust learning and deeper conceptual processing (Fischer *et al*., 2013:1877).

In addition to shape and basic geometric exploration and instruction, attention should be given to activities encouraging general spatial awareness and spatial orientation in the preprimary school class as a foundation for early geometry (Charlesworth, 2012:140). Spatial orientation is a broad term that not only refers to a child's ability to mentally rotate shapes, but also to a child's ability of knowing position and location, and direction and navigation (Gifford, 2005:120). Between the ages of 4 and 7, children begin to see objects in relation to each other and thereby begin to structure space (Troutman & Lichtenberg, 2003:413). This is important for the development of ideas about left and right and about symmetry, as well as the use of horizontal lines as references (Troutman & Lichtenberg, 2003:414).

Very little research has been conducted in the area of general spatial concept development in preprimary school children (Thorpe, 1995:64). Thorpe's own research corroborates the idea that spatial concepts in young children develop through interaction with the environment and hands-on play (Thorpe, 1995:64). The important role that the environment plays in spatial awareness was suggested, however, long before in the work of Piaget and Inhelder (1967, in Clements *et al*., 1999:193) who argue that spatial representations and constructions are built up through prior active manipulation of the spatial environment.

3.4.7 Conservation

Conservation is a cognitive skill that allows a person to perceive that quantity remains the same, despite changes in appearance, unless something has been added or taken away (Gifford, 2005:84). Conservation is believed to have a direct effect on addition and subtraction fluency within a child (Wubbena, 2013:154).

The notion of conservation is almost synonymous with the work of Piaget (see "Piaget's Theory of Cognitive Development" par 2.2.2.1.f) who believed that "conservation is a necessary condition for all rational activity" (Piaget, 2013:3). In light of this statement, it could be argued that conservation of number is the foundation on which all other mathematical skills and relations should be built, yet Piaget believed that conservation is only comprehensible to children in the concrete operational stage (typically age 7-11 years), and therefore the preprimary school child would apparently be unable to understand the idea that the redistribution of material does not affect mass, number or volume (McLeod, 2010).

It is believed that children can begin conserving liquids around the age of 7, and the conservation of number develops only after this. Therefore, Piaget hypothesised that although young children may be able to count, they will not have a true understanding of a number until they are able to think logically in the concrete operational stage (Dowker, 2005:81). For example, Piaget describes his classic experiment where a pre-school child is able to place six blue counters corresponding to six red counters, but once these blue counters have been placed further apart, the child will disbelieve the equivalence between the two sets (Piaget, 1950:132).

Piaget's notion of number conservation has come under severe criticism over the years and is seen by many as occurring "certainly significantly earlier than Piaget thought" (Dowker, 2005:81). There has since been evidence through research that preprimary school children can be trained to perform well on Piagetian conservation tasks (Berk, 2013:249).

A specific criticism of Piaget's tasks involving number conservation lies in the fact that the adult asks children the same question twice. In other words, the adult asks the question, moves objects around for some reason unknown to the child, and then repeats the question. It has been argued that this process obscures the child's reasoning in that children feel adults usually do things for a reason, and ask the same question twice because they did not like the first answer given (Dowker, 2005:81). Gold argues that "*the question of whether young children's failure on the conservation task is due to a conceptual deficit or to an inability to cope with the task's communicational demands would seem to be one of the most obvious and fundamental questions that can be asked*…" (Gold, 1986:164).

On the basis of language incomprehension or inappropriate *interaction* between the adult and child, a further challenge to Piaget's number conservation experiments is issued by researchers Mehler and Bever (1967). These experimenters replaced stones or marbles with palatable treats (M&M's), and instead of being asked questions regarding the larger amount of numbers represented in each row, children were permitted to select one of the two rows to consume immediately. In these experiments, children as young as two selected the larger of the two sets, demonstrating their numerical competence and understanding of conservation way before the expected age of competence. The researchers caution that the perceptual confusion of conservation tasks appear to only be truly overcome if children have been given sufficient motivation to do so (Mehler & Bever, 1967:142). Nevertheless, through their experiments it would seem that non-conservation is actually a temporary state that peaks between approximately 3 and 4 years of age (Mehler & Bever, 1967:141), and is not a basic characteristic of the young child's native endowment (Mehler & Bever, 1967:142).

It has also been argued that the child misinterprets the conservation questions in Piaget's tasks as referring to a length question rather than a number question. The researchers McGarrigle and Donaldson (1975) used a "naughty teddy bear" to accidently rearrange the counters or length of string in the conservation task. The result was that children were far more capable of conservation when the transformation was accidental i.e. performed by the naughty teddy bear rather than by the experimenters. This research suggests that the traditional methods for assessing conservation may greatly underestimate the young child's knowledge (McGarrigle & Donaldson, 1975:347) (see "Piaget's Theory of Cognitive Development" par 2.2.2.1.g).

The arguments for and against the possibility of attaining conservation at a preprimary school age remains in question and has been strongly debated for decades (Neilson *et al*., 1983; Gold, 1986; Moore & Frye, 1986; McEvoy & O'Moore, 1991; De Neys *et al.,* 2014).

Kidd and her associates (2008:170) point out that a preprimary school child who has not grasped the notion of conservation cannot begin to understand addition or subtraction, and moving onto these concepts before number conservation is established will result in trials of memorisation for the child, rather than true arithmetic understanding. Teaching children to think more abstractly has been argued as impossible (Piaget 1941/1952 in Kidd *et al*., 2008:172), yet a possible alternative has been suggested by researchers who use the learning set method. In earlier research, Pasnak successfully used the learning set method to teach number conservation to preprimary schoolers (Pasnak *et al*., 1991:9). Children began instruction with two rows of three safety pins each and were encouraged to verbalise that the rows had the same number of pins. Instruction became progressively more complex until children could ignore changes in appearance between two rows and explain if the rows had been made equal or unequal in number through the addition or subtraction of objects. As with all other research projects undertaken by Pasnak and his associates, post-test results for children instructed in number conservation were exceptionally noteworthy (Pasnak, 1987; Pasnak *et al.*, 1991; Pasnak *et al.*, 1996; Kidd *et al.*, 2008).

3.4.8 Sequencing and patterning

Patterning ability comprises the ability to recognise, extend, create and copy patterns (Waters, 2004:321). Patterning is found within most preprimary school mathematics curricula of the world. It is regarded as a foundational skill for algebra and algebraic thinking (Tipps *et al.*, 2011:137), but until recently, was an infrequently researched topic in the realms of education.

In an attempt to create a link between patterning and algebraic functioning, Lee *et al*. (2011) investigated the relationship between proficiencies on pattern tasks and algebraic word problems in 9- and 10-year-olds. Their findings suggest a significant correlation between proficiency in number patterning and algebraic performance (Lee *et al*., 2011:280). They conclude that algebraic reasoning will be difficult if the child has either poor computational facility or poor ability to recognise patterns in information and generalise rules about those patterns (Lee *et al*., 2011:280).

But patterning incorporates more than just algebraic functioning. In a longitudinal and cross-cultural study on reasoning abilities, English argues that patterning knowledge influences analogical reasoning in young children and that identifying, extending and generalising patterns are important components of inductive reasoning (English, 2004 in Waters, 2004:322).

In spite of the gains expected from patterning, it would appear that teachers have limited understanding of the types, levels or complexities of patterning tasks (Waters, 2004:327). There are far more varieties of patterning than the simple colour patterning one often finds in preprimary school classes. One gets pattern structures like hopscotch patterns (which explore the child's ability to rotate a unit of repeat) and growing patterns (which increase or decrease systematically) (Papic, 2007:10-12). Warren and Cooper divide early childhood patterning into two broad categories, namely repeated patterns and growing patterns (Warren & Cooper, 2006:11). Patterning not only improves reasoning, but could be used as an *intervention* strategy in the lives of young children. Mulligan and associates (Mulligan *et al*., 2006) studied 683 low achieving students aged 5-12 by involving them in a project which largely aimed at, among other things, improving children's ability to identify and apply patterns. The research implied that if low achievers had poor awareness of patterns and structure, their achievement could be improved through explicit teaching in mathematical patterns and structures (Mulligan *et al*., 2006:377). Participating children showed a marked improvement in school-based and system-wide measures of mathematical achievement, as well as PASA-scores (Pattern and Structures Assessment Scores), particularly in the early grades (Mulligan *et al*., 2006:377).

Although the abovementioned studies have been conducted in a range of foundational contexts, young children are capable of developing complex patterning concepts *prior* to formal schooling (Papic & Mulligan, 2007:599). Researchers conclude that patterning promotes other mathematical processes like multiplicative thinking and transformation skills (Papic & Mulligan, 2007:599). Papic (2007:8) describes how patterning is an essential skill in early mathematics, and is vital for the development of spatial awareness, sequencing and ordering, comparison and classification. She goes on to explain how patterning is also integral for the development of counting and arithmetic structure, base ten and multiplicative concepts, units of measure, proportional reasoning and data exploration (Papic, 2007:8). Patterning can also lead to functional thinking and the understanding of variation between data sets (Warren & Cooper, 2006:14).

A noteworthy research project into the effects of patterning and academic achievement was undertaken by Hendricks and her colleagues (2006). After a four-month patterning intervention programme researchers concluded that teaching children to understand the relations involved in patterns may promote abstract thinking and may also be an additional way to support and strengthen the development of age-appropriate mental abilities, boosting overall intellectual growth (Hendricks *et al*., 2006:88).

3.4.9 Measurement

"Measurement is an important elementary mathematical and scientific competence, but…appears to be poorly learned" (Smith *et al*., 2011:617).

Measurement is regarded as a fundamental aspect of a preprimary school mathematics programme as it bridges two important areas, namely geometry and number (National Council of Teachers of Mathematics, 2000 in Cross *et al*., 2009:79). It is a mathematics topic that is used most directly in students' daily lives (Reys *et al*., 2012:403). It is also regarded as beneficial in that it encompasses many other topics in mathematics and can be used as a pedagogical tool to engage students who would otherwise be less motivated (Reys *et al*., 2012:404).

The process of measurement is a surprisingly complex task due to the principle of compensation, which stipulates that the smaller a measurement unit is, the more of these units are required to measure an attribute (Tipps *et al.*, 2011:478). The difficulty associated with this inverse proportion concept generalises back to the classical conservation problems presented by Piaget (Carpenter & Lewis, 1976:53) (see "Piaget's theory of cognitive development" par 2.2.2.1.f). In these activities the distracting cues are not different-shaped containers, but rather different-sized units of measure. It is suggested that just as children fail to recognise the height and width compensation relationship in liquid conservation tasks, so children struggle with the unit size and number of units relationship in a measurement problem.

This Piagetian conservation problem regarding measurement can be overcome if teachers make use of ready-made systems like rulers (Cross *et al*., 2009:199-200). It would appear, however, that most recent curricula for young children follow a sequence of instruction in which children first compare lengths, measure with non-standard units and then progress to formal units of measurement. This is rooted in the belief that children need to gain experience with non-standard, informal units before progressing to standard units (Reys, 2012:413). However, Boulton-Lewis *et al*. (1996:329) argue that young children should be introduced to standard units of measurement from the initial stages and not non-standard units. This idea was also confirmed by Clements, who describes several studies that challenge the conventional wisdom regarding the teaching of non-standard before standard units (Clements, 1999).

That being said, Carpenter and Lewis investigated whether young children (Grade 1 and 2) would be able to predict an inverse relationship between unit sizes and number of units (Carpenter & Lewis, 1976:54). They concluded that children do, in fact, have some notion of this relationship at a much earlier stage than predicted by previous studies (Carpenter & Lewis, 1976:57). Strangely, they hypothesised that this notion was acquired independently of experience, and ultimately that manipulating different units of measure did not contribute to children understanding unit-size-number-of-units relationships (Carpenter & Lewis, 1976:57). This, however, does not take into account the fact that children may have had measurement experiences outside of realm of the research experiment.

Unlike Carpenter and Lewis, Tipps *et al*. (2011:474) advocate that children do need a variety of experiences to help them understand the concept of measurement and to become skilled with measurement tools and appropriate units. This idea is supported by Wall and Posamentier (2007:48), who claim that children need direct experiences with comparing objects, counting units and making connections between spatial concepts and numbers in order to establish a foundation in measurement concepts. It would therefore seem that children's ability to engage in measuring activities may depend on both their level of development and their experiences (Irwin *et al*., 2004:3).

Estimation is regarded as a useful aspect of a measurement curriculum and general functioning in daily life (Hildreth, 1983:50; Siegler & Booth, 2004:428). Unfortunately, almost no documented research has been conducted in the possible mathematical and cognitive gains of implementing the process of estimation in a measurement context at preprimary school level.

3.4.10 Working memory as an EF

An often-neglected aspect of a successful preprimary school mathematics programme is the importance of the child's working memory in understanding and developing mathematics concepts. Working memory is the more contemporary view of the so-called short-term memory store and is defined as the "mental workspace" of the mind (Berk, 2013:279). The primary purpose of the working memory is the simultaneous storage, monitoring, and encoding of incoming information and processing of new or activated information (Kroesbergen *et al*., 2014:24). A child's performance on working-memory tasks is a good predictor of his capacity to learn (Berk 2013:279).

In a study on the effects of short-term memory, working memory and executive function in preprimary schoolers as a predictor of mathematical achievement at 7 years of age, researchers concluded that strength in these attributes provided an immediate head-start to mathematics and reading for school entry children, which was maintained throughout the foundation phase (Bull *et al.*, 2008:225). It was concluded that children who presented poor visual-spatial short-term memory and working memory were particularly disadvantaged, as these skills are critical for the development of early mathematical skills and for complex mathematical solving (Bull *et al.*, 2008:225). The idea of visual working memory (visuo-spatial sketchpad) playing a primary role in young children's mathematical performance was also confirmed in the research of Holmes and Adams in their examination of the different components of working memory and their correlation to mathematical performance in the young child (Holmes & Adams, 2006:339).

Kroesbergen (2012:310) and his associates undertook to investigate the relationship between working memory skills and early numeracy, and concluded that interventions aimed at improving the preprimary school child's working memory skills were both possible and beneficial for the improvement of children's numeracy skills. Working memory skills in preprimary school children can be improved through playing games requiring memorisation to process and activate information simultaneously (Kroesbergen *et al*., 2012:300). These activities lend themselves to the preprimary school classroom, where relatively short intervention strategies have great effects, and that intervention can be achieved in small group settings with little additional resources (Kroesbergen *et al*., 2012:305, 309).

Difficulties for children of lower mathematical ability may lie in a lack of inhibition and poor working memory, resulting in problems with switching and evaluation of new strategies for dealing with particular tasks (Bull & Scerif, 2001:273). Working memory is deemed essential in the performance of tasks related to number sense (Kroesbergen *et al*., 2012:298). Further evidence of the importance of working memory as a predictor of mathematics achievement is found in the research of Passolunghi *et al*. (2008:229), who found that in a longitudinal model, working memory measured in the first and second grades predicted mathematics achievement, even more so than performance IQ. Working memory is therefore a plausible mediator in predicting mathematics achievement in primary school age children (Passolunghi *et al*., 2008:229).

In his neo-Piagetian theory, Robbie Case (Berk, 2013:283) confirms Piaget's stages of cognitive development, although he attributes movement from one stage to the next to the increase in a child's efficient usage of working memory capacity. This notion has far-reaching implications for all learning fields, but particularly in the area of mathematical reasoning. Case suggests that practicing skills will result in automisation which frees up working memory capacity for other activities.

Naturally, cognitive functioning is not only bound by working-memory constraints, but is also determined by executive functions like attention capacity, suppressing impulses in favour of adaptive responses and planning, organising, monitoring and flexibility in redirecting thought and behaviour (Berk,2013:281). All of these executive functions are integrated and dependent, yet evidence presented in our preceding arguments and other research undertakings suggest that in the area of mathematical accomplishment, working memory is paramount (Lee *et al*., 2009; Swanson, 2011; Holmes & Gathercole, 2014; Kroesbergen *et al*., 2014).

3.5 How can we help teachers to implement mathematics "correctly" in preprimary school?

"Teachers are fundamental to the development of young children's mathematical abilities*"* (Greenes, 1999:46). Few would argue with the rational idea presented by this quote, but the more daunting question it evokes is how are teachers to possess the skills necessary to develop young children's mathematical abilities?

There is very little empirical evidence making a strong claim for the connection between teacher training and quality mathematical education in early childhood settings. One noteworthy research undertaking was initiated by the U.S. Department of Education in 2006, which investigated the extent that kindergarten teacher's qualifications and instructional practices coincided with gains in reading and mathematics in students over the course of their kindergarten year, and how the instructional practices of kindergarten teachers related to their qualifications (Guarino *et al*., 2006). The researchers conclude that coursework in methods of teaching mathematics is positively associated with the use of practices that emphasise numbers and geometry, advanced numbers and operations, traditional practices and computation, student-centred instruction and mixed-achievement grouping in mathematics. These practices, in turn, are associated with higher achievement levels (Guarino *et al*., 2006:37).

Burchinal (2002:10) and his associates also investigated the link between informal teacher training (workshops and courses) and classroom quality, and conclude that caregivers with formal education who attend workshops regularly, are more sensitive in student-teacher interactions and provide better quality care than other caregivers, even when adjusting research results to accommodate differences related to teacher experience, adult-child ratios and type of classrooms (Burchinal *et al*., 2002:2). Workshops for teachers may therefore be an effective mechanism for improving child care quality.

One would assume that teachers with four year degrees will be more effective in instructing than unqualified staff. Research by McMullen and Alat into the connection between developmentally appropriate practices (DAP) in preprimary schools and the educational background of preprimary school teachers in Indiana revealed that participants with a four year degree or higher, adopted DAP more strongly as an overall philosophy in comparison with their less-educated peers (McMullen & Alat, 2002). However, another research project investigating the connection between teachers having bachelor degrees and the quality and academic outcomes of their preprimary school classes could find no correlation between the two (Early *et al*., 2007:558). It is also interesting to note that the Guarino *et al*. study (2006) provides no evidence of a direct relationship between the self-reported qualifications of teachers and student achievement.

Although making sweeping comparative claims between studies in the US and educational processes in South Africa would be irresponsible, the idea that preprimary school teacher training can be positively impacted by attending workshops/courses and not only by formal qualifications does breathe hope into the assumed problem of preprimary school teacher under-qualification in

South Africa. Unfortunately, like most developing countries, teacher in-service training opportunities are quite rare for many South African teachers (Leu, 2004:1). The proposal of high-quality workshop training ties in with the goal of the Department of Education to improve the quality of Grade R teacher capacity by 2014 and beyond (DoE, 2012a:32).

As increases in teacher knowledge and skills, as well as changes in classroom practice are related to sustained and intensive professional development (Garet *et al*., 2001:936; Brendefur *et al.*, 2013:193), quality teacher training workshops could have a direct influence on effective preprimary school mathematics instruction in our country, a notion that needs serious further investigation.

3.6 Conclusion

Preprimary school teaching is gradually being considered as paramount to the success experienced by the child in his overall academic journey (Barnett, 2008:1). Research has also strongly correlated mathematics achievement at a young age to academic accomplishment in later years (Duncan *et al*., 2007).

When considering South Africa's dire state in mathematics performance in the international arena, the need for radical intervention is becoming critical (Bilbao-Osorio *et al*., 2013:261). One possible solution is intervention at the earliest possible level, thereby improving mathematical concept formation even before entering formal schooling, and thereby increasing the child's chances of future mathematic success (Chard, 2008:12).

At a young age, intervention should be sensitive to the child's need to play and to be engaged playfully in learning (Walsh *et al*., 2011). Allowing the child to self-discover mathematical concepts through free-flow play does pose some benefit to the child, but not all play appears to be equal when it comes to cognitive development (Sylva, 1993). There is strong evidence supporting the academic benefits of adult-guided play (Sylva, 1993:29).

Literature suggests that teaching mathematical concepts playfully is ideally achieved through playing games (Ernest, 1986), using concrete apparatus (Cross *et al*., 2009:252), engaging in movement (Fedewa & Ahn, 2011) and using a learning set approach (Harlow, 1949). The time for intervention is in the preprimary school years, as this is a time of high brain plasticity (Berk, 2013:188), synaptic pruning (Nelson *et al*. 2008:24) and an ideal time for the scaffolding of developing executive function (Berk, 2013:282). One can even argue that based on empirical evidence concerning the mathematical competence of infants (McCrink & Wynn, 2004), preprimary school could already be regarded as too late to begin mathematical support. The preprimary school years are ripe with sensitive periods of development (Lillard & Jessen, 2003:6) and children are capable of advanced mathematical understanding at this time (Montessori, 1961:137).

The list of pre-mathematics concepts advocated by preprimary school curricula and programmes is exhaustive. This literature study focused on mathematical language, counting (including ordinal and cardinal numbers), seriation and ordering, classification and the oddity principle, measurement, number conservation, sequencing and patterning, shapes, spatial awareness and geometry, problem solving and basic arithmetic and working memory.

In an ideal world, teachers would have a fundamental understanding of all pre-mathematics concepts and pedagogically sound methods of instruction for teaching the preprimary school age. However, with the assumed under-qualifications of the majority preprimary school teachers in South Africa, training teachers through shorter workshops is a viable and necessary approach to uplifting the standard of our early mathematical education. Although arguably not as ideal as a full degree course, the possibility of workshop-based training is worth looking into as the most practical short-term solution to the tremendous gap in mathematics instruction at a preprimary school level in South Africa.

CHAPTER FOUR

RESEARCH DESIGN

4.1 Introduction

Little to no research is available in the specific area of Grade R mathematical readiness and ideal pedagogical approaches to teaching mathematics at an early age in South African schools.

In the light of this void, evidence based enquiry into this field within the context of educational research is imperative for the following reasons (McMillan & Schumacher, 2010:3):

- To assist educators in making professional decisions
- To provide information for non-educational policy groups who mandate changes in education
- To provide information for concerned public, professional and private groups and foundations
- To accumulate empirical evidence and identify new areas of research
- To allow educational research to become readily available
- To enhance classroom, school and system accountability

The previous chapter undertook a literature review on issues surrounding mathematical teaching in Grade R. Based on this theoretical study, an empirical research project was designed to shed some light on this hitherto underexplored educational topic.

This chapter describes the theoretical grounding of the methodology of the study, the research design, data collection and data analysis methods that were used. This chapter also addresses the issue of ethical validation, general validity and reliability within the research design selected.

4.2 Research Problem

The anticipated outcomes were that children, who had been purposefully and actively involved in playing mathematics with their teachers, would show a greater understanding of mathematics concepts before entering school. In addition, the expectation was that these results will translate into greater academic gains throughout the child's schooling (Duncan *et al.*, 2007:1428; De Sanchez, 2010:132).

4.3 Aims of the research

The primary aims of this research study can be described as:

- Conducting an empirical investigation into the manifested changes in the preprimary school child's reasoning abilities and skills in the area of mathematics after being exposed to a 30-week adult-guided play-based curriculum, and to statistically compare these participants to those who had not been exposed to this curriculum, or had been exposed to a worksheet based or free-flow-play-based mathematics curriculum during this time frame.
- Gathering information regarding the practitioner's knowledge and affective experience regarding the teaching of their particular mathematics curriculum in Grade R.

4.4 Research Design

4.4.1 Research paradigm - ontology and epistemologies

A research paradigm is defined as the model, perspective or conceptual framework that helps one to organise thoughts, beliefs, views and practices into a logical whole and to use the whole to consequently inform one's research design (Basit, 2010:14). These paradigms are derived from a worldview or belief system about the nature of knowledge and existence, and are shared by a specific scientific community, guiding how that community of researchers acts with regard to inquiry (Ayiro, 2012:64).

A combination of two particular research paradigms was considered for this particular research project. The first of these is a positivist paradigm, manifesting in a quantitative approach to the research, which assumes that there is a single, measurable reality within the study (McMillan & Schumacher, 2010:12). Positivism follows a pattern of research usually found within the natural sciences where truth is discovered through observation, experimentation, large sampling and statistical analysis. This truth is believed to be generalisable, and society is viewed as controllable and measurable, with patterns and causality (Basit, 2010:14). The performance of preprimary school learners in mathematical reasoning tasks is a quantifiable and measureable variable, so the study subsequently applied this paradigm to address the hypothesis presented in chapter one.

The use of a positivist paradigm is further recommended when investigating issues concerning the state of a phenomenon and factors predicting its change (Muijs,2004:7). As an investigation into the changes in mathematical reasoning as a result of adult intervention (or lack thereof) was envisioned, a positivist paradigm would, again, be the best overall fit for the study.

From the 1960's onwards, a new research paradigm emerged in the form of an interpretive paradigm, in which the researcher is engaged in what is known as qualitative research (McEwan & McEwan, 2003:76). As is characteristic of qualitative research, this study incorporated inductive reasoning because hypotheses were formulated only after data had been collected through methods like observations, interviews and document analysis (Lodico *et al*., 2010:11).

This interpretive paradigm was utilised in the part of the study that explored the affective and personal experiences of Grade R teachers teaching mathematics. As no predetermined hypothesis is proposed for this section of the study, it was expected that new information would be brought to light during the interviewing process. Qualitative research is a process of contemplating a variety of possible interpretations and explanations about what has been observed (McEwan & McEwan, 2003: 79) and utilising this paradigm provided invaluable information into aspects of the research problem which may not have previously been explored.

In conclusion, the above two ontological approaches culminates into a mixed-method research paradigm, which can be described as a combination of both a qualitative and a quantitative approach to research (McMillan & Schumacher, 2010:11). Both a sequential explanatory design and a concurrent triangulation design were employed, as the data obtained from the teacher interviews were utilised for elaborating and enriching quantitative research findings, but also to allow the researcher to infer more credible conclusions as data originates from two different research methods (McMillan & Schumacher, 2010:401 – 403). The advantages of this combination approach include that data are more comprehensive and that a mixed method compensates for the limitations of using a single method. In addition to this, more research questions and more complex questions can be considered. Ultimately, it should enhance the credibility of the study (McMillan & Schumacher, 2010:397).

The section below gives thought to the epistemological assumptions that guide this enquiry within this mixed-method paradigm.

The epistemological assumption of a study refers broadly to how the researcher views the basic nature of knowledge. This includes both how it is acquired and how it is communicated (Basit, 2010:6). It involves a systematic consideration of when knowledge is valid and what counts as the truth (Packer & Goicoechea, 2000:227).

Within a constructivist paradigm, the world viewed as part of the research is affected by the researcher, and knowledge is not independent of the researcher's deliberation, but is rather a product thereof (Pring, 2004:45). Knowledge is therefore influenced by the researcher's professional judgements and perspectives (McMillan & Schumacher, 2010:6).

Conversely, within a sociocultural perspective, learning and knowledge is described as what has been transmitted and mediated by materials, tools and signs. Knowledge is grounded in a purposive, social activity. Cognition and learning are complex phenomena incorporating both the learner as a whole and the activity in which the child is engaged, as well as the social and cultural world of the learner (Packer & Goicoechea, 2000:229).

In contrast to these two perspectives, logical positivism attests that knowledge is un-coverable through verification, and that only knowledge that is verifiable either logically or empirically can be cognitively meaningful (Anon, 2014d). Logical positivism rationalistically views knowledge as a single reality (McMillan & Schumacher, 2010:5).

A marriage of all three of these epistemologies forms the methodological basis of this study. Through the exploration of teacher attitudes, values and affective states, the researcher attempted to uncover yet unknown truths, and to filter these truths through a constructive process of deliberation and interpretation. This process incorporates a measure of subjectivity and professional judgement. In this context, knowledge could therefore be described as a personally constructed entity. However, certain truths are pre-established and unaffected by a researcher's interpretation and subjectivity. Knowledge can exist socio-culturally, and this knowledge is a product of the tools that society utilises and the cultural transmission of this knowledge within this society. Exploring this belief, this study strove to uncover these tools and modes of knowledge transmission and to examine their value in light of empirical findings. Lastly, the researcher believes that certain knowledge is enduring, provable and verifiable. This epistemological approach was utilised in empirical testing and the dominant use of a logical positivism paradigm.

The researcher therefore considers knowledge to be a collective body of what can be empirically proven, what has been socially transmitted and what is subjectively discovered and experienced. The study attempts to explore all facets of this combined epistemological approach through engaging in both qualitative and quantitative methods of data collection.

4.4.2 Research Methods and Data Analysis

A research design is a plan and structure of investigation, aimed at obtaining answers to research questions (Ayiro, 2012:61). Methodology, as an imperative aspect of this design, is the theory of research methods and involves the process of creating reliable and valid knowledge (Basit 2010: 6). The choice of methodology is a reflection of the ontological and epistemological approach of the researcher.

The methods most commonly used in educational research can be classified into two broad fields of methodology, namely that of quantitative and of qualitative research. The so-called ‘incompatibility thesis’ or ‘paradigm wars’ claimed that these two particular methods are mutually exclusive. Within this view, quantitative research is defined as scientific and realist, while qualitative methodologies and non-scientific and subjective (Tunmer *et al*., 2003:90, Muijs, 2004:3-4). In more recent years, support for the ‘incompatibility thesis’ has declined, as there are no longer pragmatic or epistemological reasons for viewing qualitative and quantitative research as mutually exclusive methodologies (Tunmer, *et al*. 2003:92).

The research design used in this study is an attempt to garner information compatible with the researcher’s eclectic view of knowledge. Therefore, a mixed-method research design was employed, allowing the researcher to execute large-scale experiments to gather and analyse generalisable data together with an in-depth investigation of a smaller number of issues with a smaller portion of participants (Basit, 2010:17).

The quantitative aspect of the design involves large scale testing of mathematical competence in Grade R research participants. The test administered is a paper-and-pencil type test and questions are presented to children requiring them to complete cognitive tasks. The results are summarised to obtain quantifiable data (McMillan & Schumacher, 2010:188).

Testing follows standardised procedures and the same questions are asked each time the test is used, with a specific set of directions guiding the administration of the test (McMillan & Schumacher, 2010:189). However, although most standardised tests are commercially prepared by measurement experts, no commercially available standardised group test is available to test the mathematical competence of preprimary school children within a South African context. The researcher prepared her own test instrument with the guidance and help of a panel of experts (three teachers and two experts in the field of educational psychology). The statistical significance of the difference in the means between the control groups’ and experimental groups’ results will be established through an ANOVA test analysis.

Within this quantitative design a quasi-experimental approach was thought fit. This design approximates a true experimental design that statistically draws comparisons between subjects who did and who did not experience the intervention to determine a cause-and-effect relationship. The primary difference between a true experimental design and the quasi-experimental design used here is that there is no random assignment of subjects (McMillan & Schumacher, 2010:22). As is often the case in educational research, the researcher has no control over the fact that participants are assigned to a particular class or particular teacher. In addition to this fact, research is carried out in the child's natural setting and the experimental and control groups were closely, but not perfectly matched for age, gender and ethnic origin (Basit, 2010:32). That being said, care was taken to match research participants within the experimental and control groups for origination from similar geographic regions and socio-economic status groups, thereby eliminating the need for a pre-test/post-test design and opting rather for an exclusively post-test design.

An advantage of the quasi-experimental method applied in this study is that research results were obtained in a real-world setting rather than a laboratory, which makes it a good research tool to evaluate new initiatives and educational programmes (Muijs, 2004:29). Unfortunately, exercising meticulous control of the intervention is unlikely. As per Muijs's recommendation, the researcher monitored how the intervention or non-intervention was carried out within the two groups and what the content elements of the intervention/non-intervention were by means of the qualitative research method of interviewing (Muijs, 2004:30), which helped to triangulate research results.

The in-depth face-to-face interview survey method used with participating teachers was adopted because the researcher wanted to build rapport with the respondents and clarify points they raised, facilitating a fuller response (Basit, 2010:28). A further advantage of a face-to-face interview is that the researcher can probe and rephrase questions, which, considering the cultural and language differences between the participating teachers in the research study was an imperative point to take into account. This is the primary reason why the researcher opted for an interview rather than a written questionnaire or survey, where questions could be misconstrued or answers randomly selected without in-depth clarification. Secondary to this, the researcher hoped to uncover unconsidered factors in the research study, which would be possible when using this qualitative research method.

The interview conducted was semi-structured, which means that the respondent did not have choices from which to answer, but the questions raised were fairly specific in intent (McMillan & Schumacher 2010: 206). This provided extensive in-depth information that could be probed, clarified and elaborated (Lodico *et al*., 2010:122). The detailed verbal and non-verbal responses of the respondents were recorded and contextualised.

Based on the suggestions of Tustin *et al*. (2005: 696) once the data from the interview method had been obtained, certain important steps had to be taken to interpret and analyse it. The data were coded and broken up into groups or elements that the researcher examined and translated into immediate results. Following this, these results were interpreted to produce integrated and meaningful general inferences and findings. These meaningful inferences and findings are relevant to the original aims of the research study.

4.5 Procedure of research

4.5.1 Sampling

According to Children Count South Africa, approximately 70% of South Africa's children live in the poorest 40% of households (Hall & Meintjies, 2013). Based on these findings, approximately 70% of our research sample in this study was taken from known underprivileged geographical areas so that research findings could be generalised more accurately to the overall Grade R population of South Africa.

For the quantitative aspect of the research, a sample size of approximately 100 (test group children) and 100 (control group children) was selected. The teachers of these children constituted the smaller sample for the qualitative research study.

Purposive and proportional stratified sampling was employed, allowing subgroup comparisons (McMillan & Schumacher 2010: 139) in that approximately 30% of the overall sample of 200 children was selected from schools in an urbanised township region (Kwa Thema). 40% of the overall sample was selected from schools in a rural region (Limpopo, Bolebedu South, Fobeni Village). The remaining 30% of the sample was selected from schools in an urbanised city (Kempton Park region). Schools from these regions had recently implemented an adult-guided play-based curriculum in their schools in 2014, after undergoing extensive workshop-based training in this regard. A list of these schools was provided to the researcher (information provided by the workshop facilitator). The number of schools that had undergone training conveniently fell within the proportionate quota sampling scope, in that the percentages of schools represented matched the pre-selected percentages for representation of rural, urban and urbanised township regions. These schools formed the core of the test group sample.

Sampling was also purposive as subjects had to have certain characteristics (McMillan & Schumacher 2010: 138). These characteristics were determined through introductory interviews and preliminary investigations confirming that the schools in the test group were indeed implementing an adult-guided play-based Grade R mathematics curriculum. The following criteria were carefully thought through when determining if the curriculum being implemented in the schools is truly “adult-guided and play-based”:

1. The teachers are actively involved in planned playing of mathematics games and in playful mathematics interaction with their pupils daily (1/2 hr or more).
2. The school is not following an exclusive free-flow play syllabus
3. The school is not following an exclusively worksheet/workbook-based syllabus
4. The teachers have preparatory evidence of a planned adult-guided play-based syllabus
5. There is evidence in the classes of mathematical play-based resources e.g. pegboards, blocks, dice, mathematics games etc.

For the control group, sample schools were selected from schools that do not follow the above-mentioned criteria. Snowball sampling was used to gather control group schools from the same regions as test group schools, meaning that one participating school advised on finding the next possible participant in the sampling process (McMillan & Schumacher, 2010:327).

4.5.2 Research site

Authenticity was ensured by conducting the research within the Grade R classrooms of the respective schools. The comfort and relaxation of research participants were given thought throughout.

4.5.3 Data collection procedure

- Quantitative mathematical aptitude test

Children were tested at tables in their classrooms. Dividing boards were placed between children to ensure that no copying was possible. Children were presented with tests, pencils and as little as possible external distractions. The researcher and interpreter presented each question as a separate entity. The tester and assistants confirmed that the child was at the correct question on the page before the child indicated an answer. Children were given short breaks after 20 minutes of question answering or at any time the tester noticed a general lagging of concentration.

- Qualitative interview

Teachers were interviewed wherever they felt most comfortable and without the distraction of the class (assistants attended to children during the interview). Interview comments were written down in their verbatim format. Language interpretation of interview questions was provided (when necessary), as well as the interpretation of the interviewee’s responses.

4.6 Ethical considerations

Ethical considerations are regarded as extremely important in educational research and researchers need to ensure that research is always conducted in an ethical manner (Basit, 2010:56). The researcher abided by all ethical guidelines and practices as set forth by the University of South Africa. An ethical clearance certificate was obtained from the university, and the study carefully took into account ethical concerns regarding anonymity and confidentiality, informed permission and consent and withdrawal rights of participants (see addendum A).

4.6.1 Informed permission and consent

Separate information letters and permission/consent forms were sent to principals, teachers and parents of children participating in the study. The letters and consent forms gave information relating to the purpose of the study, the types of activities involved, the need for confidentiality and the management of potential risks. No testing was conducted on children who did not have all consent forms signed and returned (see addendum B).

The primary research participants were very young, yet were regarded as capable contributors and research partners. Children were expected to give their written consent by indicating their willingness to participate on a form prior to testing. The information on the form explained the testing procedure, as well as their right to withdraw at any stage without any penalty. The form was read to the children and interpreted if necessary. The study did not require children to reveal sensitive or personal information, but merely their cognitive processing and mathematical aptitude at the time of testing.

Only teachers who gave their written, signed and verbal consent were interviewed. Teachers were allowed to decline to answer any particular interview question.

4.6.2 Anonymity/Confidentiality

Principals, teachers, parents and children were verbally reminded of the process of data collection and how data would be analysed and interpreted.

Participating schools were given their individual learners' test results. They were reminded that these results were for research purposes only. Individual results could be disclosed to parents on request, but only for the purposes of assisting a particular child in any areas of weakness and not as a comparative tool. No child's individual results were disclosed to any person other than the child's teacher, principal or parent.

Participating schools were informed of their school's mean performance as compared with other schools, but the names of all participating schools have been kept confidential in the findings.

The potential use of the interview data captured was explained to the teachers. Personal comments were kept strictly confidential and were not disclosed to principals, parents or pupils at all. Measures are in place in data processing and publication to protect the identification of participants.

4.6.3 Voluntary participation and withdrawal rights

All research participants were reminded both verbally and in writing that participation is completely voluntary. Children showing any indication of wanting to withdraw or any indications of stress or discomfort were removed from the testing process.

Particular consideration was given to parents and children who do not wish to participate in the research study. Non-participating children were placed in the care of another teacher during the time of testing.

Teachers were encouraged to answer all interview questions, but were reminded verbally that their withdrawal would be respected at all times.

4.7 Advantages of data collection instruments and data analysis methods utilised in the study

It is a logical conclusion that using a direct pen-and-paper testing method to collect data (rather than alternatives like individual interviews, portfolio examinations or personal observations) is highly effective in its time-saving capacity. In the context of large-scale testing for bigger sample sizes, this is an important criterion to consider. Furthermore, the following advantages are noted in eliciting direct responses through testing participants (McAfee & Leong, 2011:54):

- Assessment is directed at a specific behaviour (or cognitive area)
- It is more effective and reliable than using incidental or non-verbal cues
- It can illuminate a child's level of understanding, identify misconceptions and allow children to demonstrate their complex thinking skills
- It can provide information directly linked to classroom activities

Furthermore, analysis of data obtained through pen-and-paper type testing is void of subjectivity and requires little interpretation.

For the qualitative aspect of the study the advantages of selecting an interview method of data collection include (McMillan & Schumacher 2010: 205):

- Flexibility and adaptability in asking questions of different people in different circumstances
- Responses can be probed, followed up, clarified and elaborated for accuracy
- Verbal and non-verbal behaviour can be noted
- The respondent can be motivated
- There is a much higher response rate than what is obtained through questionnaires

The advantages of analysing qualitative data through coding and then visually representation the coded data in graphic format are that data are easy to read and effectively depict relations between the variables investigated and the coded results of the experimental and control group participants (Tustin *et al*. 2005: 709). Avenues for further research endeavours are also clearly displayed.

4.8 Limitations of the Study

In the utilisation of the above-described methods of research, certain limitations are unavoidable.

McAfee and Leong describe some of the limitations of using a standardised quantitative testing procedure (McAfee & Leong, 2011:178- 179):

- Technical and educational inadequacies.
  Standardised quantitative testing may not give thought to current knowledge, which emphasises that children actively construct their knowledge and skills, and these faculties, when tested in isolation, may not be good indicators of final performance. A further argument is that a child's independent performance is not a true reflection of their potential, based on the Vygoskian accredited notion of scaffolding.
- Unsuitably for the population.
  Language differences between the tester and participants pose huge threats to the accuracy of the research findings. Even when tests have been translated, there may be differences between academic language and conversational language that places the second-language participant at a decided disadvantage. The researcher attempted to overcome as many of these language barriers as possible by utilising the services of interpreters who are teachers of young children themselves, and who are familiar with the district, dialect and colloquialisms of the children.
  In addition to this, children generally experience problems with pencil-and-paper type testing in that they struggle with distractibility, boredom, feelings of unease, and difficulty in following directions or a lack of motivation to participate. The researcher hoped to overcome these limitations through energetic interaction with the children, interspersed

with short breaks during which children are encouraged to participate in light physical activities and deep breathing.

- One-shot testing is poorly suited.

  Children's cognitive development progresses unevenly, with spurts and regressions. Taking the test results of one testing procedure may present limitations in the overall progress that is real and significant in the child. However, as the quantitative results rest on the statistical differences of the means of the research groups, both groups were facing similar disadvantages, which should eliminate any limitations of one particular group.

In addition to these concerns raised, experimental research may further be limited due to some of the following factors described by Basit (2010:33):

- History – participants may undergo other experiences during the study which are beyond the control of the researcher. Fortunately a large sample size (in the case of the children) should compensate for this factor.
- Maturation – testing should ideally be undertaken over a longer period of time. Given the time frame of the research design, this suggestion is impractical in the context of the study.
- Instrumentation – even slight changes to e.g. the characteristics of the researcher during testing can impact test results. The researcher therefore endeavoured to maintain the same levels of enthusiasm and energy throughout the study.
- Selection – quasi-experimental research allows for less randomisation in sampling. The advantage is that research can, however, be undertaken in naturalistic settings.

Furthermore, by utilising a self-developed test instrument, the researcher cannot completely rule out the possibility of slight questionable technical qualities manifest in the instrument, even though great care was taken in creating a test instrument that truly measures mathematical competence of school entry aged children.

When contemplating the qualitative research aspect, there are also disadvantages and limitations to using an interview method in the study.

Even when confidentiality is promised, interviewees might be reluctant to reveal sensitive information (Lodico *et al.*, 2010:122). There is also the possibility that research participants might be faking or be less than forthright as they are concerned that sharing information might not be in their best interest (McMillan & Schumacher, 2010:206). The researcher interviewed participants in naturalistic settings, respecting all cultural differences and in a calm and relaxed manner. Participants were constantly reassured of confidentiality in an attempt to overcome limitations.

In addition to these limitations, the interview method possess the potential for subjectivity and bias (McMillan & Schumacher, 2010: 203). McAfee and Schumacher further state that the time-consuming nature of interviews is a major drawback. Furthermore, in using the data analysis process of coding and graphic representation, there is a measure of subjectivity in selecting coding units as it remains the responsibility of the researcher to select the coding units (McMillan & Schumacher 2010: 371). Other coding units may have been selected by different researchers, resulting in richer or conversely, more impoverished findings. The small sample size used in this study implies the generalizability of the results is limited.

A further realistic limitation of the study is that within the sampling process, the researcher relied on testing schools that claimed to be administering a particular intervention programme. However, the effective administration of this intervention programme may be limited by the teacher's subjective understanding of the intervention, even if all the constructs are clearly delineated. Although certain criteria had to be met to define the potential candidates for the experimental group, the researcher was dependent on the honesty of the teachers in terms of their accurate implementation of the intervention over an extended period of time. The researcher cannot account for factors like poor teaching, teacher absenteeism, teacher laziness or language barriers in teachers who are implementing a so-called adult-guided play-based intervention programme, just as the researcher cannot account for similar problems among control group participants in the study. The researcher cannot account for poor general mathematical competence and comprehension in the personal lives of the teachers participating. In summary, in the scope of this social science study, the "human factor" plays an important role in limiting accurate research findings.

4.9 Validity

Very broadly considered, validity refers to the extent to which a research instrument measures what it claims to measure (Anon: 2014g).

Within the context of quantitative research, validity can relate to both the design itself, as well as the data collection procedures employed.

According to McMillan and Schumacher (2010:105) there are four specific design validities relevant to quantitative research:

- Statistical conclusion validity. This refers to the appropriate use of statistical analysis to determine research findings. Within this study, the services of a designated statistician were contracted to illuminate the probability of such validity errors occurring.
- Internal validity. This refers to the viability of causal links between the independent and dependent variables. It is a demonstration of the way specific phenomena or perceptions that have been described are upheld by data (Basit, 2010:65). Within this study, this refers to the probability that increased mathematical reasoning ability and cognition is caused by the extent of the implementation of an adult-guided play-based intervention programme in Grade R. To illuminate the possibility of variables confounding the causality within the study, the researcher listed specific criteria which had to be met before a school could be considered as a possible sample school within the experimental or control groups of the study. Although it would be impossible to determine without a statistical doubt that the intervention programme is the exclusive determiner of changes observed in the dependent variable, it is postulated that the primary determiner of changes in the independent variable would have to be the described intervention programme, as on a 'global' scale (when taking into account the mean results of a large sample and not individual discrepancies) no other practical determiner is forthcoming.
- Construct validity. This refers to the extent to which interventions and measured variables actually represent targeted, theoretical, underlying psychological constructs and elements.

As an ‘adult-guided play-based mathematical intervention programme’ incorporates a variety of possible definitions, the researcher carefully gave thought to each construct in light of possible misconstrued definitions and described her understanding of each of these constructs in the introduction and literature review chapters of this dissertation. Sampling of intervention schools was based exclusively on her described definitions of these constructs.

The measurement of ‘mathematical competence’ as a construct was carefully considered with the advice of practitioners and experts within the field. As “mathematical competence” can be a subjectively interpreted, the researcher first contemplated the design and layout of other tests incorporating elements of mathematical competence at a school entry level e.g. the Aptitude Tests for School Beginners designed by N.M Olivier, D.J. Swart and T.M. Coetzee. The researcher also considered the Annual National Assessment administered by the South African Department of Education to Grade 1 learners to determine the expectations regarding mathematical competence within one year of the research participant’s expected age. Once the test instrument was designed based on these considerations, the advice of Dr Alta Loock (educational psychologist) and Professor de Witt (early childhood development specialist), together with the advice of three other foundation phase teachers were incorporated to ensure that the construct of ‘mathematical competence’ is accurately measured by the test instrument.

- External validity. This refers to the generalisability of the results and conclusions to other people and locations. If the constructs of the design are carefully adhered to, the researcher is confident that research results can be generalised to different people and locations within a South African context. Perhaps the biggest factor negatively influencing the possibility of generalisability is the multiple language ‘problem’ facing our South African schools. It would be very difficult to determine language equivalence for testing purposes between the 11 official languages in South Africa, as some official languages do not use mathematical vocabulary or syntax in any way resembling that of the originally designed test instrument.

Relating to data collection strategies, research validity refers primarily to test validity, where validity is a judgement of the appropriateness of a measure for specific inferences or decisions that result from the scores generated (McMillan & Schumacher, 2010:173). Once again, the researcher refers to the rigorous process of designing a test instrument that truly measures ‘mathematical competence at school entry level’, as described above under ‘construct validity’. The researcher took into consideration possible construct irrelevant variance (McMillan & Schumacher, 2010:174), and attempted to illuminate this occurrence through designing an age-appropriate user-friendly test that allows a preprimary school child to independently select answers regardless of extraneous variables like his/her inability to read or find his/her place on a given page.

To improve the validity of research findings, the study also utilised concurrent validity techniques, where data collected from one source correlates to data collected from another source (Basit, 2010:67). Methodological triangulation of the construct of ‘mathematical competence’ was obtained through both student testing and the asking of certain questions in the teacher interviews.

Within a qualitative context, validity refers to the degree of congruence between the explanations of the phenomena and the realities of the world. It is the degree to which interpretations have mutual meanings for participants and the researcher (McMillan & Schumacher, 2010:330). Based on recommendations of McMillan and Schumacher (2010:33), the researcher enhanced the qualitative validity of the research through the following techniques:

- Utilising multi-method strategies (triangulation of research findings with quantitative data)
- Recording verbatim accounts and literal statements
- Using low-inference descriptors, keeping to the almost literal detailed descriptions of people and their situations
- Using a member-checking technique, whereby topics are re-phrased and probed to obtain more complete understanding
- Searching for negative or discrepant data that may be an exception to patterns found within data

In addition to this, internal validity within the qualitative design was further strengthened through the asking of short, easy-to-understand questions in simple English. To avoid misunderstandings, the skills of an interpreter were used to clarify questions and answers in languages other than English. Semi-structured interviews were also conducted in naturalistic settings where participants feel most comfortable and are prone to honest answers reflecting the reality of their circumstances.

Regarding the external validity of the qualitative research, as a small sample size of teachers was taken since the researcher did not aim to generalise the results of the research findings, but rather aimed to enrich the understanding of the research and to provide avenues for further research endeavours.

In qualitative research, the equivalent of the study's generalisability is its comparability and transferability (Basit, 2010:66). With regard to the comparability and transferability of the interview data, the researcher conducted an analysis of the findings based on the degree of one or more phenomena occurring comparatively or in contrast with other phenomena. The findings were determined for applicability across similar situations and not for generalisation purposes.

4.10 Reliability

Within a quantitative context, reliability refers to the consistency of scores. It involves an instrument's ability to produce 'approximately' the same score for repeated trials or with different administrators (Lodico *et al*., 2010:93). It is also defined overall as the extent to which a measuring instrument is free from errors (McMillan & Schumacher, 2010:179).

McMillan and Schumacher attribute reliability estimates to a variety of factors, one of which is particularly relevant to the once-off, single test design of this study, namely internal consistency. There are three common types of internal test consistencies to determine a test's reliability coefficient, as described by McMillan & Schumacher (2010:181 – 182):

- Split-half reliability, where half of the test items are consistent with the other half
- Kuder-Richardson (KR) reliability, where consistency is established among right and wrong items
- Cronbach's alpha method, where consistency is established among items of a single construct

Statistical analysis was conducted using Cronbach's alpha method to determine the reliability coefficient of the study's quantitative test instrument.

Reliability within the qualitative research design was maintained by the researcher paying attention to the researcher's role, the data collection strategies and the data analysis strategies.

The researcher devoted much time and effort to making the interviewees feel non-threatened and relaxed. After introductions and careful explanations of confidentiality and ethical considerations, the researcher conducted the interviews in an open, non-judgemental manner.

A semi-structured interview guide was used and responses recorded in researcher notation format. Research participants were asked the same questions in the same order to limit researcher bias.

Recorded data were carefully analysed and coded to determine themes and categories for reflection.

4.11 The test

A full copy of the test is attached in addendum C.

Thought was given to covering a broad spectrum of mathematical topics normally expected in the Grade R mathematics curriculum. Due to the age-appropriate limited concentration abilities of the young participants, the test was designed to cover as many areas of mathematical reasoning in as few questions as possible.

The following specific areas were tested:

One-to-one correspondence and counting: questions 1, 8, 9, 11, 15, 21

Number conservation: questions 8, 11

Sequencing and patterning: questions 2, 16

Introductory mathematical vocabulary: questions 3, 4, 5, 10, 11, 24

Number sense (incorporating ordering and seriation): questions 6, 12, 19, 21, 23

Classification and oddity principle: questions 7, 14

Addition and subtraction (word problem format): questions 14, 17, 20, 22, 24

Symmetry: questions 18

Measurement and estimation: questions 25, 26

Directionality and spatial awareness: questions 7, 28, 29, 30, 31

4.12 The interview questions

A full interview schedule is attached in addendum D.

The interview schedule was carefully constructed to repetitively uncover information concerning the thoughts and emotions of the research participants i.e. the Grade R teachers. Most questions were open-ended and non-leading. Consideration was given to the teacher's global as well as local perspective in that teachers were asked to share about Grade R mathematics teaching in South Africa as a whole, as well as in their personal life-worlds.

4.13 Conclusion

This chapter described the research design of the study. Epistemological and ontological factors were explored. Reasons were presented for the mixed-method quasi-experimental design selected.

Light was shed on the research process itself, as well as the validity and reliability of the research findings. Ethical considerations were explained and the research tools utilised in the study were described.

CHAPTER FIVE

DATA ANALYSIS AND FINDINGS

5.1 Introduction

This chapter is a summation of the results of a study undertaken to gain an in-depth understanding of the impact of introducing an adult-guided play-based mathematics curriculum in Grade R classes in the South African context. Findings were obtained through empirical investigation utilising test scores and a qualitative research investigation.

The secondary aims of this study included:

- Reviewing previous studies and literature on pre-mathematic skills and their significance regarding the child's understanding of mathematics concepts as a whole.
- Investigating through a literature study, qualitative research and an empirical study, the ideal pedagogical and developmentally appropriate approach to teaching Grade R children mathematics in South Africa.
- Consideration of the benefits of a workshop-type training approach for teachers and its impact on teachers from three different geographical locations in South Africa.
- Exploring the feelings and thoughts of teachers who are attempting different approaches to teaching Grade R mathematics.
- Examining practical ways to equip and inspire teachers to re-examine their teaching methods and to make the necessary adjustments to meet the mathematical needs of the young child in our local communities.
- Examining particular areas in pre-mathematics most impacted by the intervention programme.

5.2 Hypotheses

As basis for this research study, some hypotheses were formulated with the primary aim of this study in mind, which was to determine if an adult-guided and structured play-based mathematical programme, focusing on developmentally appropriate pre-numeracy skills, significantly improves the preprimary school child's understanding of mathematical concepts upon entry into Grade 1.

Hypothesis 1: Global intervention

The null hypothesis (H_O) and alternative hypothesis (H_1) for the significance of the intervention, comparing control and experimental groups are:

$H_{0.1}$:

There is no significant difference in the averages (means) of the test scores of preprimary school children when tested on their understanding of foundational mathematics concepts at the time of entry into Grade 1 between children who have been taught using an adult-guided play-based mathematics curriculum and children who have had no formal mathematics instruction or only workbook-type instruction in Grade R.

$H_{1.1}$:

There is a significant difference in the averages (means) of the test scores of preprimary school children when tested on their understanding of foundational mathematics concepts at the time of entry into Grade 1 between children who have been taught using an adult-guided play-based mathematics curriculum and children who have had no formal mathematics instruction or only workbook-type instruction in Grade R.

Hypothesis 2: Intervention comparisons between particular geographical areas

The null hypothesis (H_O) and alternative hypothesis (H_1) for significance of intervention, comparing overall scores in specific geographical areas within South Africa:

$H_{0.2}$:

There is no significant difference between the averages (means) of the test scores of South African preprimary school children in specific geographical areas when tested on their understanding of foundational mathematics concepts at the time of entry into Grade 1

$H_{1.2}$:

There is a significant difference between the averages (means) of the test scores of South African preprimary school children in specific geographical areas when tested on their understanding of foundational mathematics concepts at the time of entry into Grade 1.

Hypotheses 3, 4 and 5 on intervention within each geographical region

The null hypothesis (H_O) and alternative hypothesis (H_1) for significance of intervention, comparing control and experimental groups within each region are as follows:

$H_{0.3}$:

There is no significant difference in the averages (means) of the test scores of preprimary school children in South African urban regions when tested on their understanding of foundational mathematics concepts at the time of entry into Grade 1 between children who have been taught using an adult-guided play-based mathematics curriculum and children who have had no formal mathematics instruction or only workbook-type instruction in Grade R.

$H_{1.3}$:

There is a significant difference in the averages (means) of the test scores of preprimary school children in South African urban regions when tested on their understanding of foundational mathematics concepts at the time of entry into Grade 1 between children who have been taught using an adult-guided play-based mathematics curriculum and children who have had no formal mathematics instruction or only workbook-type instruction in Grade R.

$H_{0.4}$:

There is no significant difference in the averages (means) of the test scores of preprimary school children in South African rural regions when tested on their understanding of foundational mathematics concepts at the time of entry into Grade 1 between children who have been taught using an adult-guided play-based mathematics curriculum and children who have had no formal mathematics instruction or only workbook-type instruction in Grade R.

$H_{1.4}$:

There is a significant difference in the averages (means) of the test scores of preprimary school children in South African rural regions when tested on their understanding of foundational mathematics concepts at the time of entry into Grade 1, between children who have been taught using an adult-guided play-based mathematics curriculum and children who have had no formal mathematics instruction or only workbook-type instruction in Grade R.

$H_{0.5}$:

There is no significant difference in the averages (means) of the test scores of preprimary school children in South African township regions when tested on their understanding of foundational mathematics concepts at the time of entry into Grade 1 between children who have been taught using an adult-guided play-based mathematics curriculum and children who have had no formal mathematics instruction or only workbook-type instruction in Grade R.

$H_{1.5}$:

There is a significant difference in the averages (means) of the test scores of preprimary school children in South African township regions when tested on their understanding of foundational mathematics concepts at the time of entry into Grade 1 between children who have been taught using an adult-guided play-based mathematics curriculum and children who have had no formal mathematics instruction or only workbook-type instruction in Grade R.

5.3 Analysis of empirical data

The following analysis of the data was employed:

1. Single variable descriptive statistics (mean, standard deviation and frequency distributions) giving insight into non-intervention group and intervention group test scores and performance on the individual items.
2. The reliability of the scores for the test procedure was determined by Cronbach's alpha coefficient.

3. An ANOVA-test was carried out to determine the level of statistical significance of the global differences between the means of the control and experimental groups.
4. An ANOVA-test was carried out to determine the level of statistical significance of the differences in means of performance in mathematics between different geographical areas.
5. ANOVAS-were conducted to determine the level of statistical significance of the differences between the means of the control and experiment group participants in the three designated geographical areas.
6. The level of statistical significance of the study was established at a critical value at the one-percent level of significance ($Sig<0.01$).

5.4 Reliability of the scores derived from the instrument

Cronbach's α (alpha) was used. This is a coefficient of internal constancy, which is used as an estimate of an instrument's reliability (Anon, 2014a).
Internal consistency utilising Cronbach's α (alpha) can commonly be interpreted using the following rule of thumb (Anon, 2014a):

Table 5.4.1. Internal consistency indicated with a Cronbach's alpha table

Cronbach's alpha	Internal consistency
$\alpha \geq 0.9$	Excellent (High-Stakes testing)
$0.7 \leq \alpha < 0.9$	Good (Low-Stakes testing)
$0.6 \leq \alpha < 0.7$	Acceptable
$0.5 \leq \alpha < 0.6$	Poor
$\alpha < 0.5$	Unacceptable

Table 5.4.2. Reliability Statistics

Cronbach's Alpha	N of Items
.918	30

Statistical reliability of the research instrument was established at a coefficient of 0.918. This can be translated as an excellent indication of the internal consistency of the instrument, and therefore establishes the instrument's reliability.

5.5 Frequency distribution tables for test scores

Frequency table 5.5.1. tabulates the combined scores of all research participants (where 0 represents an incorrect response and 1 a correct response, and the test composed a total of 30 questions)

	Correct/ incorrect	Frequency	Percent	Valid Percent	Cumulative percent
Question 1	0	44	21.3	21.3	21.3
	1	163	78.7	78.7	100
	Total	207	100.0	100.0	
Question 2	0	99	47.8	47.8	47.8
	1	108	52.2	52.2	100.0
	Total	207	100.0	100.0	
Question 3	0	103	49.8	49.8	49.8
	1	104	50.2	50.2	100.0

	Total	207	100.0	100.0	
Question 4	0	83	40.1	40.1	40.1
	1	124	59.9	59.9	100.0
	Total	207	100.0	100.0	
Question 5	0	124	59.9	59.9	59.9
	1	83	40.1	40.1	100.0
	Total	207	100.0	100.0	
Question 6	0	133	64.3	64.3	64.3
	1	74	35.7	35.7	100.0
	Total	207	100.0	100.0	
Question 7	0	118	57.0	57.0	57.0
	1	89	43.0	43.0	100.0
	Total	207	100.0	100.0	
Question 8	0	105	50.7	50.7	50.7
	1	102	49.3	49.3	100.0
	Total	207	100.0	100.0	
Question 9	0	79	38.2	38.2	38.2
	1	128	61.8	61.8	100.0
	Total	207	100.0	100.0	
Question 10	0	141	68.1	68.1	68.1
	1	66	31.9	31.9	100.0
	Total	207	100.0	100.0	

Question 11	0	107	51.7	51.7	51.7
	1	100	48.3	48.3	100.0
	Total	207	100.0	100.0	
Question 12	0	100	48.3	48.3	48.3
	1	107	51.7	51.7	100.0
	Total	207	100.0	100.0	
Question 13	0	115	55.6	55.6	55.6
	1	92	44.4	44.4	100.0
	Total	207	100.0	100.0	
Question 14	0	106	51.2	51.2	51.2
	1	101	48.8	48.8	100.0
	Total	207	100.0	100.0	
Question 15	0	64	30.9	30.9	30.9
	1	143	69.1	69.1	100.0
	Total	207	100.0	100.0	
Question 16	0	59	28.5	28.5	28.5
	1	148	71.5	71.5	100.0
	Total	207	100.0	100.0	
Question 17	0	156	75.4	75.4	75.4
	1	51	24.6	24.6	100.0
	Total	207	100.0	100.0	
	0	116	56.0	56.0	56.0

Question 18	1	91	44.0	44.0	100.0
	Total	207	100.0	100.0	
Question 19	0	144	69.6	69.6	69.6
	1	63	30.4	30.4	100.0
	Total	207	100.0	100.0	
Question 20	0	145	70.0	70.0	70.0
	1	62	30.0	30.0	100.0
	Total	207	100.0	100.0	
Question 21	0	93	44.9	44.9	44.9
	1	114	55.1	55.1	100.0
	Total	207	100.0	100.0	
Question 22	0	112	54.1	54.1	54.1
	1	95	45.9	45.9	100.0
	Total	207	100.0	100.0	
Question 23	0	94	45.4	45.4	45.4
	1	113	54.6	54.6	100.0
	Total	207	100.0	100.0	
Question 24	0	167	80.7	80.7	80.7
	1	40	19.3	19.3	100.0
	Total	207	100.0	100.0	
Question 25	0	117	56.5	56.5	56.5
	1	90	43.5	43.5	100.0

	Total	207	100.0	100.0	
Question 26	0	111	53.6	53.6	53.6
	1	96	46.4	46.4	100.0
	Total	207	100.0	100.0	
Question 27	0	103	49.8	49.8	49.8
	1	104	50.2	50.2	100.0
	Total	207	100.0	100.0	
Question 28	0	123	59.4	59.4	59.4
	1	84	40.6	40.6	100.0
	Total	207	100.0	100.0	
Question 29	0	91	44.0	44.0	44.0
	1	116	56.0	56.0	100.0
	Total	207	100.0	100.0	
Question 30	0	98	47.3	47.3	47.3
	1	109	52.7	52.7	100.0
	Total	207	100.0	100.0	

Frequency Table 5.5.2. tabulates the test scores for control group and experimental/ intervention group participants separately for each question posed in the test instrument

		Correct/ Incorrect	Frequency	Percent	Valid Percent	Cumulative Percent
Question 1	Control Group	0	36	38.3	38.3	38.3
		1	58	61.7	61.7	100.0
		Total	94	100.0	100.0	
	Experimental Group	0	8	7.1	7.1	7.1
		1	105	92.9	92.9	100.0
		Total	113	100.0	100.0	
Question 2	Control Group	0	59	62.8	62.8	62.8
		1	35	37.2	37.2	100
		Total	94	100.0	100.0	
	Experimental Group	0	40	35.4	35.4	35.4
		1	73	64.6	64.6	100.0
		Total	113	100.0	100.0	

Question 3	Control Group	0	60	63.8	63.8	63.8
		1	34	36.2	36.2	100.0
		Total	94	100.0	100.0	
	Experimental Group	0	43	38.1	38.1	38.1
		1	70	61.9	61.9	100.0
		Total	113	100.0	100.0	
Question 4	Control Group	0	48	51.1	51.1	51.1
		1	46	48.9	48.9	100.0
		Total	94	100.0	100.0	
	Experimental Group	0	35	31.0	31.0	31.0
		1	78	69.0	69.0	100.0
		Total	113	100.0	100.0	
Question 5	Control Group	0	67	71.3	71.3	71.3
		1	27	28.7	28.7	100.0
		Total	94	100.0	100.0	
	Experimental Group	0	57	50.4	50.4	50.4
		1	56	49.6	49.6	100.0
		Total	113	100.0	100.0	

Question 6	Control Group	0	71	75.5	75.5	75.5
		1	23	24.5	24.5	100.0
		Total	94	100.0	100.0	
	Experimental Group	0	62	54.9	54.9	54.9
		1	51	45.1	45.1	100.0
		Total	113	100.0	100.0	
Question 7	Control Group	0	63	67.0	67.0	67.0
		1	31	33.0	33.0	100.0
		Total	94	100.0	100.0	
	Experimental Group	0	55	48.7	48.7	48.7
		1	58	51.3	51.3	100.0
		Total	113	100.0	100.0	
Question 8	Control Group	0	53	56.4	56.4	56.4
		1	41	43.6	43.6	100.0
		Total	94	100.0	100.0	
	Experimental Group	0	52	46.0	46.0	46.0
		1	61	54.0	54.0	100.0
		Total	113	100.0	100.0	

Question 9	Control Group	0	41	43.6	43.6	43.6
		1	53	56.4	56.4	100.0
		Total	94	100.0	100.0	
	Experimental Group	0	38	33.6	33.6	33.6
		1	75	66.4	66.4	100.0
		Total	113	100.0	100.0	
Question 10	Control Group	0	77	81.9	81.9	81.9
		1	17	18.1	18.1	100.0
		Total	94	100.0	100.0	
	Experimental Group	0	64	56.6	56.6	56.6
		1	49	43.4	43.4	100.0
		Total	113	100.0	100.0	
Question 11	Control Group	0	64	68.1	68.1	68.1
		1	30	31.9	31.9	100.0
		Total	94	100.0	100.0	
	Experimental Group	0	43	38.1	38.1	38.1
		1	70	61.9	61.9	100.0
		Total	113	100.0	100.0	

Question 12	Control Group	0	66	70.2	70.2	70.2
		1	28	29.8	29.8	100.0
		Total	94	100.0	100.0	
	Experimental Group	0	34	30.1	30.1	30.1
		1	79	69.9	69.9	100.0
		Total	113	100.0	100.0	
Question 13	Control Group	0	74	78.7	78.7	78.7
		1	20	21.3	21.3	100.0
		Total	94	100.0	100.0	
	Experimental Group	0	41	36.3	36.3	36.3
		1	72	63.7	63.7	100.0
		Total	113	100.0	100.0	
Question 14	Control Group	0	63	67.0	67.0	67.0
		1	31	33.0	33.0	100.0
		Total	94	100.0	100.0	
	Experimental Group	0	43	38.1	38.1	38.1
		1	70	61.9	61.9	100.0
		Total	113	100.0	100.0	

Question 15	Control Group	0	43	45.7	45.7	45.7
		1	51	54.3	54.3	100.0
		Total	94	100.0	100.0	
	Experimental Group	0	21	18.6	18.6	18.6
		1	92	81.4	81.4	100.0
		Total	113	100.0	100.0	
Question 16	Control Group	0	44	46.8	46.8	46.8
		1	50	53.2	53.2	100.0
		Total	94	100.0	100.0	
	Experimental Group	0	15	13.3	13.3	13.3
		1	98	86.7	86.7	100.0
		Total	113	100.0	100.0	
Question 17	Control Group	0	76	80.9	80.9	80.9
		1	18	19.1	19.1	100.0
		Total	94	100.0	100.0	
	Experimental Group	0	80	70.8	70.8	70.8
		1	33	29.2	29.2	100.0
		Total	113	100.0	100.0	

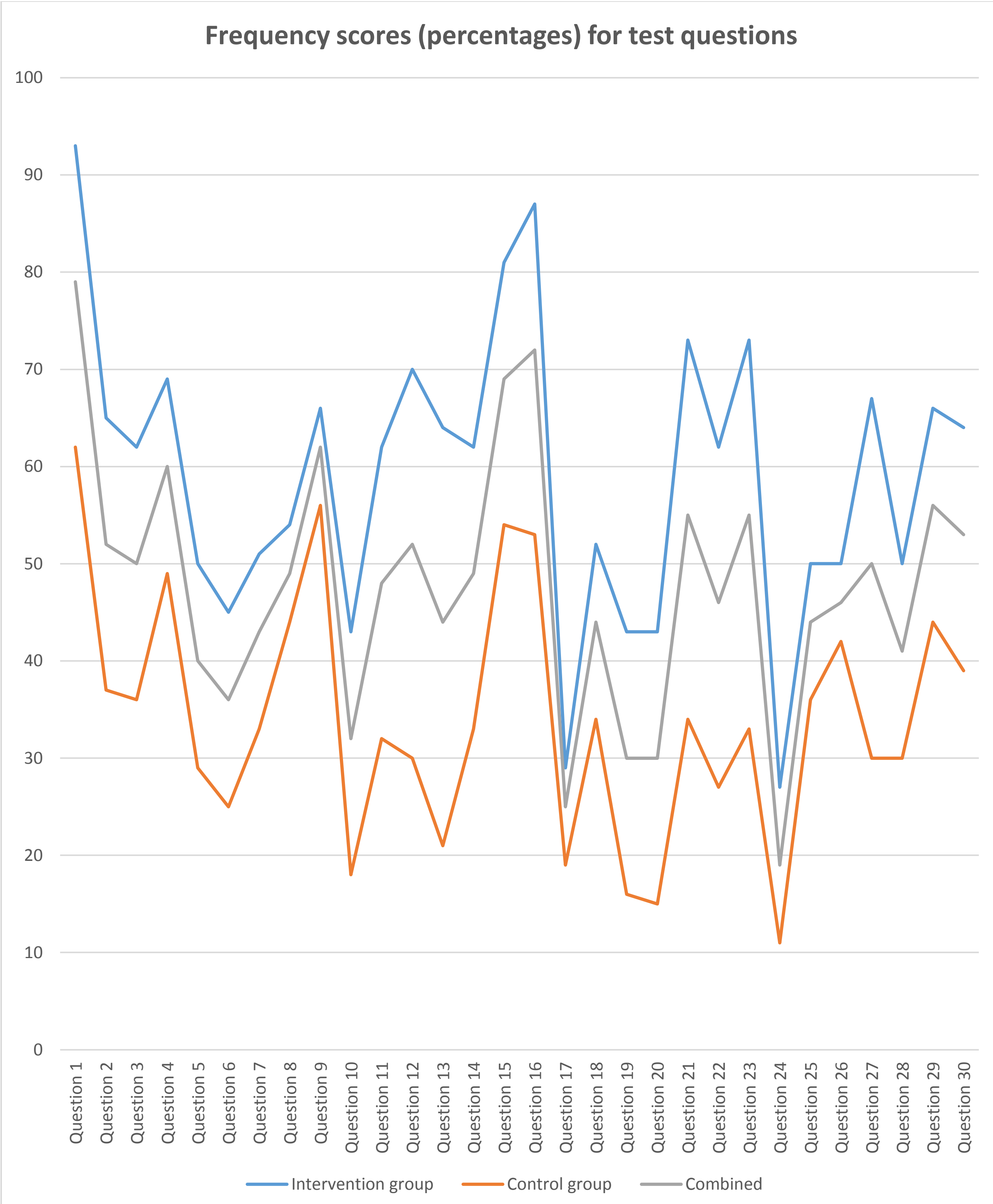
	Control Group	0	62	66.0	66.0	66.0
		1	32	34.0	34.0	100.0
		Total	94	100.0	100.0	
Question 18	Experimental Group	0	54	47.8	47.8	47.8
		1	59	52.2	52.2	100
		Total	113	100.0	100.0	
	Control Group	0	79	84.0	84.0	84.0
		1	15	16.0	16.0	100.0
		Total	94	100.0	100.0	
Question 19	Experimental Group	0	65	57.5	57.5	57.5
		1	48	42.5	42.5	100.0
		Total	113	100.0	100.0	
	Control Group	0	80	85.1	85.1	85.1
		1	14	14.9	14.9	100.0
		Total	94	100.0	100.0	
Question 20	Experimental Group	0	65	57.5	57.5	57.5
		1	48	42.5	42.5	100.0
		Total	113	100.0	100.0	

	Control Group	0	62	66.0	66.0	66.0
		1	32	34.0	34.0	100.0
		Total	94	100.0	100.0	
Question 21	Experimental Group	0	31	27.4	27.4	27.4
		1	82	72.6	72.6	100.0
		Total	113	100.0	100.0	
	Control Group	0	69	73.4	73.4	73.4
		1	25	26.6	26.6	100.0
		Total	94	100.0	100.0	
Question 22	Experimental Group	0	43	38.1	38.1	38.1
		1	70	61.9	61.9	100.0
		Total	113	100.0	100.0	
	Control Group	0	63	67.0	67.0	67.0
		1	31	33.0	33.0	100.0
		Total	94	100.0	100.0	
Question 23	Experimental Group	0	31	27.4	27.4	27.4
		1	82	72.6	72.6	100.0
		Total	113	100.0	100.0	

Question 24	Control Group	0	84	89.4	89.4	89.4
		1	10	10.6	10.6	100.0
		Total	94	100.0	100.0	
	Experimental Group	0	83	73.5	73.5	73.5
		1	30	26.5	26.5	100.0
		Total	113	100.0	100.0	
Question 25	Control Group	0	60	63.8	63.8	63.8
		1	34	36.2	36.2	100.0
		Total	94	100.0	100.0	
	Experimental Group	0	57	50.4	50.4	50.4
		1	56	49.6	49.6	100.0
		Total	113	100.0	100.0	
Question 26	Control Group	0	55	58.5	58.5	
		1	39	41.5	41.5	100.0
		Total	94	100.0	100.0	
	Experimental Group	0	56	49.6	49.6	49.6
		1	57	50.4	50.4	100.0
		Total	113	100.0	100.0	

Question 27	Control Group	0	66	70.2	70.2	
		1	28	29.8	29.8	100.0
		Total	94	100.0	100.0	
	Experimental Group	0	37	32.7	32.7	32.7
		1	76	67.3	67.3	100.0
		Total	113	100.0	100.0	
Question 28	Control Group	0	66	70.2	70.2	70.2
		1	28	29.8	29.8	100.0
		Total	94	100.0	100.0	
	Experimental Group	0	57	50.4	50.4	50.4
		1	56	49.6	49.6	100.0
		Total	113	100.0	100.0	
Question 29	Control Group	0	53	56.4	56.4	56.4
		1	41	43.6	43.6	100.0
		Total	94	100.0	100.0	
	Experimental Group	0	38	33.6	33.6	33.6
		1	75	66.4	66.4	100.0
		Total	113	100.0	100.0	

Question 30	Control Group	0	57	60.6	60.6	60.6
		1	37	39.4	39.4	100.0
		Total	94	100.0	100.0	
	Experimental Group	0	41	36.3	36.3	36.3
		1	72	63.7	63.7	100.0
		Total	113	100.0	100.0	



Graph 5.5.3. Frequency scores (in percentages) for each test question for the experimental and control groups, as well as the total frequency scores for the combination of both groups.

The highest combined frequency scores (above 60%) were recorded in questions 1, 4, 9, 15 and 16. Areas specifically tested by these questions include one-to-one correspondence (including counting), introductory mathematics vocabulary and sequencing and patterning.

The lowest combined frequency scores (below 40%) were recorded in questions 5, 6, 10, 17, 19, 20 and 24. Areas specifically tested by these questions include introductory mathematics vocabulary, number conservation, number sense, addition and subtraction (word problem format). It would appear that attainment in introductory mathematics vocabulary is variable, depending on the wording and context used.

Questions showing the greatest differences (35% or more) between control group and experimental group frequencies include questions 12, 13, 21, 22, 23 and 27. This indicates that the tested areas experiencing the greatest positive impact from the intervention programme were number sense, addition and subtraction (word problem format), one-to-one correspondence (including counting), directionality and spatial awareness.

5.6 Differences between means

5.6.1 Test for hypothesis 1

Table 5.6.1.1 Descriptives utilised in test for hypothesis 1

Total

					95% Confidence Interval for Mean			
	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Control	94	10.20	6.865	.708	8.80	11.61	0	27
Experimental	113	17.71	7.066	.665	16.39	19.02	0	30
Total	207	14.30	7.903	.549	13.22	15.38	0	30

The descriptive statistics above show the mean of the experimental group to be 17.71, while the control group had a mean of 10.21.

Table 5.6.1.2 Test of homogeneity of variances for hypothesis 1

Total

Levene Statistic	df1	df2	Sig.
.350	1	205	.555

There is no significant difference between the variances of the 2 groups (p>0.05), and therefore the standard ANOVA was used.

Table 5.6.1.3 Anova test results for hypothesis 1

Total

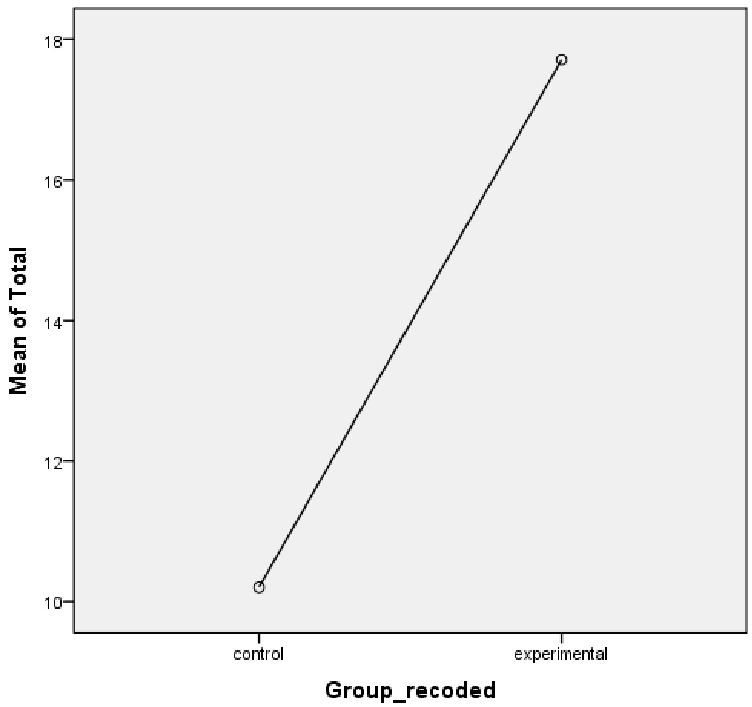
	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	2890.908	1	2890.908	59.415	.000
Within Groups	9974.522	205	48.656		
Total	12865.430	206			

$P \leq 0.01$

The ANOVA-table indicates that there is a significant difference between the mean total scores of the experimental and control groups (p<0.01). It can therefore be said that the experimental group performed significantly better than the control group.

Plot 5.6.1

The overall mean of the experimental/intervention group is 17.71 and the overall mean of the control group is 10.21



A statistically significant difference between the means of the experimental and control groups was established at a 99% level of confidence.

5.6.2 Test for hypothesis 2

Table 5.6.2.1 Descriptives utilised in test for hypothesis 2

Total

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Rural	78	11.14	7.629	.864	9.42	12.86	0	27
Township	47	9.70	5.493	.801	8.09	11.31	0	23
Urban	82	19.94	5.684	.628	18.69	21.19	8	30
Total	207	14.30	7.903	.549	13.22	15.38	0	30

The descriptive statistics above show that the urban group had the highest mean score (19.94), while the rural and township groups had lower scores (11.14 and 9.70 respectively).

Table 5.6.2.2 Test of homogeneity of variances for hypothesis 2

Total

Levene Statistic	df1	df2	Sig.
8.410	2	204	.000

Levene's test shows that there are significant differences between the variances of the 3 groups ($p<0.01$). The more robust Brown-Forsythe ANOVA was subsequently used.

Table 5.6.2.3 Robust Tests of Equality of Means for hypotheis 2

Total

	Statistic	df1	df2	Sig.
Brown-Forsythe	55.368	2	186.176	.000

The ANOVA shows that there is a significant difference between the 3 groups with regard to their mean total scores. Post hoc tests were subsequently performed and are reported below.

Table 5.6.2.4 Post Hoc Tests - Multiple Comparisons

Dependent Variable: Total

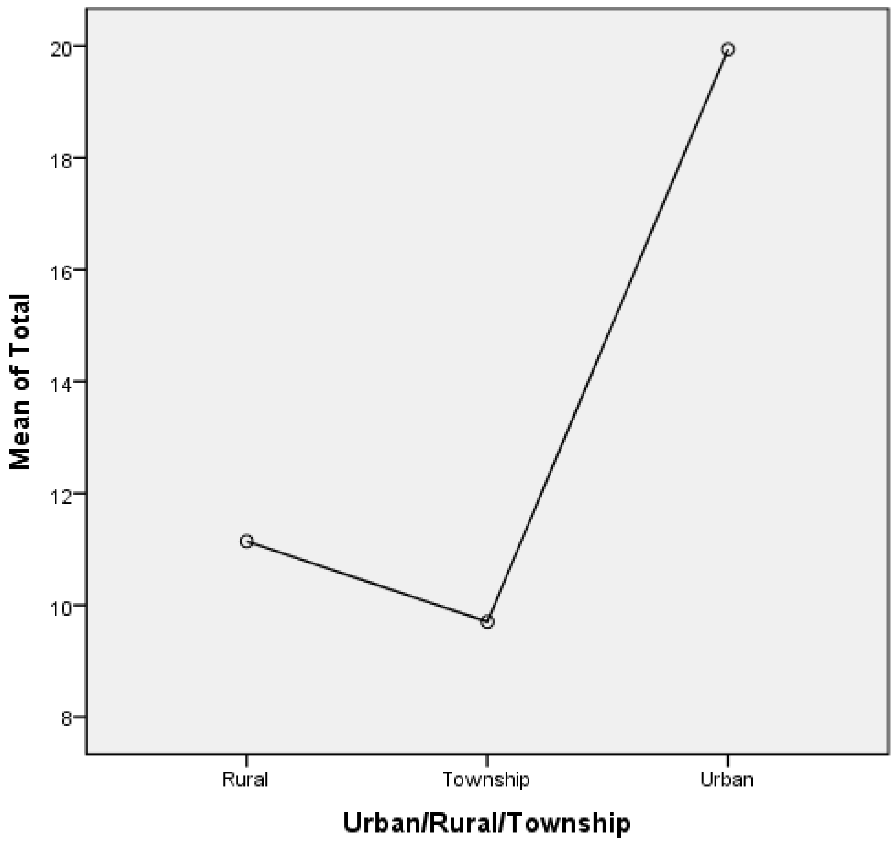
Scheffe

(I) Urban/Rural/Township	(J) Urban/Rural/Township	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Rural	Township	1.439	1.191	.483	-1.50	4.38
	Urban	-8.798	1.020	.000	-11.31	-6.28
Township	Rural	-1.439	1.191	.483	-4.38	1.50
	Urban	-10.237	1.180	.000	-13.15	-7.33
Urban	Rural	8.798	1.020	.000	6.28	11.31
	Township	10.237	1.180	.000	7.33	13.15

$P \leq 0.01$

Post hoc tests show that there was a significant difference between the urban group on the one hand, and the rural and township groups on the other. There was not a significant difference between the rural and the township groups. It may therefore be concluded that the urban group performed significantly better than the rural and township groups.

Plot 5.6.2 The overall means for rural is 11.14, township is 9.70 and urban is 19.94.



A statistically significant difference between the means of the urban and rural/township groups was established at a 99% level of confidence.

This difference is attributed to factors outside of the scope of this study. Possible factors would include slight age differences of tested pupils, differences in socio-economic status, household stability factors, language differences between educators and pupils, availability of teaching resources and levels of teacher qualification.

5.6.3 Tests for hypotheses 3,4 and 5

Table 5.6.3.1 Descriptives utilised in test for hypothesis 3,4 and 5

Total

Urban/Rural/Township		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Rural	Control	33	5.00	2.969	.517	3.95	6.05	0	11
	Experimental	45	15.64	6.813	1.016	13.60	17.69	0	27
	Total	78	11.14	7.629	.864	9.42	12.86	0	27
Township	Control	20	6.00	3.825	.855	4.21	7.79	0	15
	Experimental	27	12.44	4.933	.949	10.49	14.40	2	23
	Total	47	9.70	5.493	.801	8.09	11.31	0	23
Urban	Control	41	16.44	4.955	.774	14.88	18.00	8	27
	Experimental	41	23.44	3.969	.620	22.19	24.69	9	30
	Total	82	19.94	5.684	.628	18.69	21.19	8	30

The descriptive statistics above show the means of the experimental group for rural to be 15.64, township to be 12.44 and urban to be 23.44. The control group means for rural are 5, township 6 and urban 16.44 respectively.

Table 5.6.3.2 Test of Homogeneity of Variances

Total

Urban/Rural/Township	Levene Statistic	df1	df2	Sig.
Rural	37.153	1	76	.000
Township	1.151	1	45	.289
Urban	3.535	1	80	.064

$P \leq 0.01$

For the rural group there was a significant difference between the variances ($p<0.05$), therefore the robust ANOVA should be used in the case of the rural comparison.

Table 5.6.3.3 ANOVA test results

Total

Urban/Rural/Township		Sum of Squares	df	Mean Square	F	Sig.
Rural	Between Groups	2157.138	1	2157.138	70.534	.000
	Within Groups	2324.311	76	30.583		
	Total	4481.449	77			
Township	Between Groups	477.163	1	477.163	23.579	.000
	Within Groups	910.667	45	20.237		
	Total	1387.830	46			
Urban	Between Groups	1004.500	1	1004.500	49.845	.000
	Within Groups	1612.195	80	20.152		
	Total	2616.695	81			

Table 5.6.3.4 Robust Tests of Equality of Means

Total

Urban/Rural/Township		Statistic	df1	df2	Sig.
Rural	Brown-Forsythe	87.257	1	63.848	.000
Township	Brown-Forsythe	25.435	1	44.877	.000
Urban	Brown-Forsythe	49.845	1	76.360	.000

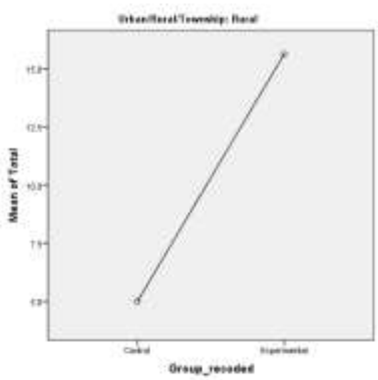
$P \leq 0.01$

The ANOVA-table indicates that there is a significant difference between the mean total scores of the experimental and control groups ($p<0.01$) in each region independently.

<u>Means Plots</u>

Plot 5.6.3.1

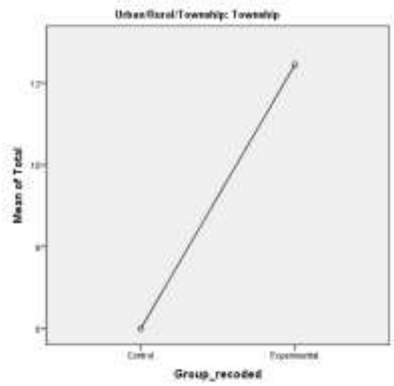
The overall mean of the experimental/intervention group within the rural area is 15.64 and the overall mean of the control group is 5



A statistically significant difference between the means of the experimental and control groups in the rural region was established at a 99% level of confidence.

Plot 5.6.3.2

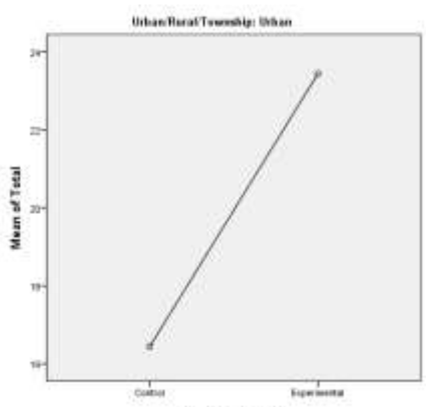
The overall mean of the experimental/intervention group within the township area is 12.44 and the overall mean of the control group is 6



A statistically significant difference between the means of the experimental and control groups in the township region was established at a 99% level of confidence.

Plot 5.6.3.3

The overall mean of the experimental/intervention group within the urban area is 23.44 and the overall mean of the control group is 16.44



A statistically significant difference between the means of the experimental and control groups in the urban region was established at a 99% level of confidence.

5.7 Analysis of qualitative data

Initial steps of the qualitative analysis process involved collecting and transcribing verbal information into text form. Data were captured and transpired on a laptop computer. Although units of analysis were broadly pre-determined through set interview questions, some units of analysis evolved implicitly rather than being determined explicitly and were chosen on the basis of the research objectives (Auer-Srnka & Koeszegi, 2007:36). Most of the data was available in short statements in answer to questions, which allowed for them to be used directly as units of analysis. Units of meaning selected comprised of an idea communicated, regardless if expressed in a sentence or implied in expression or further verbal elaboration (Auer-Srnka & Koeszegi, 2007:36).

In order to enhance validity, an attempt to retain as much data detail as possible was made in selecting data coding categories (Auer-Srnka & Koeszegi, 2007: 37).

The following is a tabulated coding manual utilised for the qualitative data analysis:

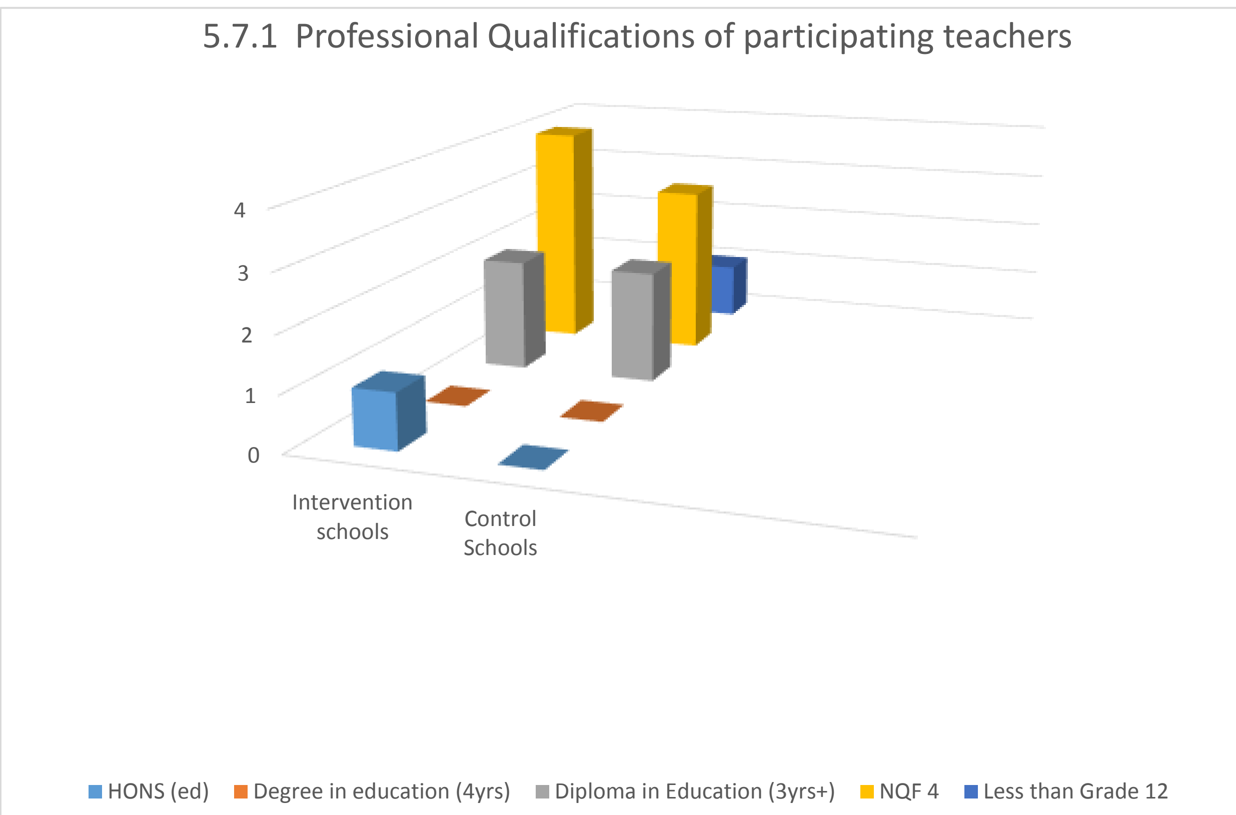
Visual representation	Variable	Origin of raw data i.e. interview questions utilised (see addendum D & E)	Coding units selected
Graph 5.7.1	Professional qualifications	Introduction	• Hons • 4 yr degree • Education diploma (3yrs+) • NQF level 4 • Less than Grade 12
Graph 5.7.2	Years of teaching experience	1	• Longer than 4 years • 3-4 years • 1-2 years • Less than a year
Graph 5.7.3	Perceived preparation received for instructing in mathematics	8	(More than one coding unit could be selected per respondent) • Poor • Adequate – through qualification

			• Adequate - through workshop training • Excellent - through qualification • Excellent – through workshop training
Graph 5.7.4	Daily time spent teaching mathematics	2	• More than an hour • 30 min- hour • Less than 30 min • Very little – incidental or integrated into my other subjects
Graph 5.7.5	Daily preparation time for mathematics instruction	3	• 30 min – 1 hour daily • 15 min – 29 min daily • Less than 15 minutes daily • None
Graph 5.7.6	Opinion on national mathematics standard (Grade R)	4	• Positive • Negative • Neutral / no opinion
Graph 5.7.7	Emotional response of teachers towards teaching mathematics	5	• Negative i.e. dislike/ disgust/ hate • Scared i.e. fear/concern • Neutral/ no opinion • Positive
Graph 5.7.8	Perceived emotional response of pupils towards mathamatics	6	• Negative • Neutral/ no opinion • Positive • Varied based on activities or performance
Graph 5.7.9	Expectations regarding pupil performance in Grade 1	7	• Varied/ some will perform well others not • A weak start and then a stronger finish • Poorly • Well/ high expectations
Graph 5.7.10	Availability of resources for teaching mathematics effectively	9	• Sufficient • Insufficient
Graph 5.7.11	Opinion regarding the most effective teaching method for Grade R mathematics	11	• Free flow play • Adult-guided play • Combination of adult-guided play and worksheets

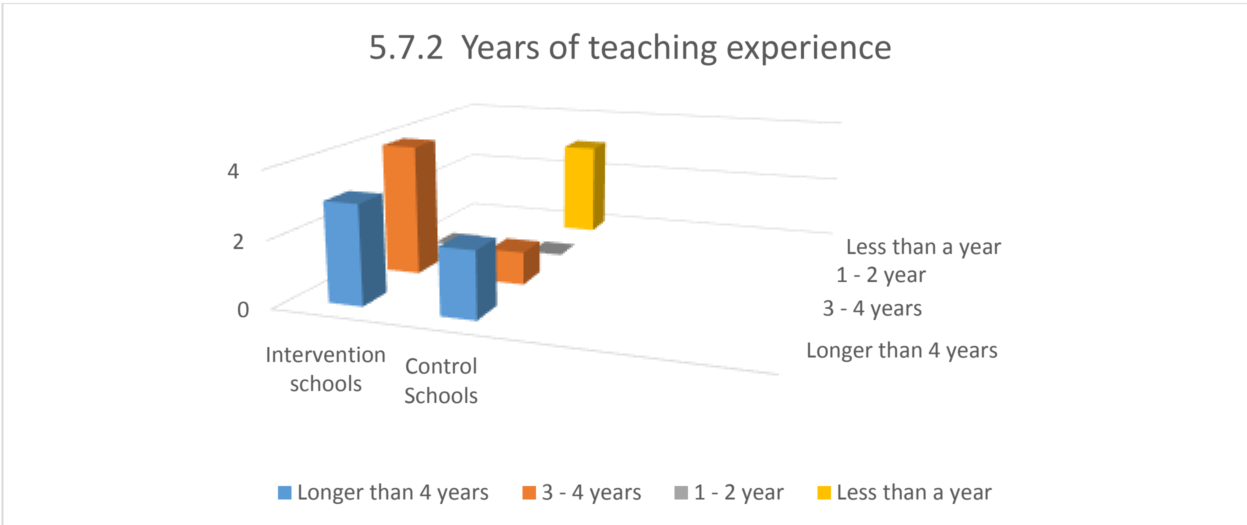
			• Formal instruction (demonstration followed by worksheet) • Only counting
Graph 5.7.12	Personal insecurities felt in teaching mathematics	13	(More than one could be selected per respondent) • Feelings of inexperience • Inherent fear • Lack of confidence • Learner underperformance • None
Graph 5.7.13	Identified areas of concern in current Grade R mathematics trends in South Africa	17	(More than one could be selected per respondent) • Poor teacher training • Poor qualifications • Insufficient resources • Too formal approach • Pressurised syllabus • Lack of awareness of the importance of mathematics
Graph 5.7.14	Beliefs concerning the most effective method for teaching Grade 1 mathematics	22	• Adult-guided play and manipulating concrete materials • Adult-guided play combined with worksheets/ written work • Formal (worksheets/ written) • No opinion/ no ideas
Graph 5.7.15	Most recent area of growth in personal understanding regarding Grade R mathematics instruction	18	(More than one option could be selected) • Children vary in their mathematics abilities • Mathematics is not daunting • Mathematics needs repetition and practice • You can allocate corners in your classroom to mathematics • There are alternative methods to teaching mathematics • Teaching mathematics is fun and children can learn through play
Graph 5.7.16	Perceived personal barriers to effective teaching of Grade R mathematics	19, 20	(More than one option could be selected) • Classroom design • Language barriers • Insufficient time • Poor pupil support

			• Low salary • Professional pressure to perform • Personal inexperience/ under qualification • Insufficient resources • Mixed age group of pupils
Graph 5.7.17	Satisfaction levels regarding current teaching approach to mathematics	19, 21, 11	• Largely satisfied but open to growth • Largely dissatisfied and wanting to change

The following graphs visually represent the coding and analysis results of the qualitative data, obtained from in-depth interviews with participating teachers.

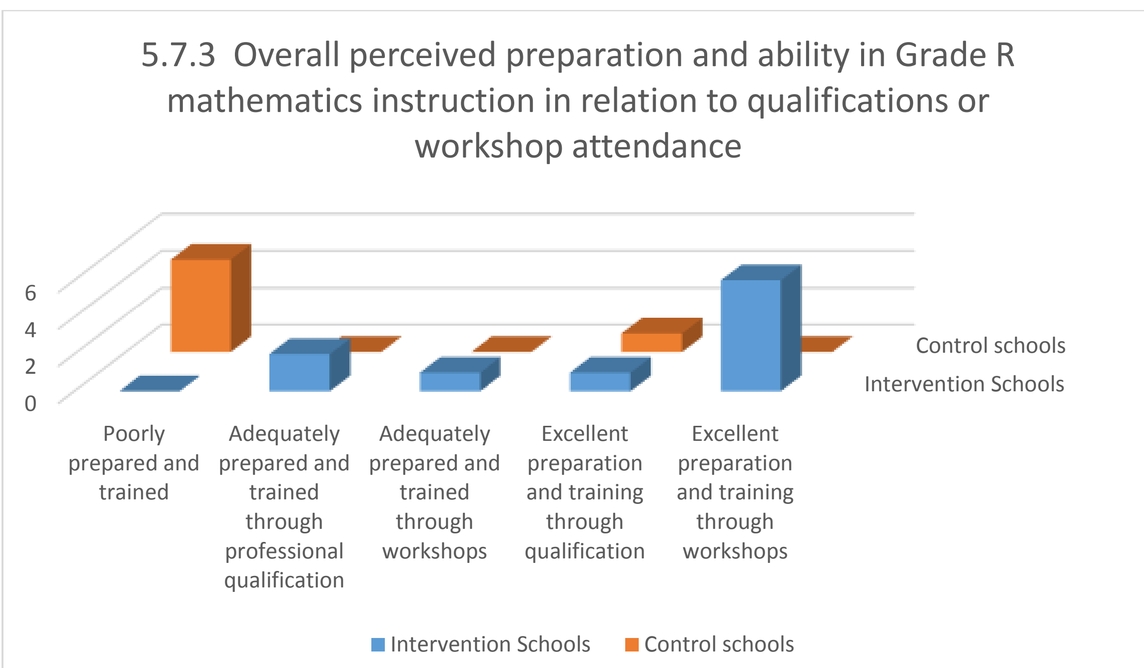


The largest portion of teachers within the control and intervention groups had obtained a level 4 qualification (equivalent of senior matric certification within the NQF). Four teachers had teaching diplomas and one had an honours degree.



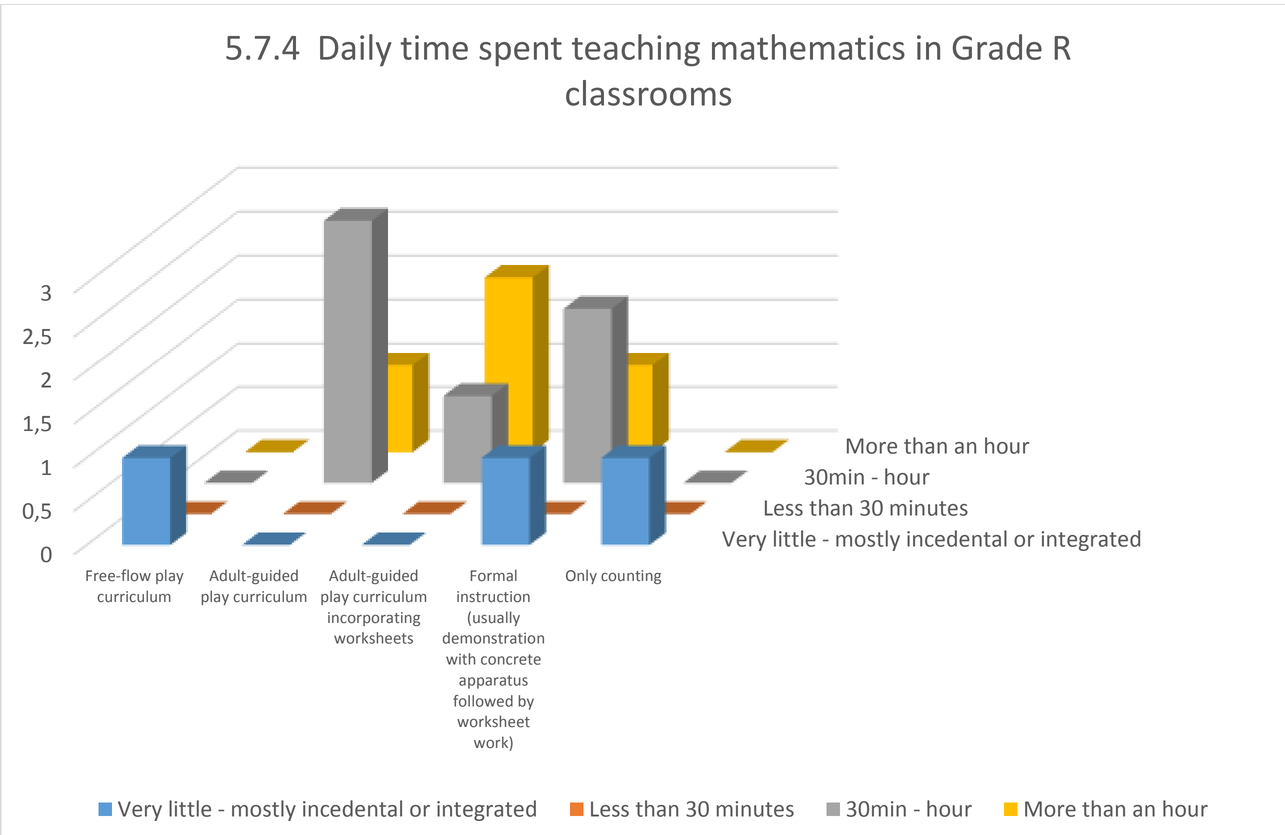
Graph 5.7.2

Five teachers had been teaching Grade R for longer than 4 years and five had been teaching for 3 – 4 years. Three teachers in the control group had been teaching for less than a year. The cumulative years of teaching experience were higher in the intervention schools than the control schools.



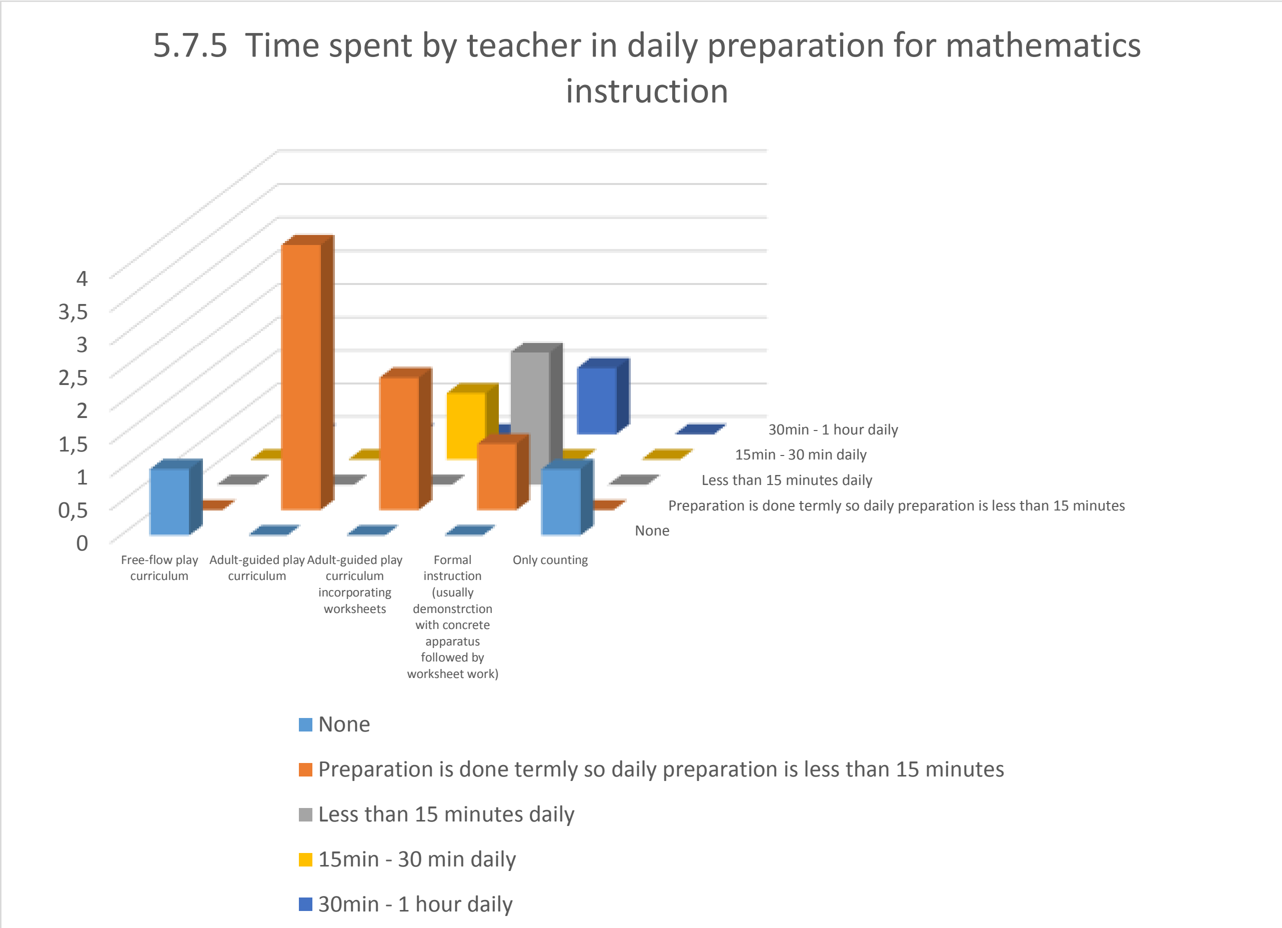
Graph 5.7.3

The majority of control teachers felt insufficiently prepared and trained for Grade R mathematics instruction. Only one teacher within this group felt that her Johannesburg College of Education diploma had given her excellent preparation and training in the field. Within the intervention group two teachers believed that they had been adequately prepared through their professional qualifications and one teacher believed her professional qualification was of an excellent standard. Most of the intervention teachers, however, believed that they were excellently prepared through the intervention programme (training workshops), although one felt that more regular follow-up assistance would be ideal.



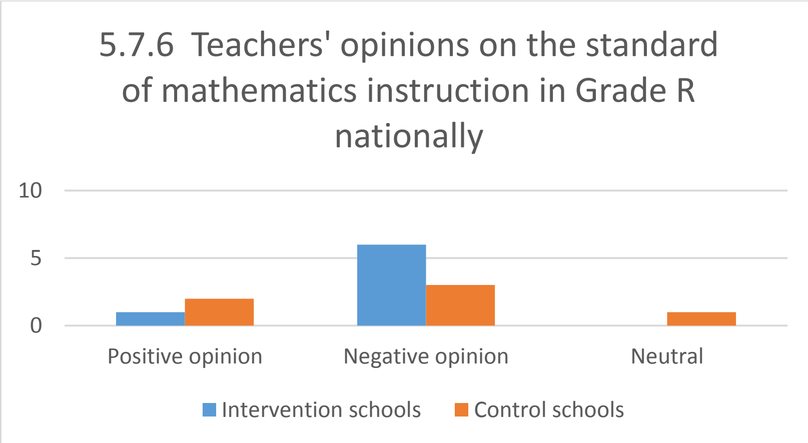
Graph 5.7.4

The majority of teachers claim to spend 30 minutes to an hour daily in teaching mathematics to their pupils. The exclusively adult-guided play-based curriculum seems to require an average of 30 minutes to an hour daily for effective implementation. Further time is required when teachers combine the adult-guided play-based curriculum with a worksheet-based curriculum, translating into an average mathematics teaching time of more than an hour. Teachers who use formal instruction seem to have a variety of teaching time experiences.



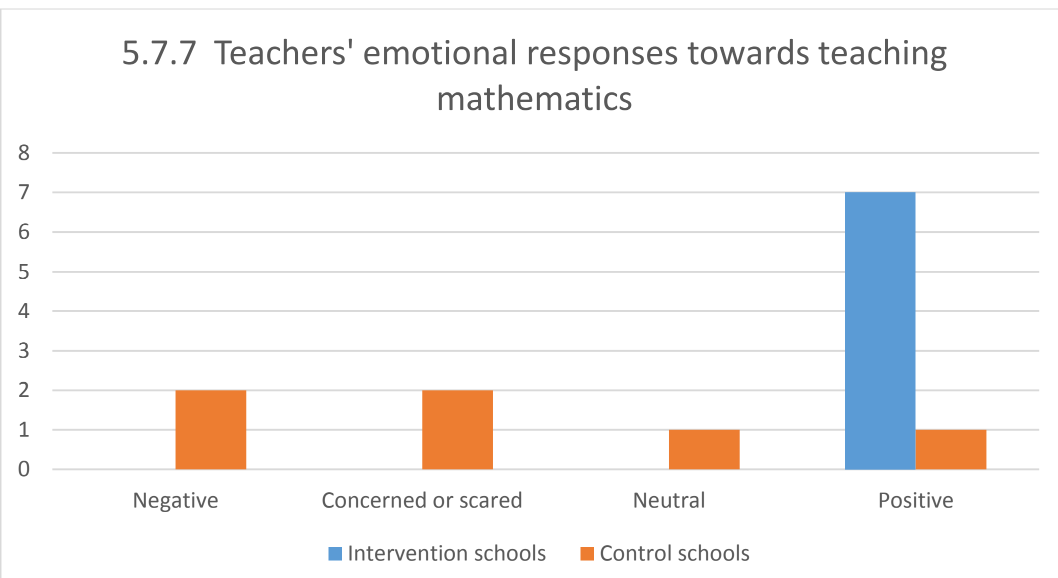
Graph 5.7.5

Very little time is spent in daily preparation for those teachers opting for an exclusively adult-guided play-based curriculum. All teachers employing this method prefer preparation once termly and then engage in a quick re-visit of preparation notes before weekly lessons commence. The formal instruction method is most varied in preparation time, with some teachers taking less than 15 minutes daily and some almost an hour.



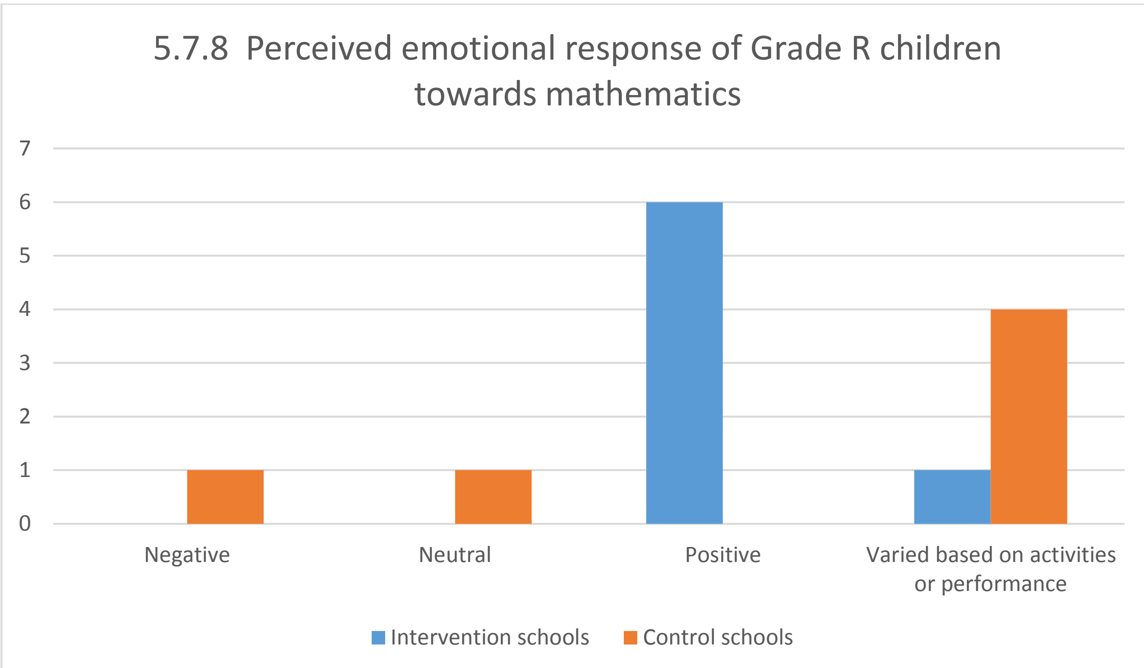
Graph 5.7.6

Six teachers using an adult-guided play-based curriculum believed that the standard of mathematics instruction in South Africa Grade R can be described as deeply concerning. Only one within this group had a positive opinion regarding the national standard. Varied opinions were found amongst the control teachers, with three showing concern, two opting for a positive opinion and one undecided.



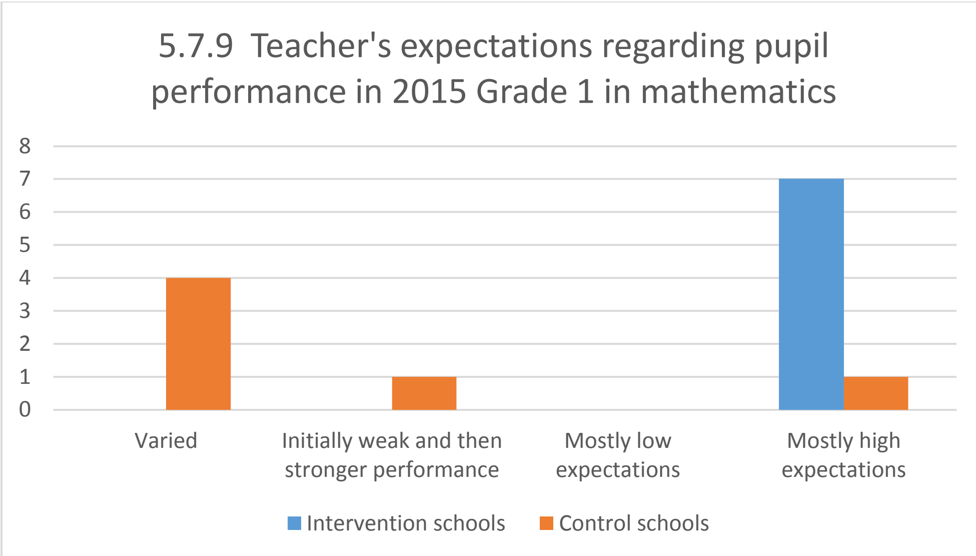
Graph 5.7.7

All teachers engaging in an adult-guided play-based curriculum expressed excitement and general positivity towards the method of instruction. The majority of control group teachers was negative or expressed concern about their methods of mathematics instruction. Only one control group teacher felt positive about her formal approach, and one remained indecisive.



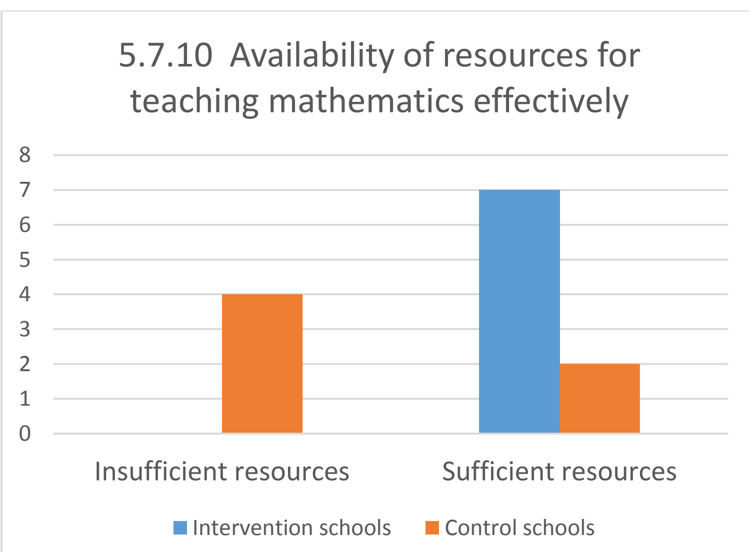
Graph 5.7.8

Almost all control group teachers believed their pupils were excited and positive about the method. One teacher within this group believed that her pupils did not enjoy two particular activities as much as the others. The majority of the control group teachers attributed pupil enjoyment to the choice of activity selected. One teacher within this group felt that her pupils were negative towards mathematics and one remained indecisive.



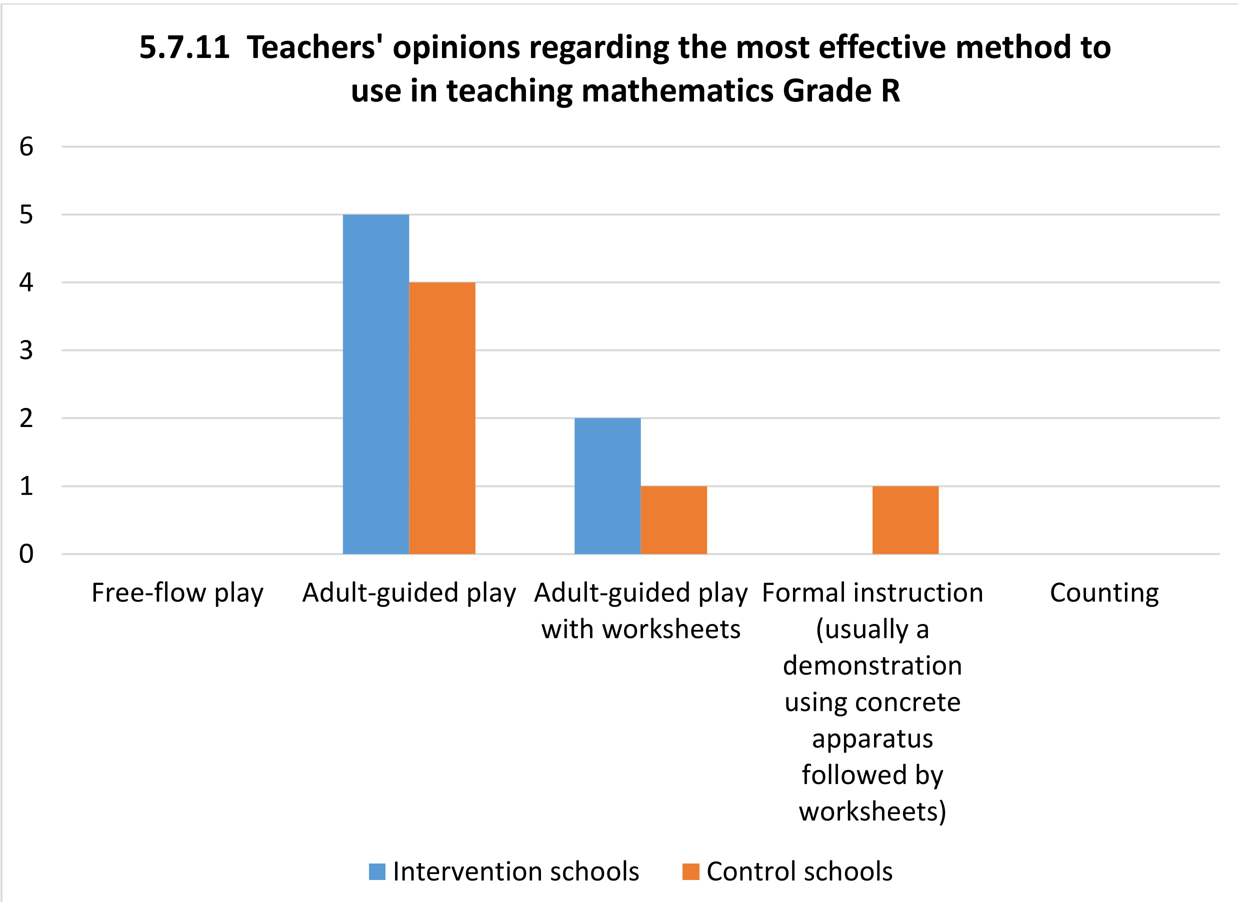
Graph 5.7.9

Intervention group teachers all demonstrated complete confidence in their pupils' preparation for Grade 1 and had high expectations for their pupils for the next year. Control group teachers were less confident in their expectations for their pupils with only one teacher in this group demonstrating confidence and the most believing that their pupils would have varied results, based on their pupils' personal abilities.



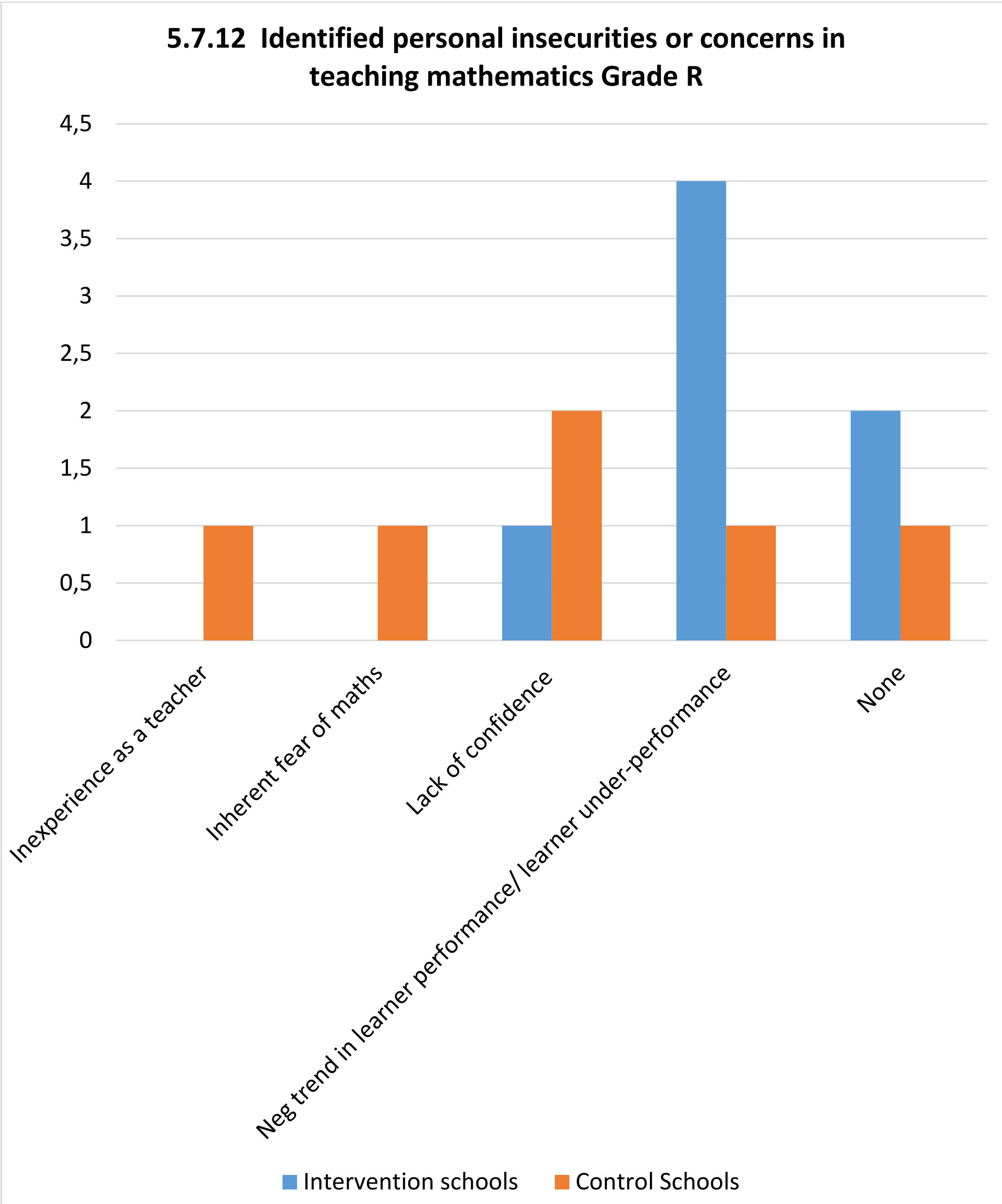
Graph 5.7.10

All intervention group teachers were satisfied with the amount of teaching resources they have for mathematics instruction. Four control group teachers were concerned about their lack of resources and only two felt they have adequate resources.



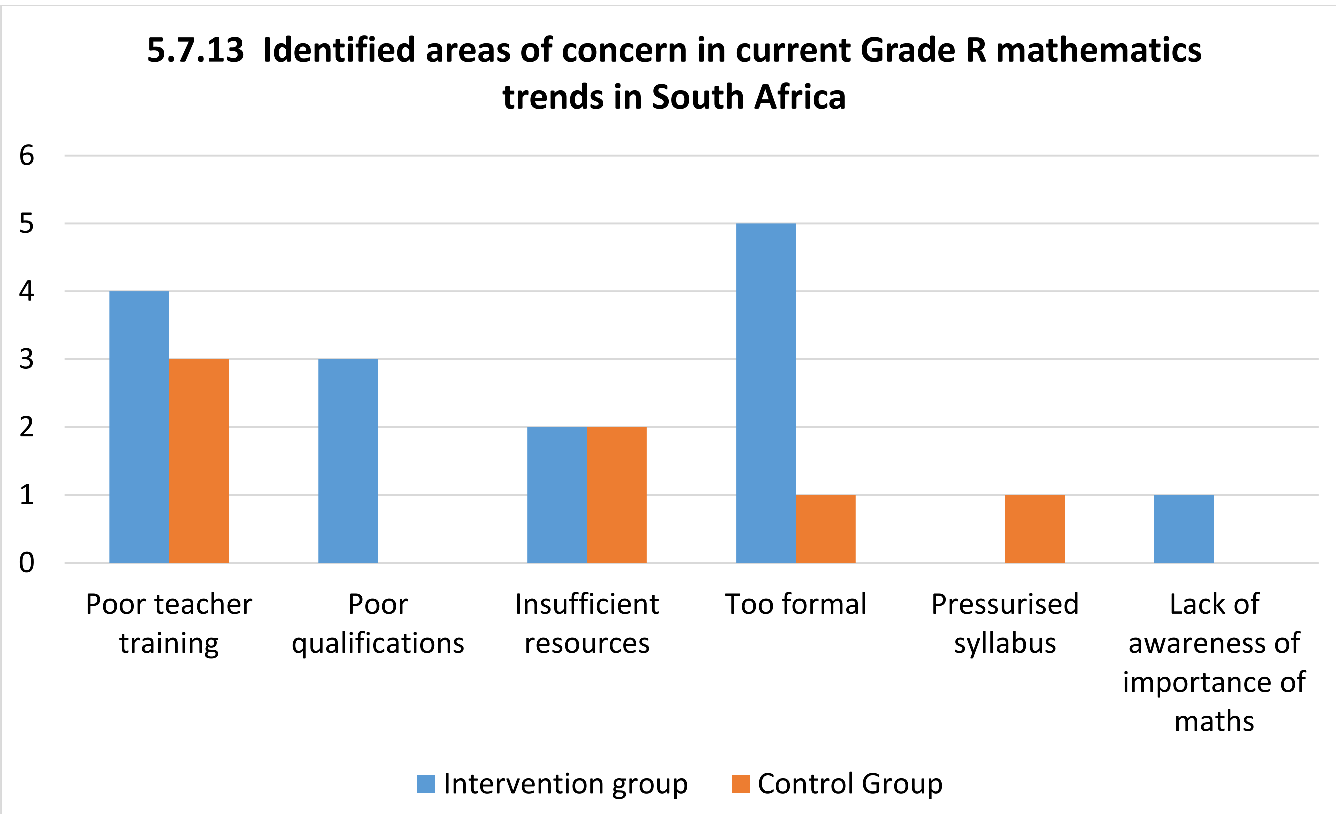
Graph 5.7.11

The majority of teachers within the control and intervention groups felt that adult-guided play was the most effective method for mathematics instruction in Grade R. Two intervention group teachers and one control group teacher believed that adult-guided play should be combined with worksheets. Only one control group teacher advocated formal instruction as ideal.


5.7.12 Identified personal insecurities or concerns in teaching mathematics Grade R
4,5
4
3,5
3
2,5
2
1,5
1
0,5
0
Inexperience as a teacher
Inherent fear of maths
Lack of confidence
Neg trend in learner performance/ learner under-performance
None
Intervention schools
Control Schools

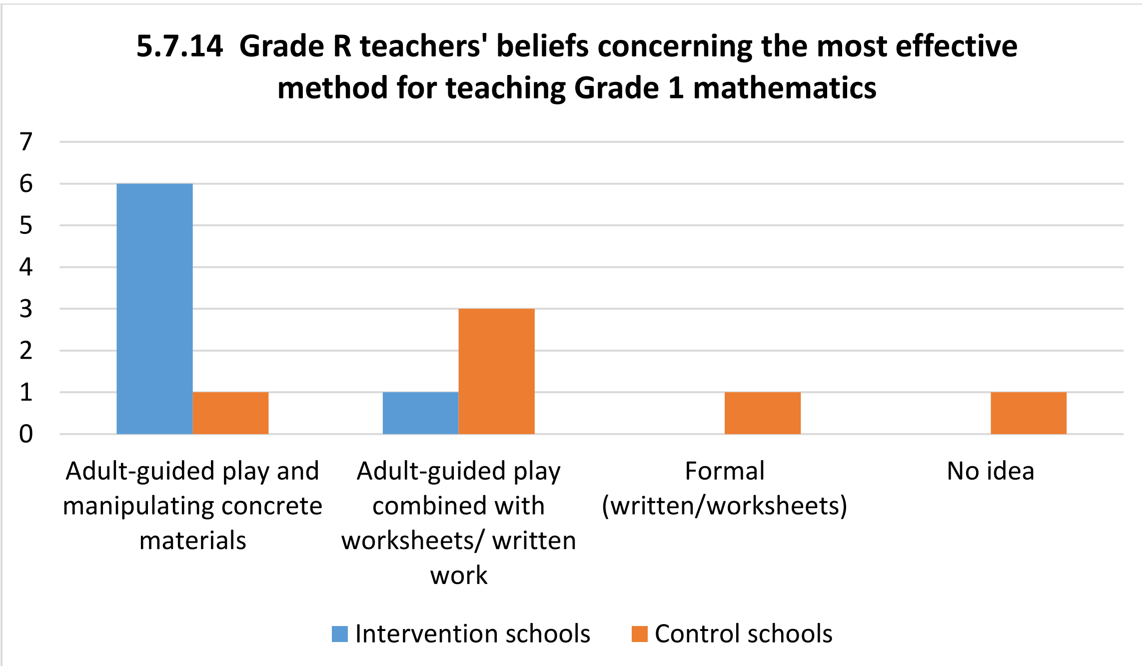
Graph 5.7.12

Four teachers in the intervention group expressed their concern about a downward trend in pupil performance over their years of teaching experience. One teacher in this group felt somewhat insecure in her administration of an adult-guided play-based curriculum as she would have preferred more constant feedback concerning her performance during the course of the year. Four control group teachers expressed personal insecurities and concerns related to teaching mathematics and one concurred that there was a downward trend in pupil performance each year.



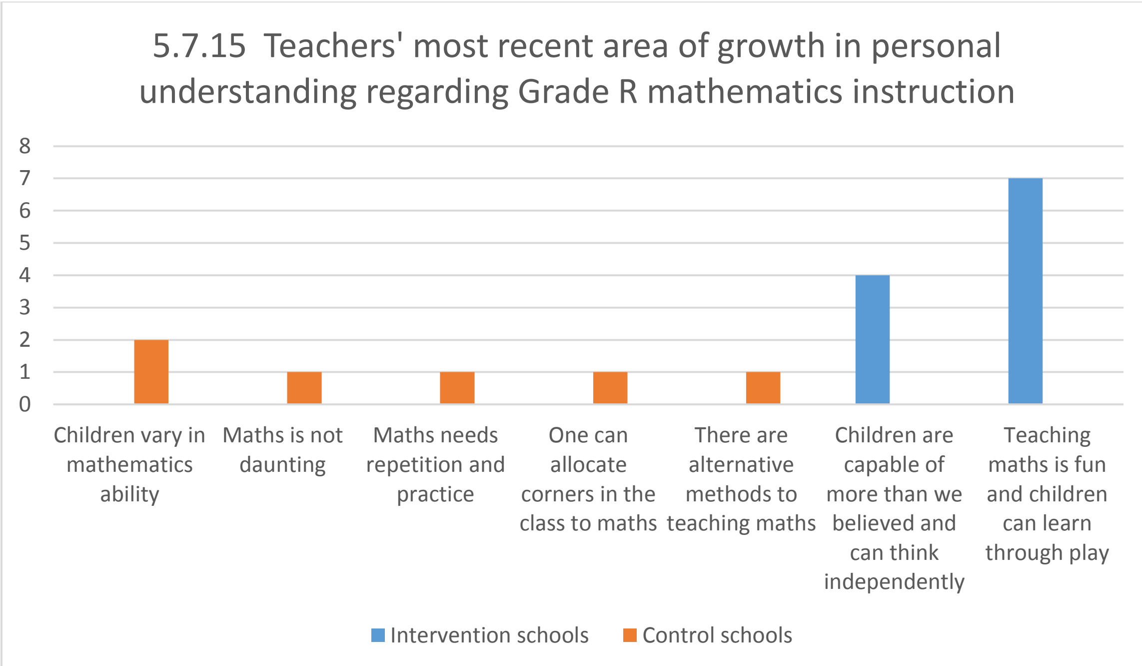
Graph 5.7.13

A variety of areas were identified when teachers were asked to isolate areas of national concern in the Grade R mathematics curriculum. The majority of intervention group teachers felt that the curriculum used by most teachers was too formal. Both groups expressed concern about insufficient training and three teachers from the intervention group were concerned about poor teacher qualifications. Both groups identified poor teaching resources as a national concern and one control group teacher felt that the national syllabus (CAPS) was excessively pressurised. One intervention group teacher believed that a lack of awareness of the importance of mathematics at this young age was an extreme concern.



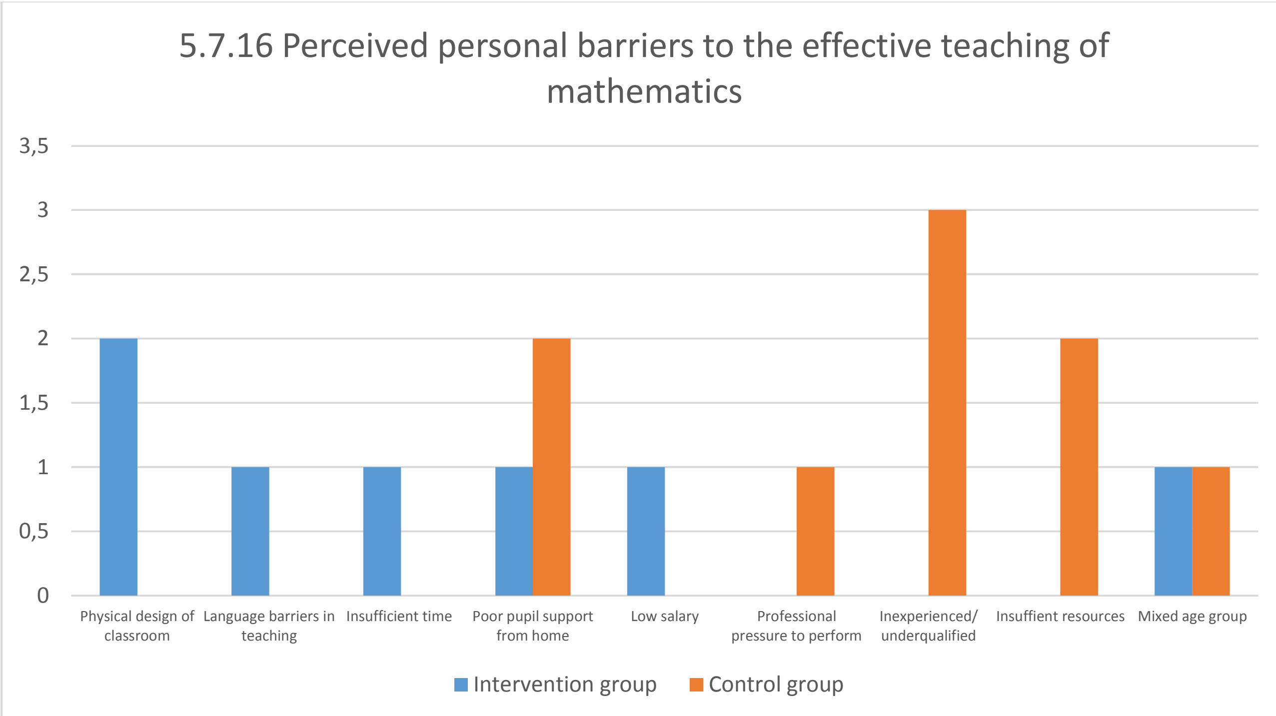
Graph 5.7.14

All intervention group teachers believed that the Grade 1 mathematics curriculum should be an extension of the adult-guided play-based curriculum they are employing in Grade R. Only one teacher from this group mentioned the importance of combining this approach with worksheets. There was a varied response from the control group teachers, with three advocating an adult-guided play-based curriculum combined with worksheets.



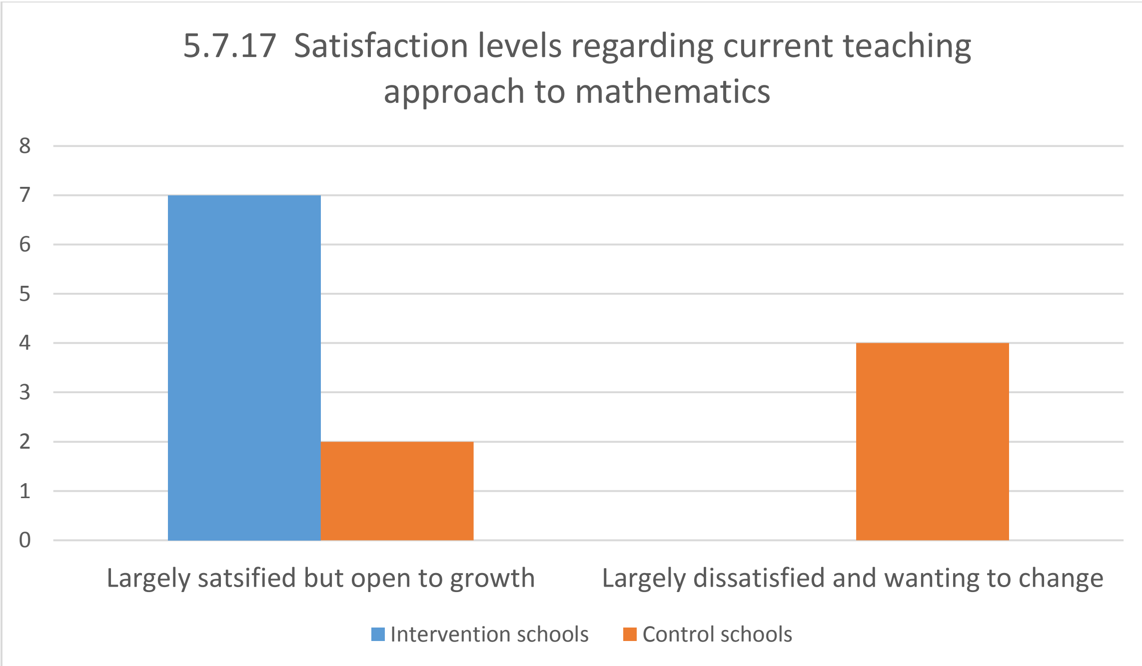
Graph 5.7.15

A large variety of responses was received when respondents were asked to identify recent areas of professional growth and understanding in the area of Grade R mathematics. Four intervention group teachers expressed amazement at the level of independent thinking their learners had attained this year. All intervention group teachers described development in their understanding of the fun and positive outcomes of an adult-guided play-based curriculum. Almost all control group teachers isolated completely different areas of personal growth in understanding. Two agreed that children’s mathematical ability varies greatly.



Graph 5.7.16

A large variety of perceived barriers to the effective teaching of mathematics were identified. Two intervention group teachers believed that their classroom designs are not conducive to large-scale mathematics activities. Three teachers from both groups identified poor parental support and poor cognitive support from home as barriers. Three control group teachers felt personally inexperienced and two from this group identified insufficient resources as a barrier. Other areas identified included language differences within the class, professional pressure to perform, poor salaries and insufficient teaching time.



Graph 5.7.17

All intervention group teachers expressed satisfaction with their current approach to teaching mathematics. Only two control group teachers were satisfied with their approach and four of the control group expressed a desire to change.

5.8 Triangulation of data

The triangulation process is utilised when a study component is used to corroborate, confirm or cross-validate the research findings of another component in the study (McMillan & Schumacher 2010: 399).

The primary purpose of this research is to determine if an adult-guided and structured play-based mathematical programme, focusing on developmentally appropriate pre-numeracy skills, significantly improves the preprimary school child's understanding of mathematical concepts upon entry into Grade 1.

The empirical findings of the study have confirmed the above question at a statistically significant level. These results can be triangulated with the qualitative findings illustrated in Graph 5.7.9. The teachers applying an adult-guided, play-based curriculum were unanimous in their high expectations of their pupil's mathematics performance in Grade 1 in 2015. The same could not be said of teacher's using other teaching methods. It could also be implied that by expressing general satisfaction and by advocating their current mathematics approach to teaching, the experiment group teachers demonstrated a confidence in a programme's ability to adequately prepare pupils for Grade 1. Higher confidence and satisfaction is expressed in Graph 5.7.11 and Graph 5.7.17 by those employing an adult-guided play-based approach in comparison to teachers using other methods.

Furthermore, pupil enjoyment and teacher enjoyment could be argued as indicators of the mastery of subject content resulting in feelings of relaxation while teaching. Higher levels of both teacher and pupil enjoyment were indicated in graph 5.7.7 and Graph 5.7.8 for those participating in an adult-guided play approach compared to those utilising other methods.

5.9 Conclusion

The ultimate purpose of data analysis is to determine if there are any patterns, trends or themes that can be identified in the findings (Mouton, 2001:108). Single variable descriptive statistics (mean, standard deviation and frequency distributions) provided insight into intervention and non-intervention group test scores. To determine the reliability of the scores, Cronbach's alpha coefficient was computed.

It is evident that the interventions had the required impact, with large differences between the experimental and control group test scores. It is also evident that there is a significant difference in the overall scores of urban areas (higher SES) to township and rural areas.
Concluding remarks are discussed in chapter 6.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

It is claimed that substandard education, particularly in the field of mathematics, reading and writing skills, remains the biggest stumbling block on the road to South Africa creating a successful society (Ramphele, 2014). South Africa's poor performance in mathematics in particular remains a sensitive focal point of media and educational experts alike (Siyepu, 2013:1; Evans, 2013). It stands to reason that mathematics instruction needs urgent investigation, and intervention in this arena during a child's early years in the South African context might reap hitherto minimally explored positive, long-term results.

This study aimed to provide scientific evidence and an in-depth understanding of the impact of an early play-based intervention programme in the field of preprimary school mathematics. The results of the study suggest that the introduction of an adult-guided play-based mathematics curriculum, focusing on developmentally appropriate pre-numeracy skills, had a significantly positive impact on the preprimary school child's understanding of mathematical concepts upon entry into Grade 1.

In the literature study conducted in chapter 3, the dire need for research into the field of South African preprimary school mathematics became apparent. While many early childhood development centres in South Africa offer a worksheet-based or free-flow play based curriculum, few teachers are tapping into the power of a play-based curriculum for teaching mathematics in the early years. The literature study revealed that a playful, adult-guided approach offers numerous benefits to facilitating learning (Walsh *et al.*, 2011; Sylva, 1993; Weisberg *et al.*, 2013), yet many South African teachers are ill-equipped and under-qualified to introduce such a programme in their classrooms. Further literature study also revealed that no information is available on the qualification standards of preprimary school teachers in South Africa, and very little research has been conducted into the benefits of workshop training to improve the standards and skills of early childhood teachers preparing tomorrow's mathematics matriculants.

In this study, research was conducted using a combination of macro-methodologies, namely descriptive/interpretive (teacher interviews) methods and positive/experimental (pupil pen-and-paper type testing) methods. Experimental and control groups were selected from similar geographical regions. Data from this mixed method approach were triangulated to corroborate findings, as well as to enrich and elaborate information (McMillan & Schumacher, 2010:401-403).

Research was undertaken in three particular geographical areas within South Africa. A higher SES area was selected (Kempton Park), as well as a township area (Kwa Thema and Tsakane) and a rural area (Motupa circuit in Limpopo). Teachers who had been teaching using predominantly an adult-guided play-based curriculum were selected for the experimental group, while teachers employing a free-flow play or predominantly worksheet-based curriculum were considered for the control group. The adult-guided play-based curriculum had been introduced to an experimental group of teachers through a workshop training programme offered during the school holiday periods of 2014. Research was conducted predominantly in private institutions (private primary schools and home-based crèche's) and one public primary school.

The primary purpose of the research study was to determine if an adult-guided and structured play-based mathematical programme, focusing on developmentally appropriate pre-numeracy skills, could significantly improve the preprimary school child's understanding of mathematical concepts upon entry into Grade 1.

The overarching aim of the study was further subdivided into the following specific research questions:

The overarching aim of the study can be subdivided into the following specific research questions:

- Is the outcome of the primary research question significant for specific regions in South Africa?
- Can we gain insight into the child's understanding of mathematics concepts as a whole through reviewing previous studies and literature?
- What is the ideal pedagogical and developmentally appropriate approach to teaching Grade R children mathematics in South Africa, and can this be determined by means of a literature study, qualitative research and an empirical study?
- What are the benefits of a workshop-type training approach for pre-school teachers in South Africa?
- What are the feelings and thoughts of teachers who are attempting different approaches to teaching Grade R mathematics?
- In which ways can we equip and inspire teachers to re-examine their teaching methods and to make the necessary adjustments to meet the mathematical needs of the young child in different communities?
- Which particular areas in pre-mathematics are most impacted by the intervention programme?

6.2 Discussion relating to the primary research purpose and proposed research questions

To formulate a response to the primary purpose of the study, the following hypothesis was considered:

Hypothesis 1: Global intervention through a structured play-based curriculum

The null hypothesis (H_O) and alternative hypothesis (H_1) for the significance of intervention, comparing control and experimental groups are as follows:

$H_{0.1}$:

There is no significant difference in the averages (means) of the test scores of preprimary school children when tested on their understanding of foundational mathematics concepts at the time of entry into Grade 1 between children who have been taught using an adult-guided play-based mathematics curriculum and children who have had no formal mathematics instruction or only workbook-type instruction in Grade R.

$H_{1.1}$:

There is a significant difference in the averages (means) of the test scores of preprimary school children when tested on their understanding of foundational mathematics concepts at the time of entry into Grade 1 between children who have been taught using an adult-guided play-based mathematics curriculum and children who have had no formal mathematics instruction or only workbook-type instruction in Grade R.

It was determined through research and statistical analysis that an adult-guided and structured play-based mathematical programme, focusing on developmentally appropriate pre-numeracy skills, could indeed significantly improve the preprimary school child's understanding of mathematical concepts upon entry into Grade 1.

Furthermore, the specific research question regarding the regional significance of the primary research finding was explored through the following hypotheses:

Hypothesis 2: Intervention comparisons between particular geographical areas

The null hypothesis (H_O) and alternative hypothesis (H_1) for the significance of intervention, comparing overall scores in specific geographical areas within South Africa are:

$H_{0.2}$:

There is no significant difference in the averages (means) of the test scores of South African preprimary school children in specific geographical areas when tested on their understanding of foundational mathematics concepts at the time of entry into Grade 1

$H_{1.2}$:

There is a significant difference in the averages (means) of the test scores of South African preprimary school children in specific geographical areas when tested on their understanding of foundational mathematics concepts at the time of entry into Grade 1.

Hypotheses 3, 4 and 5 intervention within each geographical region

The null hypothesis (H_O) and alternative hypothesis (H_1) for the significance of the intervention, comparing control and experimental groups within each region, were as follows:

$H_{0.3}$:

There is no significant difference in the averages (means) of the test scores of preprimary school children in South African urban regions when tested on their understanding of foundational mathematics concepts at the time of entry into Grade 1 between children who have been taught using an adult-guided play-based mathematics curriculum and children who have had no formal mathematics instruction or only workbook-type instruction in Grade R.

$H_{1.3}$:

There is a significant difference in the averages (means) of the test scores of preprimary school children in South African urban regions when tested on their understanding of foundational mathematics concepts at the time of entry into Grade 1 between children who have been taught using an adult-guided play-based mathematics curriculum and children who have had no formal mathematics instruction or only workbook-type instruction in Grade R.

$H_{0.4}$:

There is no significant difference in the averages (means) of the test scores of preprimary school children in South African rural regions when tested on their understanding of foundational mathematics concepts at the time of entry into Grade 1 between children who have been taught using an adult-guided play-based mathematics curriculum and children who have had no formal mathematics instruction or only workbook-type instruction in Grade R.

$H_{1.4}$:

There is a significant difference in the averages (means) of the test scores of preprimary school children in South African rural regions when tested on their understanding of foundational mathematics concepts at the time of entry into Grade 1 between children who have been taught using an adult-guided play-based mathematics curriculum and children who have had no formal mathematics instruction or only workbook-type instruction in Grade R.

$H_{0.5}$:

There is no significant difference in the averages (means) of the test scores of preprimary school children in South African township regions when tested on their understanding of foundational mathematics concepts at the time of entry into Grade 1 between children who have been taught using an adult-guided play-based mathematics curriculum and children who have had no formal mathematics instruction or only workbook-type instruction in Grade R.

$H_{1.5}$:

There is a significant in between the averages (means) of the test scores of preprimary school children in South African township regions when tested on their understanding of foundational mathematics concepts at the time of entry into Grade 1 between children who have been taught using an adult-guided play-based mathematics curriculum and children who have had no formal mathematics instruction or only workbook-type instruction in Grade R.

The null hypothesis 1 was rejected at the 0.1% level of significance, meaning that there is a significant difference between the control group and experimental group's performance in Grade 1 entry-level mathematics. This result was true for the combined scores of all geographical regions. The second null hypothesis was also rejected at a 0.1% level of significance, meaning that there is a significant difference in the performance of school entry children in mathematics based on their geographical location.

Plot 5.6.1 makes it quite apparent that the schools who implemented an adult-guided play-based curriculum (experimental group) outperformed schools who did not implement this particular curriculum (control group). Although regional differences were noted, an adult-guided play-based curriculum made a statistically significant difference in the rural, township and higher SES urban regions where the research was conducted.

An extensive literature review was undertaken in chapter 3, where previous studies were examined to determine the young child's understanding of mathematics concepts. The argument for play was expounded, as well as the importance of manipulating concrete apparatus, the use of movement and the learning set approach in teaching mathematics. The importance of beginning at a young age was emphasised by exploring literature that deals with the young brain, the process of

scaffolding and the notion of sensitive periods. Ten particular areas of intervention were examined in an attempt to gain insight into the preschooler's understanding of mathematics concepts as a whole.
Based on the literature review, qualitative research and empirical aspects of this study – the conclusion is that a play-based, comprehensive and early approach is ideal, both pedagogically and developmentally, for teaching Grade R mathematics

The benefits of a workshop-type training approach for pre-schoolers in South Africa was assessed by means of an eight–month-long play-based intervention programme, during which teachers were trained and monitored in their programme delivery. According to statistical results and interview data, attendance of workshop training provided teachers with practical skills and tools to use in the teaching of maths, as well as a better understanding of the impact and power of a playful approach to teaching.

Interview data further demonstrated that teachers implementing play-based methods in mathematics instruction expressed higher perceived levels of success in their pupils. Quantitatively, the progress shown in mathematical skill acquisition was substantially greater among pupils taught through an adult-guided play based programme than pupils who did not receive such an intervention. Teachers were discovered to have far more positive attitudes towards mathematics instruction and higher confidence levels when they were teaching through play, rather than opting for alternative teaching methods.

Based on interview findings and the expressed feelings of confidence and contentment, training teachers in a play-based curriculum through workshop attendance proves quite inspirational for teachers. Regardless of regional disparities, the play-based approach to early mathematics teaching is flexible and practical in meeting the needs of young children in different communities.

Statistical analysis revealed that the pre-mathematics areas most positively impacted by adult-guided play-based intervention programme were number sense, addition and subtraction (word problem format), one-to-one correspondence (including counting), directionality and spatial awareness.

In the mixed melting pot of South African pre-school teachers, there are those who face extreme challenges like professional under-qualification, limited resources (including running water and electricity) and poor infrastructure. We also find highly qualified teachers facing challenges like excessive formality and curriculum pressure. Within the extremes of these opposite challenges, an adult-guided play-based mathematical curriculum has proven to be flexible, successful and robust in bearing fruit and providing a mathematical head start for those beginning Grade 1.

6.2.1 Reliability of the instrument

As is seen in graph 5.5.3, based on the relatively large sample sizes selected from control and experimental groups, subjects displayed consistent scores relative to each other. Higher results within the experimental group were found in each question posed by the test instrument. Results of the control group remained consistently lower than those of the experimental group.

The reliability of the test instrument was also firmly established through a Cohen's alpha coefficient.

It can be deduced that not only does the intervention have a positive impact on overall mathematics performance of the Grade R pupil, it also positively impacts each particular area (subset) of mathematical competence tested by the instrument.

6.2.2 Effects of the intervention programme

In graph 5.5.3 the significant difference between the scores of the experimental and control groups in mathematical competence is clearly demonstrated. Plot 5.6.1 also highlights the statistically significant differences between the means of the experimental and control groups.

An ANOVA-test was conducted to determine the level of statistical significance of the difference between the control group and experimental group's mean score. Significance was established at a $p<0.01$ (0.1 % level). This suggests that the study is highly significant, and that results will be evident in 99% of all cases. The first null hypothesis is rejected at the 0.1% level of significance, allowing us to accept the hypothesis that there is indeed a significant difference in the averages (means) of the test scores of preprimary school children when tested on their understanding of foundational mathematics concepts at the time of entry into Grade 1 between children who were taught through an adult-guided play-based mathematics curriculum and children who have had no formal mathematics instruction or only workbook-type instruction in Grade R.

Plot 5.6.1 further illustrates the differences between the mean scores of the groups selected from different geographical areas. Even though a statistically significant difference was established between the performance of control and experimental group subjects globally, the independent performance of rural and township subjects remains concerning locally. The significance of the different performances of urban preprimary school children when compared to rural and township children was established through an ANOVA-test at $p<0.01$ (0.1% significance level). We therefore accept the second hypothesis that there is a significant difference between the averages (means) of the test scores of South African preprimary school children in respect of their specific geographical areas when tested on their understanding of foundational mathematics concepts at the time of entry into Grade 1.

The noted differences between urban groups and rural/township groups could be attributed to factors like differences in SES, household stability factors, language differences between educators and pupils, availability of teaching resources and level of teacher qualifications. Test subjects were also generally younger (by a few months, but still falling within the defined criteria of a Grade R pupil) in the township and rural areas than those in the urban areas.

In spite of the statistically significant difference of overall scores between the urban and rural/township regions, it was further established that within each of these regions the difference between the scores of pupils experiencing the intervention and those who did not, remained statistically significant.

ANOVA-tests were conducted to determine the level of statistical significance of the difference between the control group and experimental groups' mean scores within each geographical area. Significance was established at a $p<0.01$ (0.1 % level). This suggests that the results are highly significant in each region specifically. The third, fourth and fifth null hypotheses are rejected at the 0.1% level of significance, allowing us to accept our alternative third, fourth and fifth hypotheses that when tested on their understanding of foundational mathematics concepts at the time of entry into Grade 1, there is indeed a significant difference in the averages (means) of the test scores of preprimary school children between children who were taught through an adult-guided play-based mathematics curriculum and children who have had no formal mathematics instruction or only workbook-type instruction in Grade R, in all three geographical regions (urban, rural and township).

In graph 5.7.3. it was established that among the teachers participating in the research study, professional qualifications did not necessarily provide sufficient practical training and skills for mathematics instruction in Grade R. Workshop training through the intervention programme produced the most convincing results in terms of teacher preparation for mathematics instruction.

Further findings from the data include that the overall daily time spent in implementing an adult-guided play-based curriculum was slightly longer than the average time spent in teaching using formal instructional methods, and much more time intensive than the free-flow curriculum (see graph 5.7.4). In general the daily preparation time, however, was less for adult-guided play than other methods, as preparation was mostly done once a term (see graph 5.7.5). Although experimental group teachers generally had a more negative opinion concerning the national performance of Grade R pupils in mathematics when compared to control group teachers (see graph 5.7.6), their personal optimism towards teaching mathematics was exceptionally higher than control group teachers (see graph 5.7.7). In addition to this, the experimental group of teachers perceived a more positive emotional response among their pupils towards the subject of mathematics than their control group counterparts, who mostly believed pupil enthusiasm to be linked to individual activities and not the topic as a whole (see graph 5.7.8). Experimental group teachers had exceptionally high expectations of their pupils' performance in Grade 1 for 2015 (see graph 5.7.9) and showed high satisfaction levels regarding their teaching methods, compared to the mixed expectation levels and mixed satisfaction levels of control group teachers (graph 5.7.17). Within both the experimental and control groups, most teachers acknowledged their belief that an adult-guided play-based syllabus would be the most effective method for teaching mathematics to young children, both in Grade R and in Grade 1, although a smaller portion believed that the syllabus would be more effective when combined with worksheets (see graph 5.7.11 and graph 5.7.14). Among experimental group teachers, concerns in teaching mathematics were more centred on external factors like observable trends in pupil performance over the years. Only one experimental group teacher expressed slight personal insecurity in teaching mathematics. Control group teachers described a larger variety of concerns, including an inherent fear of mathematics, and personal inexperience (see graph 5.7.12).

In the study, interviewed teachers identified several barriers to the effective national execution of a successful mathematics programme in Grade R. Listed from most mentioned to least these barriers included poor teacher training, an excessively formal syllabus, insufficient resources, poor formal qualifications, lack of awareness of the importance of early mathematics intervention tied with a too pressurised syllabus (see graph 5.7.13). Personally, barriers to effective mathematics teaching were quite varied and were listed (from most mentioned to least mentioned) as inexperience and under-qualification, tied with poor pupil support from home, the poor physical design of the classroom tied with insufficient resources and tied with mixed age-group teaching. This was followed by language barriers, tied with insufficient teaching time, low salary and professional pressure to perform (see graph 5.7.16). No experimental group teacher expressed a concern at her personal lack of teaching resources (see graph 5.7.10).

The pupil test administered in the study indicated that syllabus areas experiencing the greatest positive impact due to the intervention programme were number sense, addition and subtraction (word problem format), one-to-one correspondence (including counting), directionality and spatial awareness (see graph 5.5.3).

6.3 Conclusions

A highly significant result was obtained when comparing the mathematical performance of young learners exposed to an adult-guided play-based curriculum compared to learners who had no such exposure. This outcome was established at a 99% statistical level of confidence in three geographical regions within South Africa (rural, urban and township).
Effective intervention through a structured play-based curriculum will allow pupils entering Grade 1 to have a more solid foundation of pre-mathematical concepts on which to further build their mathematical understanding. It is believed that this intervention will increase the likelihood of mathematical success in later grades (Duncan *et al*., 2007:1428; De Sanchez, 2010:132).

Little is known about the national level of qualifications of preprimary school teachers. For many unqualified or underqualified teachers, professional qualifications are simply unobtainable due to financial constraints, poor personal academic capabilities and the inaccessibility of further training institutions. Local workshop training presented in a practical and active way is a viable solution to this multifaceted problem. Improved practical knowledge can empower teachers to better equip preprimary school children in areas like pre-school mathematics, which will have a ripple effect on the overall standard of education in the country.

6.4 Recommendations

6.4.1 Intervention programme

Training preprimary school teachers in pedagogically sound (play-based) educational programmes should be a high priority in South Africa. Programmes like the adult-guided play-based mathematics programme equips teachers practically for mathematics instruction for the young child.

Curriculums that are structured and playful are enjoyable for both teachers and pupils. Training workshops for these curriculums need to be very practical with real-life examples and hands-on experience. Post-workshop training follow-up is also recommended to ensure that objectives are being met and that practitioners are successfully implementing principles taught.

6.4.2 Resources

It is reported that South Africa spent 21% of the national budget on education in 2013 (Anon, 2014b). In this study it was noted that due to private ownership, many teachers lacked sufficient resources for play-based mathematics instruction. Those who had resources, but had not undergone intervention training, did not know how to use the resources they had effectively. Until such time as Grade R is officially recognised as the first year of schooling in legislation, and thereby fully incorporated into public institutions of learning, effective government resource management for Grade R would require subsidising lower SES private day-care centres and crèche's, to equip them with the resources necessary for executing a play based curriculum. Provision of resources would have to be considered in conjunction with practical guidance and training on how to use these resources.

6.4.3 Reassessing existing curriculums

Many existing preprimary school curriculums in South Africa are worksheet-based or solely free-flow based. This study, and others (Grossman, 1997; De Sanchez, 2010), clearly argue against the dominant use of worksheets as a foundation for successful instruction in Grade R. The official CAPS document for Grade R states "in order to reinforce learning, written work (workbook, worksheet examples, work cards etc.) should form part of the group session where possible. Learners should have writing materials (class work books, etc.) available for problem-solving activities" (DoE, 2011:12). The workbook and graded worksheet idea is further promoted in the CAPS document as one of the first alternatives a preprimary school teacher should use when selecting an independent mathematical learning activity (DoE, 2011:13).

Through the findings of this study it is argued that preprimary school teaching is more enjoyable and successful without the dominant use of worksheets. Both South African curriculum developers (DoE) and practitioners need to re-asses their stance for abstract and developmentally inappropriate worksheet-based work in Grade R. Study findings should be made available to practitioners, principals and parents to eliminate the fear of “lack of physical evidence” (i.e.worksheets) of learning. According to De Witt (2011:51), learning is a potentiality given with childhood and children themselves will often take the initiative to learn. The responsibility of active participation in this learning process rests in our hands. The study highlights that predominantly worksheet-based curriculums require passive involvement on the part of the educator, while structured play-based curriculums require an intense active and involved role.

In addition to the above, this study demonstrates that exclusive free-flow play curriculums are not producing academically sound results either. Practitioners utilising this approach need to be motivated to incorporate adult-guided activities to enrich the learning experience of their young pupils.

6.5 Recommendations for further studies

“Just as the focus of mathematics has changed toward a balanced curriculum, recommended teaching strategies reflect new understandings of how students learn based on cognitive research on how children learn” (Tipps *et al.*, 2011:3).

The world of preprimary school mathematics is rapidly changing. It is a field ripe with opportunities for further investigation. Although studies have shown that early intervention in mathematics is of great benefit (refer to chapter 3), further studies into the types of teaching approaches and usefulness of certain teaching resources would be of noteworthy benefit to education in South Africa as a whole.

Specific recommendations for further studies include:

1. Further investigation into the output results of predominantly worksheet-based curriculums versus guided play-based curriculums in early childhood education.

2. Investigation into the impact of promoting adult-guided play-based curriculum development at a national level; FET-level (further education and training); and at a grassroots level (practitioner level).

3. Investigating alternative training methods for adult-guided play-based education in Grade R. e.g. active workshops or DVD workshops.

6.6 Limitations of the study

The study was limited to Grade R children who were taught in Sepedi, isiZulu and English. Although the study presented rich qualitative and quantitative findings with a large research sample over three geographical regions, findings should not be generalised to other contexts. Most schools involved in the study were private institutions. A large limitation to the study was the inability of the researcher to accurately determine the extent to which an adult-guided play-based curriculum was being successfully implemented in each classroom. Factors like practitioner cognitive ability, raw talent and language differences between teacher and pupils played an important role in the successful implementation of the recommended intervention teaching strategies.

Standardised quantitative testing and one-shot testing is not considered highly suitable for Grade R.

A further limitation was the fact that pre-testing was not considered viable (many children without any prior exposure to numbers would be completely unable to answer a pen-and-paper type test on entry into Grade R). It was assumed therefore that post-testing would account for the differences in research findings as extreme measures were taken to ensure that experimental and control groups were equally matched in location, school design, age and language capabilities.

6.7 Closing remarks

The preprimary school years are some of the most precious and undeniably important years of a child's life. Children need to be nurtured and trained in ways that are developmentally appropriate and truly respect the wonder of play. Teaching a child need not involve forfeiting this self-created world of fun and excitement. It is in harnessing this powerful and universal drive towards play that truly successful education may begin.

"It is paradoxical that many educators and parents still differentiate between a time for learning and a time for play without seeing the vital connection between them" – Leo F. Buscaglia (1924 – 1988) (Professor at the University of Southern California, motivational speaker and author)

REFERENCE LIST

Ainley, J. 1990. Playing games and learning mathematics. (*In* Steffe, L.P. & Wood, T., *eds*. Transforming children's mathematics education: International perspectives. New Jersey: Lawrence Erlbaum Associates. p. 84-91).

Almon, J. 2003. The vital role of play in early childhood education. (*In*: Olfman, S., *ed.* All work and no play: How educational reforms are harming our preschoolers. Westport: Praeger Publishers. 17-42).

Anon. 2012. Cautious Optimism Over Improved Matric Results. *Business Day*. 8 Aug. http://www.businessday.co.za/articles/Content.aspx?id=162065 Date of access 20 Jun. 2013.

Anon. 2013a. Active Learning. http://en.wikipedia.org/wiki/Active_learning Date of access: 24 Jun. 2013.

Anon. 2013b. Biology online: Learning set. http://www.biology-online.org/dictionary/Learning_set Date of access: 22 Jun. 2013.

Anon. 2013c. Counting. http://en.wikipedia.org/wiki/Counting Date of access: 24 Jun. 2013.

Anon. 2013d. Pre-math skills. http://en.wikipedia.org/wiki/Pre-math_skills Date of access: 14 Jan. 2013.

Anon. 2014a. Cronbach's alpha. http://en.wikipedia.org/wiki/Cronbach%27s_alpha Date of access: 6 Oct. 2014.

Anon. 2014b. Education in South Africa. en.wikipedia.org/wiki/Education_in_South_Africa Date of access: 8 Oct. 2014.

Anon. 2014c. Harold Harlow. Wikipedia, the free encyclopedia. http://en.wikipedia.org/wiki/Harry_Harlow Date of access: 3 Nov. 2014.

Anon. 2014d. Logical Positivism. http://en.wikipedia.org/wiki/Logical_positivism Date of access: 9 Aug. 2014.

Anon. 2014e. Motshekga announces 78.2 % matric pass rate. *Times Live*. 6 Jan. http://www.timeslive.co.za/local/2014/01/06/motshekga-announces-78.2-matric-pass-rate Date of access: 28 Jan. 2014.

Anon. 2014f. Peter Huttenlocher. http://en.wikipedia.org/wiki/Peter_Huttenlocher Date of access: 14 Jul. 2014.

Anon. 2014g. Validity. http://en.wikipedia.org/wiki/Validity_(statistics) Date of access: 9 Aug. 2014.

Antell, S.E. & Keating, D.P. 1983. Perception of Numerical Invariance in Neonates. *Child Development,* 54(3):695-701.

Arnas, Y.A. & Aslan, D. 2007. Three-to-six-year-old children's recognition of geometric shapes. *International Journal of Early Years Education,* 15(1):83-104.

Aubrey, C. 1993. An Investigation of the Mathematical Knowledge and Competencies which Young Children Bring into School. *British Educational Research Journal,* 19(1):27-41.

Auer-Srnka, K.J. & Koeszegi, S. 2007. From words to numbers: how to transform qualitative data into meaningful quantitative results. *Schmalenbach Business Review,*59: 29-57.

Ayiro, L.P. 2012. A functional approach to educational research methods and statistics. Qualitative, quantitative and mixed methods approaches. New York: Edwin Mellen Press.

Barnett, W.S. 2008. Preschool education and its lasting effects: Research and policy Implications. (*In* Boulder & Tempe. Education and the Public Interest Centre and Education Policy Research Unit. http://epicpolicy.org/publication/preschool-education Date of access: 26 Jun. 2013).

Basit, T.N. 2010. Conducting research in educational contexts. London: Continuum International Publishing Group.

Beard, V. 1962. Mathematics in kindergarten. *The Arithmetic Teacher,* 9(1):22-25.

Berk, L.E. 2013. Child Development. 9th ed. Boston: Pearson Education.

Bilbao-Osorio, B., Dutta, S. & Lavin, B., *eds.* 2013. The global information technology report 2013: Growth and jobs in a hyperconnected world. *World Economic Forum:*1-383 http://www3.weforum.org/docs/WEF_GITR_Report_2013.pdf Date of Access: 3 Jul. 2013.

Blair, C. & Razza, R.P. 2007. Relating effortful control, executive function, and false belief understanding to emerging math and literacy ability in kindergarten. *Child Development,* 78(2):647-663.

Bodovski, K. & Farkas, G. 2007. The roles of beginning knowledge, student engagement, and instruction. *The Elementary School Journal,* 108(2):115-130.

Bohlin, L., Durwin, C.C. & Reese-Weber, M. 2012. EdPsych modules. 2nd ed. New York: McGraw-Hill.

Bonwell, C.C. & Eison, J.A. 1991. Active Learning: Creating excitement in the classroom. ASHE-ERIC Higher Education Report No.1. Washington D.C: The George Washington University, School of Education and Human Development.

Booth, J. & Siegler, R.S. 2006. Developmental and individual differences in pure numerical estimation. *Developmental Psychology* 41(6):189-201.

Botha, M., Maree, J.G. & de Witt, M.W. 2005. Developing and piloting the planning for facilitating mathematical processes and strategies for preschool learners. *Early Childhood Development and Care*, 175(7-8):697-717.

Boulton-Lewis, G.M., Wilss, L.A. & Mutch, S.L. 1996. An analysis of young children's strategies and use of devices for length measurement. *The Journal of Mathematical Behaviour,* 15(3):329-347.

Brainerd, C.J. 1978. The stage question in cognitive-developmental theory. *The Behavioural and Brain Sciences,* 2:173-213.

Brendefur, J., Strother, S., Thiede, K., Lane, C. & Surges-Prokop, M.J. 2013. A professional development program to improve math skills among preschool children in head start. *Early Childhood Education Journal,* 41:187-195.

Brown, C.S. 2009. More than Just Number. *Teaching Children Mathematics*, 15(8):474-479.

Bruce, T. 2011. Learning through play. 2nd ed. London: Hodder Education Publishers

Bruner, J.S. 1964. The course of cognitive growth. *American psychologist,* 19(1):1-15.

Bryan, T. & Bryan, J. 1991. Positive mood and math performance. *Journal of Learning Disabilities,* 24(8):490-494.

Bull, R. & Scerif, G. 2001. executive functioning as a predictor of children's mathematics ability: Inhibition, switching and working memory. *Developmental Neuropsychology,* 19(3):273-293.

Bull, R., Espy, K.A. & Wiebe, S.A. 2008. Short-term memory, working memory, and executive functioning in preschoolers: Longitudinal predictors of mathematical achievement at age 7 years. *Developmental Neuropsychology,* 33(3):205-228.

Burchinal, M.R., Cryer, D., Clifford, R.M. & Howes, C. 2002. Caregiver training and classroom quality in child care centres. *Applied Developmental Science*, 6(1):2-11.

Buscaglia, L. 2014. Brainy Quotes. http://www.brainyquote.com/quotes/quotes/l/leobuscagl121939.html Date of access: 8 Oct. 2014.

Butterworth, B. 1999a. The mathematical brain. London: Macmillan.

Butterworth, B. 1999b. What counts, how every brain is hardwired for math. New York: The Free Press.

Campbell, G. & Prew, M. 2014. Behind the matric results: The story of maths and science. *Mail and Guardian*. 7 January. http://mg.co.za/article/2014-01-07-behind-the-matric-results-the-story-of-maths-and-science Date of access: 28 Jan. 2014.

Carpenter, T.P. & Lewis, R. 1976. The development of the concept of a standard unit of measure in young children. *Journal for Research in Mathematics Education*, 7(1):53-58.

Casey, B.J., Jones, R.M. & Hare, T.A. 2008. The adolescent brain. *Annals of the New York Academy of Sciences*, 1121(1):111-126.

Chard, D.J., Baker, S.K., Clarke, B., Jungjohann, K., Davis, K. & Smolkowski, K. 2008. preventing early mathematics difficulties: The feasibility of a rigorous kindergarten mathematics curriculum. *Learning Disability Quarterly*, 31(1):11-20.

Charlesworth, R. 1998. Developmentally appropriate practice is for everyone. *Childhood Education*, 74(5):274-282.

Charlesworth, R. 2012. Experiences in math for young children. 6th ed. Boston: Cengage Learning.

Charlesworth, R. & Lind, K. 2012. Math and science for young children. 7th ed. Boston: Cengage Learning.

Child Development Institute. 2011. Play is the work of the child: Maria Montessori. http://childdevelopmentinfo.com/child-development/play-work-of-children/ Date of access: 27 Jun. 2013.

Ciancio, D., Sadovsky, A., Malabonga, V., Trueblood, L. & Pasnak, R. 1999. Teaching classification and seriation to preschoolers. *Child Study Journal,* 29(3):193-205.

Clements, D.H. 1999. Teaching length measurement: Research challenges. *School Science and Mathematics,* 99(1):5-11.

Clements, D.H., Swaminathan, S., Hannibal, M.A.Z. & Sarama, J. 1999. Young children's concept of shape. *Journal for Research in Mathematics Education,* 30(2):192-212.

Clements, D.H. 1999. Teaching length measurement: Research challenges. *School Science and Mathematics,* 99(1):5-11.

Collins Concise Dictionary. 1999. Glasgow: Harper Collins Publishers.

Compton, A., Fielding, H. & Scott, M. 2007. Supporting numeracy. A guide for school support staff. London: Paul Chapman Publishing.

Copley, J.V. 2004. The early childhood collaborative: A professional development model to communicate and implement the standards. http://gse.buffalo.edu/org/conference/ConfWritings2/Revised_Copley_paper.pdf Date of access: 14 Mar. 2014.

Copple, C. & Bredekamp, S. 2006. Basics of developmentally appropriate practice. an introduction for teachers of children 3 to 6. NAEYC, Washington D.C

Cross, C.T., Woods, T.A. & Schweingruber, H., *eds.* 2009. National Research Council Committee on Early Childhood Mathematics: Mathematics learning in early childhood. Washington, D.C.: National Academies Press.

Crowley, M.L. 1987. The van Hiele model of the development of geometric thought. (*In* Lindquist, M. *ed*. 1987. Learning and Teaching Geometry, K-12. Yearbook of the national council of teachers of mathematics . p 1-16).

De Neys, W., Lubin, A. & Houde, O. 2014. The smart nonconserver: Pre-schoolers detect their number conservation errors. *Child development research*, 2014:1-7.

De Sanchez, G.A. 2010. The use of worksheets in early childhood mathematics education. (*In* Doiron, R. & M. Gabriel *ed.* Research in early child development in Prince Edward Island: A research monograph. p.127–139). Charlottetown, PE: Centre for Education Research, University of Prince Edward Island.

De Witt, M.W. 2011. The Young Child in Context: A thematic approach. Perspectives from educational psychology and sociopedagogics. Pretoria: Van Schaik.

Department of Basic Education, *see* South Africa.

Diamond, A. 2000. Close interrelation of motor development and cognitive development and of the cerebellum and prefrontal cortex. *Child Development,* 7(1):44-56.

Diamond, A. & Lee, K. 2011. Interventions shown to aid executive function development in children 4-12 years old. *Science,* 333(6045):959-964.

Dowker, A. 2005. Individual differences in arithmetic. Implications for psychology, neuroscience and education. New York: Psychology Press.

Duncan, G.J., Dowsett, C.J., Claessens, A., Magnuson, K., Huston, A.C., Klebanov, P., Pagani, L.S., Feinstein, L., Engel, M., Brooks-Gunn, J., Sexton, H., Duckworth, K. & Japel, C. 2007. School readiness and later achievement. *Developmental Psychology,* 43(6):1428-1446.

Duncan, J. & Lockwood, M. 2008. Learning through play. A work-based approach for the early years professional. New York: Continuum International Publishing Group.

Early, N.M. Maxwell, K.L., Burchinal, M., Alva, S. Bender, R.H., Bryant, D. & Zill, N. 2007. Teacher's education, classroom quality, and young children's academic skills: Results from seven studies of preschool programs. *Child development,* 78(2):558-580.

Edie, D. & Schmid, D. 2007. Brain development and early learning: research on brain development. Quality matters. *Wisconsin Council on Children and Families,* 1:1-4.

Ernest, P. 1986. Games. A rationale for their use in the teaching of mathematics in school. *Mathematics in School,* 15(1):2-5.

Erwin, H. Fedewa, A. Beighle, A. & Ahn, S. 2012a. A quantitative review of physical activity, health, and learning outcomes associated with classroom-based physical activity interventions. *Journal of Applied School Psychology,* 28(1):14-36.

Erwin, H., Fedewa, A. & Ahn, S. 2012b. Student academic performance outcomes of a classroom physical activity intervention: A pilot study. *International Electronic Journal of Elementary Education,* 4(3):473-487.

Evans, S. 2013. SA ranks its maths and science second last in the world. *Mail and Guardian*. 17 April. http://mg.co.za/article/2013-04-17-sas-maths-science-education-ranked-second-last-in-world. Date of access: 10 Oct. 2014

Fedewa, A.L. & Ahn, S. 2011. The effects of physical activity and physical fitness on children's achievement and cognitive outcomes: A meta-analysis. *Research Quarterly for Exercise and Sport,* 82(3):521-535

Feigenson, L., Dehaene, S. & Spelke, E. 2004. Core systems of number. *Trends in Cognitive Sciences,* 8(7):307-314.

Fisher, K.R., Hirsch-Pasek, K., Newcombe, N. & Golinkoff, R.M. 2013. taking shape: supporting preschoolers' acquisition of geometric knowledge through guided play. *Child development* 84(6):1872-1878.

Frank, A.R. 1989. Counting Skills – A Foundation for Early Mathematics. *The Arithmetic Teacher*. 37(1):14-17.

Freeman, N.K. & Brown, M.C. 2004. The moral and ethical dimensions of controlling play. (*In* Clements, R.L. & Fiorentino, L. *eds*. 2004. The child's right to play: A Global approach. Westport: Praeger Publishers. P 9-15).

Frobisher, L., Frobisher, A., Orton, A., & Orton, J. 2007. Learning to teach shape and space. a handbook for students and teachers in the primary school. Cheltenham: Nelson Thornes.

Fuson, K.C. 1988. Children's counting and concepts of number. New York: Springer-Verlag.

Gallahue, D.L. & Donnelly, F.C. 2003. Developmental physical education for all children. Fourth Edition. Champaign: Human Kinetics Publishers.

Garet, M.S., Porter, A.C., Desimone, L., Birman, B.F., & Yoon, K.S. 2001. What makes professional development effective? Results from a national sample of teachers. *American Educational Research Journal*, 38(4):915-945.

Gaser, C. & Schlaug, G. 2003. Brain structures differ between musicians and non-musicians. *The Journal of Neuroscience,* 23(27):9240-9245.

Geist, E. 2010. The anti-anxiety curriculum: Combating math anxiety in the classroom. *Journal of Instructional Psychology*, 37(1):24.

Gelman, R. & Baillargeon, R. 1983. A review of some Piagetian concepts. *Handbook of child psychology*, 3:167-230.

Gelman, R. & Gallistel, C.R. 1978. The child's understanding of number. Cambridge: Harvard University Press.

Gifford, S. 2005. Teaching mathematics 3-5. Developing learning in the foundation stage. Berkshire: Open University Press.

Ginsburg, H.P., Lee, J.S. & Boyd, J.S. 2008. Mathematics education for young children: What it is and how to promote it. *Social Policy Report*, 22(1):3-22.

Gogtay, N., Giedd, J.N., Lusk, L., Hayashi, K.M., Greenstein, D., Vaituzis, A.C. &Thompson, P.M. 2004. Dynamic mapping of human cortical development during childhood through early adulthood. (*In* Proceedings of the National Academy of Sciences of the United States of America, 101(21):8174-8179).

Gold, R. 1986. Performance on Donaldson and McGarrigle's "Cars and Garages": Task as evidence about the reasons for failure on Piaget's number-conservation task. *The Journal of Genetic Psychology: Research and Theory on Human Development*, 147(2):151-165.

Gopnik, A. 1996. The Post-Piaget Era. *Psychological Science,* 7(4):221-225.

Gordon, A.M. & Browne, K.W. 2011. Beginnings and beyond, foundations in early childhood education. 8th eds. Belmont: Wadsworth Cengage Learning.

Gray, P. 2011. The decline of play and the rise of psychopathology in children and adolescents. *American Journal of Play,* 3(4):443-463.

Greenes, C. 1999. Ready to learn: Developing young children's mathematical powers. (*In* Copely, J.V. *ed*. 1999. Mathematics in the Early Years. p 39-47. Washington D.C.: National Association for the Education of Young Children).

Griffin, S. 2004. Teaching number sense. *Educational Leadership,* 61(5):39-43.

Grossman, B.D. 2004. Play and cognitive development: A Piagetian perspective. (*In* Clements, R.L. & Fiorentino, L. *eds*. 2004. The child's right to play: A global approach. Westport: Praeger Publishers. p 89-94).

Grossman, S. 1997. The Worksheet Dilemma: Benefits of Play-Based Curricula. http://www.kidnkaboodle.net/noworksheet.html Date of access: 9 Jul. 2013.

Guarino, C.M., Hamilton, L.S. & Lockwood, J.R. 2006. Teacher qualifications: Instructional practices and reading and mathematics gains of kindergartners. (*In* National Center for Education Statistics. 2006. Research and Development Report. http://webcache.googleusercontent.com/search?q=cache:http://nces.ed.gov/pubs2006/2006031.pdf Date of access: 18 Jul. 2014).

Halford, G.S. 1989. Reflections on 25 years of Piagetian cognitive developmental psychology, 1963-1988. *Human Development,* 32(6):325-257.

Hall, K. & Meintjies, H. 2013. Demography - Children in South Africa. Children's Institute. University of Cape Town. http://www.childrencount.ci.org.za/indicator.php?id=1&indicator=1 Date of access: 14 Mar. 2014.

Hamel, B.R. 1974. *Children from 5 to 7: Some aspects of the number concept.* Rotterdam: Rotterdam University Press.

Hancock, R.E. 1981. A comparison of two forms of play methods which foster cognitive development in kindergarten children. St Louis: Saint Louis University. (Dissertation – PhD).

Harlene, G. 1994. Developmentally appropriate practice: Myths and facts. *Principal,* 73(5):20-22.

Harlow, H. F. 1949. The Formation of Learning Sets. *Psychological Review,* 56(1):51-65.

Hendricks, C., Trueblood, L. & Pasnak, R. 2006. Effects of teaching patterning to 1st-graders. *Journal of Research in Childhood Education,* 21(1):79-89.

Hernandez, G. 2013. Development of a game-based mathematics curriculum for preschool. http://digitalcommons.fiu.edu/cgi/viewcontent.cgi?article=1312&context=sferc&sei-redir=1&referer=http%3A%2F%2Fscholar.google.co.za%2Fscholar%3Fq%3Drelated%3AMj5RhWy3BrkJ%3Ascholar.google.com%2F%26hl%3Den%26as_sdt%3D0%2C5#search=%22related%3AMj5RhWy3BrkJ%3Ascholar.google.com%2F%22 Date of access: 12 Jul. 2014.

Hildreth, D.J. 1983. The use of strategies in estimating measurement. *The Arithmetic Teacher, (30)5*:50-54.

Holmes, J. & Adams, J.W. 2006. Working memory and children's mathematical skills: Implications for mathematical development and mathematics curricula. *Educational Psychology*, 26(3):339-366.

Holmes, J. & Gathercole, S.E. 2014. Taking working memory training from the laboratory into schools. *Educational Psychology*, 34(4):440-450.

Howard, J. 2007. Curriculum development. http://ocw.tudelft.nl/fileadmin/ocw/courses/DevelopmentofTeachingandActiveLearning/Article_Judith_Howard_on_Curriculum_Design.pdf. Date of access: 11 Nov. 2011.

Howard, J., Bellin, W. & Rees, V. 2002. Eliciting children's perceptions of play and exploiting playfulness to maximize learning in the early years classroom. Paper presented at the British Educational Research Association (BERA) Annual Conference, September 2002. http://www.leeds.ac.uk/educol/documents/00002574.htm Date of access: 12 July 2014.

Human Sciences Research Council. 2011. Highlights from TIMSS 2011: The South African perspective. .http://sds.ukzn.ac.za/files/Reddy_TIMMS_seminar%20presentation.pdf Date of access: 23 Jun. 2013.

Irwin, K.C., Vistro-Yu, C.P. & Ell, F.R. 2004. Understanding linear measurement: A comparison of Filipino and New Zealand Children. *Mathematics Educational Research Journal, 16(2)*:3-24.

Jansen, J. 2012. *Wiskunde op skool kan beter.* http://www.ufs.ac.za/dl/Userfiles/Documents/00001/1182_eng.pdf Date of access: 10 Jun. 2013.

John, V. 2012. Improved annual national assessment results impossible, say academics. *Mail and Guardian*. 7 Dec. http://mg.co.za/article/2012-12-07-improved-annual-national-assessment-results-impossible-say-academics Date of access: 29 Jan. 2014.

Jordan, N.C. Kaplan, D. Locuniak, M & Ramineni, C. 2009. Early math matters: Kindergarten number competence and later mathematics outcomes. *Developmental Psychology*, 45(3):850-867.

Jordan, N.C. Locuniak, M.N. Ramineni, C. & Kaplan, D. 2007. Predicting first-grade math achievement from developmental number sense trajectories. *Learning Disabilities Research and Practice*, 22(1):37-47.

Keeley, T.J.H. & Fox, K.R. 2009. The impact of physical activity and fitness on academic achievement and cognitive performance in children. *International Review of Sport and Exercise Psychology*, 2(2):198-214.

Kidd, J.K., Curby, T.W., Boyer, C.E., Gadzichowski, K.M., Gallington, D.A., Machado, J.A. & Pasnak, R. 2012. Benefits of an intervention focused on oddity and seriation. *Early Education and Development*, 23(6):900-918.

Kidd, J.K., Pasnak, R., Gadzichowski, M., Ferral-Like, M. & Gallington, D. 2008. Enhancing early numeracy by promoting the abstract thought involved in the oddity principle, seriation, and conservation. *Journal of Advanced Academics*, 19(2):164-200.

Klibanoff, R.S., Levine, S.C., Huttenlocher, J. & Vasilyeva, M. 2006. Preschool children's mathematical knowledge: The effect of teacher "math talk". *Developmental Psychology*, 42(1):59-69.

Knudsen, E.I. 2004. Sensitive periods in the development of the brain and behaviour. *Journal of Cognitive Neuroscience*:1412-1425.

Koechlin, E. 1997. Numerical transformations in five-month-old human infants. *Mathematical Cognition, 3(2)*:89-104.

Kroesbergen, E.H., Van't Noordende, J.E. & Kolkman, M.E. 2012. Number sense in low-performing kindergarten children: Effects of a working memory and an early math training. (*In* Breznitz, Z. Rubinsten, O. Molfese, V.J. Molfese, D.L. *eds*. 2012 Reading, writing, mathematics and the developing brain: listening to many voices. New York: Springer. p 295-313).

Kroesbergen, E.H., Van‘t Noordende, J.E. & Kolkman, M.E. 2014. Training working memory in kindergarten children: Effects on working memory and early numeracy. *Child Neuropsychology: A Journal on Normal and Abnormal Development in Childhood and Adolescence, 20(1):*23-37.

Kruger, C. 2012a. Maklikste wiskunde pootjie SA se onnies. http://www.rapport.co.za/Suid-Afrika/Nuus/Maklikste-wiskunde-pootjie-SA-se-onnies-20120714. Date of access: 20 Jun. 2013.

Kruger, C. 2012b. Wiskunde bly Grieks vir matrieks. http://m.news24.com/nuus24/Suid-Afrika/Nuus/Wiskunde-bly-Grieks-vir-matrieks-20120108 Date of access: 20 Jun. 2013.

Kruger, C. 2012c. Wiskunde in SA ‘word moeiliker’. http://www.rapport.co.za/Suid-Afrika/Nuus/Wiskunde-in-SA-word-moeiliker-20120721 Date of access: 20 Jun. 2013.

La Paro, K., Karen, M. & Pianta, R. 2000. Predicting children’s competence in the early school years: A meta-analytic review. *Review of Educational Research,* 70(4):443-484.

Lee, J.S. & Ginsburg, H.P. 2009. Early childhood teacher’s misconceptions about mathematics education for young children in the US. *Australasian Journal of Early Childhood,* 34(4):37-45.

Lee, K., Ng, E.L. & Ng, S.W. 2009. The contributions of working memory and executive functioning to problem representation and solution generation in algebraic word problems. *Journal of Educational Psychology, 101(2)*:373-387.

Lee, K., Ng, S.F., Bull, R., Pe, M.L. & Ho, R.H.M. 2011. Are patterns important? An investigation of the relationships between proficiencies in patterns, computation, executive functioning and algebraic word problems. *Journal of Educational Psychology,* 103(2):269 - 281.

Lenroot, R.K. & Giedd, J.N. 2006. Brain development in children and adolescents: Insights from anatomical magnetic resonance imaging. *Neuroscience and Biobehavioral Reviews,* 30:718-729.

Leu, E. 2004. The patterns and purposes of school-based and cluster teacher professional development programs. *Issues Brief,* 1:1-10.

Lewis, K. 2011. The importance of free-flow play. *Early Learning HQ.* http://www.earlylearninghq.org.uk/earlylearninghq-blog/the-importance-of-free-flow-play/ Date of access: 22 Jun. 2013.

Lillard, P.P. & Jessen, L.L. 2003. Montessori from the start. New York: Schocken Books.

Locuniak, M.N. & Jordan, N.C. 2008. Using kindergarten number sense to predict calculation fluency in second grade. *Journal of Learning Disabilities,* 41(5):451-459.

Lodico, M.G., Spaulding, D.T. & Voegtle, K.H. 2010. Methods in *Educational Research*. From theory to practice. 2nd ed. San Francisco: Jossey-Bass.

Louw, P. 2013. Grade R is likely to be made compulsory. *Times Live*. 22 Aug. http://www.timeslive.co.za/thetimes/2013/08/22/grade-r-is-likely-to-be-made-compulsory Date of access: 28 Jan. 2014.

Makman, L. 2004. The right to a work-free and playful childhood: A historical perspective. (*In* Clements, R.L. & Fiorentino, L. *eds*. 2004. The child's right to play: A global approach. Westport: Praeger Publishers. p 3-8).

Maloney, E.A. & Beilock, S.L. 2012. Math anxiety: Who has it, why it develops, and how to guard against it. *Trends in cognitive sciences*, 16(8):404-406.

Manning, J.P. 2005. Rediscovering Froebel: A call to re-examine his life & gifts. *Early Childhood Education Journal*, 32(6):371-376.

Maree, K. 1994. Kick start for maths. Pretoria: Van Schaik.

Martlew, J., Stephen, C. & Ellis, J. 2011. Play in the primary school classroom? The experience of teachers supporting children's learning through a new pedagogy. *Early Years: An International Research Journal, (31)1*:71-83.

Mazzocco, M.M. & Thompson, R.E. 2005. Kindergarten predictors of math learning disability. *Learning Disabilities Research and Practice*, 20(3):142-155.

McAfee, O. & Leong, D.J. 2011. Assessing and guiding young children's development and learning. 5th ed. Boston: Pearson.

McCrink, K. & Wynn, K. 2004. Large-number addition and subtraction by 9-month-old-infants. *Psychological Science*, 15(11):776-781.

McEvoy, J. & O'Moore, A.M. 1991. Number conservation: A fair assessment of numerical understanding? *The Irish Journal of Psychology*, 12(3):325-337.

McEwan, E.K. & McEwan, P.J. 2003. Making sense of research. What's good, what's not and how to tell the difference. California: Corwin Press.

McGarrigle, J. & Donaldson, M. 1975. Conservation accidents. *Cognition,* 3(4):341-350.

McLeod, S. 2008. Bruner. http://www.simplypsychology.org/bruner.html Date of access: 9 Jul. 2014.

McLeod, S. 2010. Concrete operational stage. *SimplyPsychology.* http://www.simplypsychology.org/concrete-operational.html Date of access: 13 Jul. 2013.

McLeod, S. 2012. Bruner. http://www.simplypsychology.org/bruner.html. Date of access: 11 Nov. 2014.

McMillan, J.H. & Schumacher, S. 2010. Research in education. Evidence-based inquiry. 7th ed. New Jersey: Pearson Education.

McMullen, M.B. & Alat, K. 2002. Education matters in the nurturing of the beliefs of preschool caregivers and teachers. *Early Childhood Research and Practice,* 4(2):2.

McNeil, N. & Jarvin, L. 2007. When theories don't add up: Disentangling the manipulatives debate. *Theory Into Practice,* 46(4):309-316.

Mehler, J. & Bever, T.G. 1967. Cognitive capacity of very young children. *Science, New Series,* 158(3797):141-142.

Mercer, N. & Sams, C. 2006. Teaching children how to use language to solve maths problems. *Language and education,* 20(6):507-52.

8

Milteer, R.M., Ginsburg, K.R., Mulligan, D.A., Ameenuddin, N., Brown, A., Christakis, D.A. & Cross, A. 2012. the importance of play in promoting healthy child development and maintaining strong parent-child bond: Focus on children in poverty. *Pediatrics,* 129(1):e204-e213.

Mix, K.S., Huttenlocher, J. & Levine, S.C. 2002. Quantitative development in infancy and early childhood. New York: Oxford University Press.

Moeller, K., Fischer, U., Cress, U., & Nuerk, H. 2012. Diagnostics and intervention in developmental dyscalculia: Current issues and novel perspectives. (*In* Breznitz, Z., Rubinsten, O., Molfese, V.J. & Molfese, D.L. *eds*. 2012. Reading, writing, mathematics and the developing brain: listening to many voices. New York: Springer: 233 – 275).

Montessori, M. 2012. The absorbent mind. *Kindle ed*. Amazon Digital Services, Inc.

Montessori, M.M. 1961. Maria Montessori's contribution to the cultivation of the mathematical mind. *International Review of Education,* 7(2):134-141.

Moore, C. & Frye, D. 1986. The effect of experimenter's intention on the child's understanding of conservation. *Cognition,* 22(3):283-298.

Morgan, P.L., Farkas, G. & Wu, Q. 2009. Five-year growth trajectories of kindergarten children with learning difficulties in mathematics. *Journal of Learning disabilities,* 42(4):306-321.

Moseley, B. 2005. Pre-service early childhood educators' perceptions of math-mediated language. *Early Education and Development,* 16(3):385-398.

Mouton, J. 2001. How to succeed in your master's and doctoral studies. A South African guide and resource book. Pretoria: Van Schaik Publishers.

Moyer, P.S. 2001. Are we having fun yet? How teachers use manipulatives to teach mathematics. *Educational Studies in Mathematics,* 47(2):175-197.

Moyles, J.R. 1994. Introduction. (*In* Moyles, J.R. *ed*. 1994. The excellence of play. Buckingham: Open University Press. p 2-11).

Muijs, D. 2004. Doing quantitative research in education with SPSS. London: Sage publications.

Mulligan, J., Papic, M., Prescott, A. & Mitchelmore, M. 2006. Improving early numeracy through a pattern and structure mathematics awareness program (PASMAP). (*In* Building connections: Theory, research and practice. Proceedings of the 28th annual conference of the Mathematics Education Research Group of Australia. p 376-383).

Neilson, I., Dockrell, J. & McKechnie, J. 1983. Justifying conservation: A reply to McGarrigle and Donalson. *Cognition*, 15(1-3):277-291.

Nelson, C.A., Thomas, K.M. & de Haan, M. 2008. Neural bases of cognitive development. (*In* Damon, W. & Lerner, R.M. *eds*. 2008. Child and adolescent development. An advanced course. New Jersey: John Wiley and Sons.

O'Donnell, A. 2012. Constructivism. (*In* Harris, K.R., Graham, S. & Urdan, T. *eds*. 2012. APA Educational psychology handbook: Vol. 1. Theories, constructs, and critical issues. Washington: American Psychological Association.

Omotoso, H. & Shapiro, B. 1976. Conservation, seriation, classification and mathematics achievement in Nigerian children. *Psychological Reports*, 38:1335-1339.

Osborn, D.K. 1991. Early childhood education in historical perspective. Athens: Daye Press.

Packer, M.J. & Goicoechea, J. 2000. Sociocultural and constructivist theories of learning: ontology, not just epistemology. *Educational Psychologist*, 35(4):227-241.

Papalia, D.E. & Feldman, R.D. 2011. A child's world. Infancy through adolescence. New York: McGraw-Hill.

Papic, M. & Mulligan, J.T. 2007. The growth of early mathematical patterning: An intervention study. *Mathematics: Essential research, essential practice:*591-600.

Papic, M.M. 2007. Promoting Repeating patterns with young children – more than just alternating colours! *Australian Primary Mathematics Classroom*, 12(3):8-13.

Parten, M.B. 1932. Social participation among preschool children. *Journal of abnormal and social psychology*, 27:243-269.

Pasnak, R. 1987. Acceleration of cognitive development of kindergartners. *Psychology in the Schools,* 24(4):358-363.

Pasnak, R., Holt, R., Campbell, J.W. & McCutcheon, L. 1991. Cognitive and achievement gains for kindergartners instructed in piagetian operations. *The Journal of Educational Research,* 85(1):5-13.

Pasnak, R., Madden, S.E., Malabonga, V.A., Holt, R. & Martin, J.W. 1996. Persistence of gains from instruction in classification, seriation and conservation. *The Journal of Educational Research,* 90(2):87-92.

Passolunghi, M.C., Mammarella, I.C. & Gianmarco, A. 2008. cognitive abilities as precursors of the early acquisition of mathematical skills during first through second grades. *Developmental Neuropsychology,* 33(3):229-250.

Patterson, C.M. 2004. Play-based curriculum: A strong foundation for future learning. (*In* Clements, R.L. & Fiorentino, L. *eds*. 2004. The child's right to play: A global approach. Westport: Praeger Publishers. p 111-117).

Piaget, J. 1950. The psychology of intelligence. New York: Routledge and Kegan Paul Limited.

Piaget, J. 1962. Play, dreams and imitation in childhood. New York: Norton.

Piaget, J. 2013. Child's conception of number. Piaget: selected works. Vol 2. New York: Routledge.

Pring, R. 2004. Philosophy of educational research. 2nd eds. London: Continuum.

Rabel, S. & Wooldridge, I. 2013. Exploratory talk in mathematics: what are the benefits? *Education 3 – 13: International Journal of Primary, Elementary and Early Years Education* 41(1):15-22.

Ramani, G.B., Siegler, R.S. & Hitti, A. 2012. Taking it to the classroom: number board games as a small group learning activity. *Journal of Educational Psychology*, 104(3):661-672.

Ramphele, M. 2014. We throw away our children's future. *Sunday Times*. 28 Sept. p 18.

Raphael, D. & Wahlstrom, M. 1989. The influence of instructional aids on mathematics achievement. *Journal for Research in Mathematics Education,* 20(2):173-190.

Reeves, N. 1990. Action research for professional development: Informing teachers and researchers. (*In* Steffe, L.P. & Wood, T. *eds*. 1990. Transforming children's mathematics education. International perspectives. New Jersey: Lawrence Erlbaum Associates. p 436-447).

Resnick, M. 1998. Technologies for lifelong kindergarten. *Educational Technology Research and Development*, 46(4):43-55.

Reys, R.E., Lindquist, M.M., Lambdin, D.V., Smith, N.L., Rogers, A., Falle, J. Frid, S. & Bennett, S. 2012. Helping children learn mathematics. 1st Australian Eds. Milton: John Wiley & Sons Australia.

Rodgers, M.S. 2012. Structured play and student learning in kindergarten: an outcome evaluation. (Thesis – PhD). http://hdl.handle.net/2047/d20002606 Date of access: 11 Jul. 2014.

Rudd, L.C., Lambert, M.C., Satterwhite, M., Zaier, A. 2008. Mathematical language in early childhood settings: What really counts. *Early Childhood Education Journal,* 36:75-80.

Samuelsson, I.P. & Pramling, N. 2013. Play and learning. (*In* Encyclopedia on Early Childhood Development. http://www.child-encyclopedia.com/documents/Pramling-Samuelson-PramlingANGxp1.pdf Date of access: 11 Jul. 2014).

Santer, J., Griffiths, C. & Goodall, D. 2007. Free play in early childhood: A literature review. London: National Children's Bureau.

Saxe, G. M., Gearhart, M. & Guberman, S.R. 1991. The social organization of early number development. (*In* Scales, B. Almy, M. Nicolopoulou, A. & Ervin-Tripp, S. *ed*s. 1991. Play and the social context of development in early care and education. New York: Teachers College Press. p 143-155).

Schrier, A.M. 1984. Learning how to learn: The significance and current status of learning set formation. *Primates,* 25(1):95-102.

Schweinhart, L.J. & Weikart, D.P. 1990. The High/Scope Perry Preschool Study: Implications for early childhood care and education. *Prevention in Human Services,* (7)1:109-132.

Seel, N.M. 2012. Bruner, Jerome S (1915-). (*In* Encyclopedia of the Sciences of Learning: 488 - 491

Shute, N. 2002. Madam Montessori. *Smithsonian,* 33(6):70-74.

Siegel, L.S. 1993. Amazing new discovery: Piaget was wrong! *Canadian Psychology,* 34(3):239-245.

Siegler, R.S. & Booth, J.L. 2004. Development of numerical estimation in young children. *Child Development,* 75(2):428-444.

Silliphant, V.M. 1983. Kindergarten reasoning and achievement in grades K-3. *Psychology in the Schools*, 20:289-294.

Simon, T.J., Hespos, S.J. & Rochat, P. 1995. Do infants understand simple arithmetic? A replication of Wynn (1992). *Cognitive development,* 10(2):253-269.

Sinclair, H. 1990. Learning: The interactive recreation of knowledge. (*In* Steffe, L.P. & Wood, T. *eds*. 1990. *Transforming children's mathematics education: International perspectives.* New Jersey: Lawrence Erlbaum Associates. p 19-29).

Singer, D.G., Singer, J.L., Plaskon, S.L. & Schweder, A.E. 2003. A role for play in the preschool curriculum. (*In* Olfman, S. *ed*. 2003. All work and no play. Westport: Praeger Publishers. p. 43-70).

Siyepu, S. 2013. The zone of proximal development in the learning of mathematics. *South African Journal of Education, 33(2):1-13.* <http://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S0256-01002013000200011&lng=en&nrm=iso> Date of access: 7 Oct. 2014.

Smilansky, S. 1968. The effects of sociodramatic play on disadvantaged preschool children. New York: Wiley.

Smith, J.P., Van den Heuvel-Panhuizen, M. & Teppo, A.R. 2011. Learning, teaching, and using measurement: introduction to the issue. *ZDM Mathematical Education,* 43(5):617-620.

Smith, P.K. 1994. Play and the uses of play. (*In* Moyles, J.R. *ed*. 1994. The excellence of play. Buckingham: Open University Press. p. 15-26).

Smith, P.K., Takhvar, M., Gore, N., & Vollstedt, R. 1985. Play in young children: problems of definition, categorisation and measurement. *Early Child Development and Care,* 19(1-2):25-41.

Sophian, C. 2007. The origins of mathematical knowledge in childhood. New York: Lawrence Erlbaum Associates.

Sousa, D.A. 2008. How the brain learns mathematics. California: Corwin Press.

South Africa. Department of Basic Education. 2011. Curriculum and assessment policy statement, foundation phase, Grade R, English Mathematics. Pretoria: Department of Basic Education. http://www.thutong.doe.gov.za/supportformatrics/MathematicsCAPSFoundationPhase/tabid/5004/Default.aspx Date of access: 1 Jul. 2013.

South Africa. Department of Basic Education. 2012a. Annual Report. http://www.education.gov.za/LinkClick.aspx?fileticket=Yl%2BhMxe4mVU%3D&tabid=422&mid=1263 Date of access: 22 Jun. 2013.

South Africa. Department of Basic Education. 2012b. Report on the annual national assessments of 2011. http://www.fedsas.org.za/english/downloads/16_44_54_Annual%20National%20Assessment%20of%202011.pdf Date of access: 3 Jul. 2013.

South Africa. Department of Basic Education. 2013a. National diagnostic report on the national senior certificate examination of 2012. http://www.education.gov.za/LinkClick.aspx?fileticket=Keou0ykx4Tc%3D&tabid=358&mid=1325 Date of access: 30 Jan. 2014.

South Africa, Department of Basic Education. 2013b. Report on the annual national assessments of 2012. http://www.education.gov.za/LinkClick.aspx?fileticket=YyzLTOk5IYU%3D&tabid=298 Date of access: 15 Jul. 2013.

South Africa. Department of Basic Education. 2014a. National diagnostic report on the national senior certificate examination of 2013.

http://www.education.gov.za/LinkClick.aspx?fileticket=aXCqsTfost4%3D&tabid=175&mid=2910 Date of access: 28 Jan. 2014.

South Africa. Department of Basic Education. 2014b. report on the annual national assessments of 2013. http://www.education.gov.za/LinkClick.aspx?fileticket=Aiw7HW8ccic%3D&tabid=36 Date of access: 28 Jan. 2014.

South Africa. Department of Education. 2014c. Child registration. http://www.education.gov.za/Parents/Childregistration/tabid/407/Default.aspx Date of access: 29 Jan. 2014.

Spaull, N. 2013. Assessment results don't make sense. *Mail and Guardian*. 5 Dec. http://mg.co.za/article/2013-12-05-ana-results-are-not-comparable Date of access: 29 Jan. 2014.

Starkey, P. & Cooper, R.G. 1980. Perception of numbers by human infants. *Science,* 210(1)4473:1033-1035.

Starkley, P. & Klein, A. 2000. Fostering parental support for children's mathematical development: an intervention with head start families. *Early Education and Development,* 11(5):659-680.

Sternberg, R.J. 1999. Cognitive psychology. 2nd ed. Orlando: Harcourt College Publishers.

Stipek, D. 2013. Mathematics in early childhood education: Revolution or evolution? *Early Education and Development,* 24(4):431-435.

Stodolsky, S.S. 1985. Telling math: Origins of math aversion and anxiety. *Educational Psychologist,* 20(3):125-133.

Sun Lee, J. & Ginsburg, H.P. 2009. Early childhood teacher's misconceptions about mathematics education for young children in the US. *Australasian Journal of Early Childhood, 34(4)*:37-45.

Swanson, H.L. 2011. Working memory, attention, and mathematical problem solving: A longitudinal study of elementary school children. *Journal of Educational Psychology*, 103(4):821-837.

Swenson, R. 2006. Review of clinical and functional neuroscience. http://www.dartmouth.edu/~rswenson/NeuroSci/chapter_9.html Date of access: 19 Jul. 2014.

Sylva, K. 1984. A hard-headed look at the fruits of play. *Early Childhood Development and Care*, 15(2-3):171-183.

Sylva, K. 1993. Work or play in the kindergarten? *Singapore Journal of Education,* 13(1):26-31.

Taylor, S. 2011. Uncovering indicators of effective school management in South Africa using the National School Effectiveness Study. *Stellenbosch Economic Working Papers*, 10/11: 1 – 51

Thompson, I. 1995. 'Pre-number activities' and the early years number curriculum. *Mathematics in School*, 24(1):37-39.

Thorpe, P. 1995. Spatial concepts and young children. *International Journal of Early Years Education*, 3(2):63-74.

Tipps, S., Johnson, A. & Kennedy, L.M. 2011. Guiding children's learning of mathematics. Twelfth edition. Boston: Wadsworth Cengage Learning.

Troutman, A.P. & Lichtenberg, B.K. 2003. Mathematics. A good beginning. Belmont: Wadsworth/Thomson Learning.

Tunmer, W., Prochnow, J.E. & Chapman, J.W. 2003. Science in educational research. (*In* Swann, J. & Pratt, J. *eds*. 2003. Educational research in practice. Making sense of methodology. London: Continuum. p. 84 - 97).

Tustin, D.H., Ligthelm, A.A., Martins, J.H. & Van Wyk, H de J. 2005. Marketing research in practice. Pretoria: Unisa Press

Van Hiele, P.M. 1959. The child's thought and geometry. English translation of selected writings of Dina van Hiele-Geldof and Pierre M. van Hiele. ERIS/SMEAC. (*In* Carpenter, T.P., Dossey, J.A. & Koehler, J.A. *eds*. 2004. Classics in mathematics education research. Reston, VA: National Council of Teachers of Mathematics. p.60 - 67).

Van Hiele, P.M. 1999. Developing geometric thinking through activities that begin with play. *Teaching Children Mathematics,* 3:310-316.

Venter, M. 2013. What do the ANAs tell us? *Teacher's Monthly,* 4 Feb 2013. http://www.teachersmonthly.com/what-to-the-anas-tell-us/ Date of access: 29 Jan. 2014.

Verster, T.L. 1992. A Historical pedagogical investigation of infant education. Pretoria: University of South Africa.

Vukovic, R.K., Kieffer, M.J., Bailey, S.P. & Harari, R.R. 2013. Mathematics anxiety in young children: concurrent and longitudinal associations with mathematical performance. *Contemporary Educational Psychology,* 38(1):1-10.

Wall, E.S. & Posamentier, A.S. 2007. What successful math teachers do, Grades PreK-5. Research-based strategies for the standards-based classroom. California: Corwin Press.

Walsh, G., Sproule, L., McGuinness, C. & Trew, K. 2011. Playful structure: a novel image of early years pedagogy for primary school classrooms. *Early years: An International Research Journal,* 31(2):107-119.

Warren, E. & Cooper, T. 2006. Using repeating patterns to explore functional thinking. *Australian Primary Mathematics Classroom,* 11(1):9-14.

Wassenberg, R., Feron, F.J., Kessels, A.G.H., Hendriksen, J.G., Kalff, A.C., Kroes, M., Hurks, P.P.M., Beeren, M., Jolles, J. & Vles, J.S.H. 2005. Relation between cognitive and motor performance in 5-to 6-year-old-children: Results from a large-scale cross-sectional study. *Child Development,* 76(5):1092-1103.

Waters, J.L. 2004. A study of mathematical patterning in early childhood settings. (*In* Putt, I., Faragher, R. & MacLean, M. *eds*. Proceedings Mathematics Education for the 3rd millennium: Towards 2010. The 27th Annual Conference of the Mathematics Education Research Group of Australasia, 2:321-328).

Weisberg, D.S., Hirsh-Pasek, K. & Golinkoff, R.M. 2013. Guided play: Where curricular goals meet a playful pedagogy. *Mind, Brain and Education,* 7(2):104-112.

Wood, D., Bruner, J.S. & Ross, G. 1976. The role of tutoring in problem solving. *Journal of child psychology and psychiatry,* 17:89-100.

Wood, L & Bennett, N. 1997. The rhetoric and reality of play: teachers' thinking and classroom practice. *Early Years: An International Research Journal,* 17(2):22-27.

Wood, L. 1997. Play: Future directions. *Early Years: An International Research Journal,* 17(2): 28-33.

Woolfolk, A. 2010. Educational psychology. 11th eds. Boston: Pearson Education.

Wubbena, Z.C. 2013. Mathematical fluency as a function of conservation ability in young children. *Learning and Individual Differences,* 26:153-155.

Yeld, N. 2012. SA must work to dig basic education out of deep trouble. http://www.bdlive.co.za/indepth/AfricanPerspective/2012/12/12/sa-must-work-to-dig-basic-education-out-of-deep-trouble. Date of access: 25 Jun. 2013.

ADDENDUM A

ETHICAL CLEARANCE CERTIFICATE

UNISA college of education

Research Ethics Clearance Certificate

This is to certify that the application for ethical clearance submitted by

E G Helmbold [32055617]

for a M Ed study entitled

Teacher directed play as a tool to develop emergent Mathematics concepts – a neuro-physchological perspective

has met the ethical requirements as specified by the University of South Africa College of Education Research Ethics Committee. This certificate is valid for two years from the date of issue.

Prof KP Dzvimbo
Executive Dean : CEDU

Dr M Claassens
CEDU REC (Chairperson)
mcdtc@netactive.co.za

Reference number: 2014 JULY /32055617/MC

16 JULY 2014

ADDENDUM B

SAMPLES OF CONSENT AND PERMISSION FORMS

INVITATION FOR PARTICIPATION

IN MATHEMATICAL RESEARCH PROJECT

Dear Parents

My name is Erika Helmbold, and I am currently doing research into the essential skills required for mathematical teaching in Grade R for my Masters Degree qualification through UNISA. My supervisor who is assisting and guiding me during my research undertaking is Professor M de Witt and she can be contacted at 082 366 2540.

I have personally been teaching Grade R for 17 years now, and have always been keenly interested in how early mathematical education influences children's school readiness and future academic success as a whole. As a result, I would like to research the impact of introducing a play-based mathematical curriculum in Grade R, based on recent research in the field.

For study purposes, I will need to test approximately 200 Grade R children. Some of these children have been exposed to a play-based mathematics curriculum and some have not.

Participation in the research project will mean the following for your child:

I would like to visit your child's school in September/ October and administer a mathematics test. This test will be given as a pen-and-paper type test. I will be asking your child if he/she would like to participate and will respect his/her decision. The test will be approximately 1 hour long and your child will be given short breaks during the test to remain relaxed and comfortable. The test will be administered in English and if required, Zulu.

Your child's participation is completely voluntary and they may stop participating in the test at any time. I will do my utmost to ensure that your child has a pleasant and fun testing experience. Your child's details will remain confidential and test results will be kept private.

It would be my absolute privilege if you would allow your child to participate in this research project. Please discuss the process with your child and then give your signed, voluntary consent on behalf of your child. You are most welcome to contact me for any further information regarding the research study.

Yours faithfully

Erika Helmbold

ehelmbold@gmail.com

083-988-9702 (afternoons)

011-976-5300 (mornings)

ISIMEMO ITJHEBISWANO

IN zezibalo eriseshi

Abazali Abathandekayo

Igama lami ngingu-Erika Helmbold, mina njengamanje ngokwenza ucwaningo singene ngamakhono adingekayo yokufundisa nezibalo ku Grade R ze Masters Degree eUnisa. Umphathi wami ongisizayo nongibonisa indlelonjengobangezalolucwaninga nguProfesa M de Witt. Angathintwa kulezinombolo 082 366 2540.

Mina ngineminyaka engu 17 ngifundisa ibanga lika Grade R manje,futhi nginentshisakalo yokufundisa izibalo nokuqhuqhuzela ingane ngezibalo iselula. Ngithanda nokucwaninga nangemiphumela engabakhona uma singafundisa izibala kwaGrade R.

Ngezinjongo cwaningo, kuzodingeka ukuhlola izingane cishe ezingu 200 lika Grade R. Ezinye zalezi zingane baye bathola umdlalo esekelwe izibalo kanye abanye hhayi.

Ukubamba iqhaza kule projekthi ucwaningo kuyosho okulandelayo ngengane yakho:

Ngingathanda ukuvakashela isikolo sengane yakho ngo September / October, ukuthi ngibahlole ngezibalo. Lokuhlola uyonikwa njengendlela ukuhlolwa ipeni ne phepha. Ngizobe ngibuza ingane yakho uma yena angathanda ukubamba iqhaza futhi uzobe ehloniphwe isinqumo sakhe. Ukuhlolwa kuyoba cishe ihora. Uzonikezwa nesikhathi sokuphumula mabebala. Ukuhlolwa kuzokwenziwa ngesiNgisi kanti uma kudingeka, ngesiZulu.

Ukuzinikela kwengane yakho kuzobe kungentando yakhe kanti uma angasathandi ukuqhubeka angasho. Ngiya thembisa ukuthi ngizosebenza ngokuzikhandla nokuzimiselaukuthiingane yakho ithokoze kakhulukulukuhlolwa. Imininingwane yakho uzohlala oluyimfihlo kanye nemiphumela yokuhlolwa yakhe.

Kungaba intokozo kanye nenjabulo enkulu uma ungavumela ingane yakho ukwenza lokucwaningo. Ngiyacela ukuba ukhulume nengane yakho futhi uyicazele ngalocwaningo. Bese uyasisayinela ukuthi uyavuma ukuthi ingane izinikele kulocwaningo.

Ukuthola imininingwane ngalocwaningo ungashayela lezizinombolo ezilandelayo.

Ozithobayo

Erika Helmbold

ehelmbold@gmail.com

083-988-9702 (ntambama)

011-976-5300 (ekuseni)

Signed informed consent

Name of Parent/ Guardian	M[redacted]AD
Name of Child	[redacted]
Date of birth of child	20 MAY 2009
Name of school	[redacted]AY CARE
Contact Number of parent/ Guardian	[redacted]184

By signing this form you agree to the following:

1. To allow your pupils to participate in the abovementioned testing process
2. To reserve the right to withdraw from the study at any time

We will be returning to you this signed copy as soon as we have processed all our forms.

Signature of Parent/ legal guardian: [illegible signature]

Signature of Researcher: [illegible signature]

Date: 14 . 08 . 2014

INVITATION FOR PARTICIPATION

IN MATHEMATICAL RESEARCH PROJECT AS A CONTROL GROUP

Dear Teacher

My name is Erika Helmbold, and I am currently doing research into the essential skills required for mathematical teaching in Grade R for my Masters Degree qualification through UNISA. My supervisor who is assisting and guiding me during my research undertaking is Professor M de Witt and she can be contacted at 082 366 2540.

I have personally been teaching Grade R for 17 years now, and have always been keenly interested in how early mathematical education influences children's school readiness and future academic success as a whole. As a result, I would like to research the impact of introducing a play-based mathematical curriculum in Grade R, based on recent research in the field.

For research purposes, I will need approximately 100 children to be tested as a control group in September/ October 2014.

Participation in the research project will equate to the following for your school:

I would like to visit your school in September/ October and administer a mathematics test to your Grade R pupils. This test will be given as a pen-and-paper type test. Participating pupils will be asked to participate and may withdraw at any time. The test will be approximately 1 hour long and children will be given short breaks during the test to remain relaxed and comfortable. The test will be administered in English, and if different, in the children's language of instruction.

I would also require signed, voluntary consent from parents and guardians of the pupils in your Grade R classes, giving their permission for their children to participate in the testing procedure.

Results of research/ summary of findings

Research results will be shared with the school principals and teachers participating in the research project once the dissertation has been completed. However, names of schools, staff and pupils are to remain confidential once results have been discussed within this focus group to protect the privacy of the participating institutions, teachers and pupils.

Ethical considerations

Participation in the research project is voluntary and withdrawal will be without any penalty at any time. Research participants, names of teachers and names of schools will remain confidential unless written permission has been granted for such disclosure.

It would be my absolute privilege if you would be willing to participate as a school in this research project. You are most welcome to contact me for any further information regarding the research study.

Yours faithfully

Erika Helmbold

ehelmbold@gmail.com

083-988-9702 (afternoons)

011-976-5300 (mornings)

Signed informed consent

Name of Principal	Mr [redacted]ich
Name of institution	[redacted]a Academy Independent School
Contact Number	[redacted] 14 19
Address	[redacted]treet Glen Marais
Name of participating Grade R teachers	Mrs [redacted]on
Expected number of participating Grade R pupils	25

By signing this form you hereby agree to the following:

1. To allow the Grade R children in your class, and yourself, to participate in the abovementioned research project
2. To protect the confidentiality and privacy of research participants, once research results have been disclosed to you
3. To reserve the right to withdraw from the study at any time

Signature of Teacher: [redacted]

Signature of Researcher: ________________

Date: 22 September 2014

PERMISSION FOR PARTICIPATION

IN MATHEMATICAL RESEARCH PROJECT AS A CONTROL GROUP

Dear Principal and interested parties

My name is Erika Helmbold, and I am currently doing research into the essential skills required for mathematical teaching in Grade R for my Masters Degree qualification through UNISA. My supervisor who is assisting and guiding me during my research undertaking is Professor M de Witt and she can be contacted at 082 366 2540.

I have personally been teaching Grade R for 17 years now, and have always been keenly interested in how early mathematical education influences children's school readiness and future academic success as a whole. As a result, I would like to research the impact of introducing a play-based mathematical curriculum in Grade R, based on recent research in the field.

For research purposes, I will need approximately 100 children to be tested as a control group in September/ October 2014.

Participation in the research project will equate to the following for your school:

I would like to visit your school in September/ October and administer a mathematics test to your Grade R pupils. This test will be given as a pen-and-paper type test. Participating pupils will be asked to participate and may withdraw at any time. The test will be approximately 1 hour long and children will be given short breaks during the test to remain relaxed and comfortable. The test will be administered in English, and if different, in the children's language of instruction.

I would also require signed, voluntary consent from parents and guardians of the pupils in your Grade R classes, giving their permission for their children to participate in the testing procedure.

Results of research/ summary of findings

Research results will be shared with the school principals and teachers participating in the research project once the dissertation has been completed. However, names of schools, staff and pupils are to remain confidential once results have been discussed within this focus group to protect the privacy of the participating institutions, teachers and pupils.

Ethical considerations

Participation in the research project is voluntary and withdrawal will be without any penalty at any time. Research participants, names of teachers and names of schools will remain confidential unless written permission has been granted for such disclosure.

It would be my absolute privilege if you would be willing to participate as a school in this research project. You are most welcome to contact me for any further information regarding the research study.

Your signed permission will be returned to you once copies have been made.

Yours faithfully

Erika Helmbold

ehelmbold@gmail.com

083-988-9702 (afternoons)

011-976-5300 (mornings)

Signed informed consent

Name of Principal	Math[redacted]
Name of institution	[redacted] Day Care Centre
Contact Number	011 736[redacted] 781 9561
Address	9 [redacted] Str Kwa-Thema
Name of participating Grade R teachers	Din[redacted]
Expected number of participating Grade R pupils	15

By signing this form you hereby agree to the following:

1. To allow your centre to participate in the abovementioned research project
2. To protect the confidentiality and privacy of research participants, once research results have been disclosed to you
3. To reserve the right to withdraw from the study at any time

Signature of Principal: [redacted]

Signature of Researcher: EHelmbold.

Date: 10/9/2014

ADDENDUM C

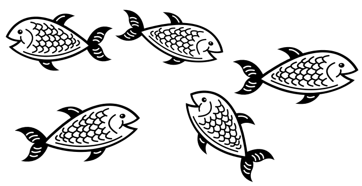
Grade R Mathematics Test

Name of child: ____________________________ Birth date: _____________________

School:____________________________________

Date of test: ______________________________

1.

	2	8	5	4	6

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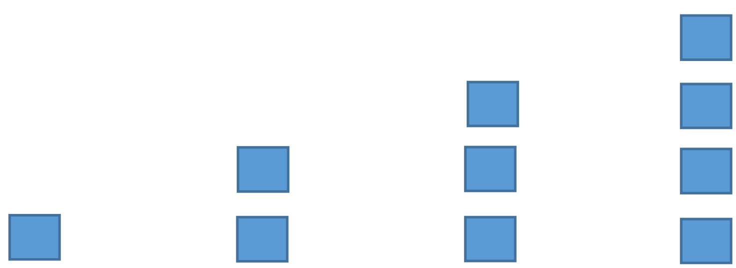

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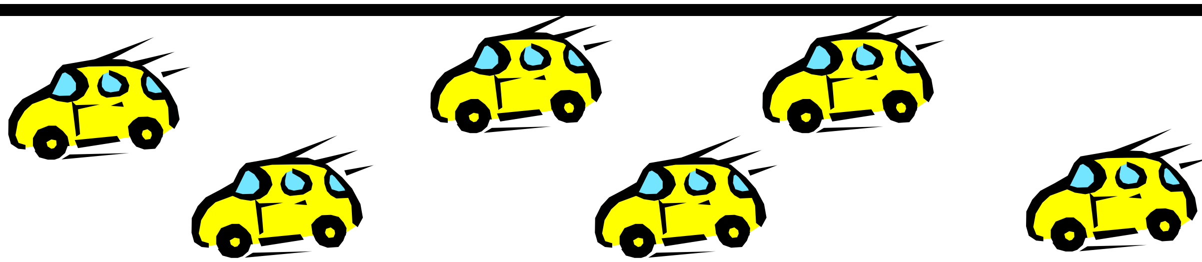

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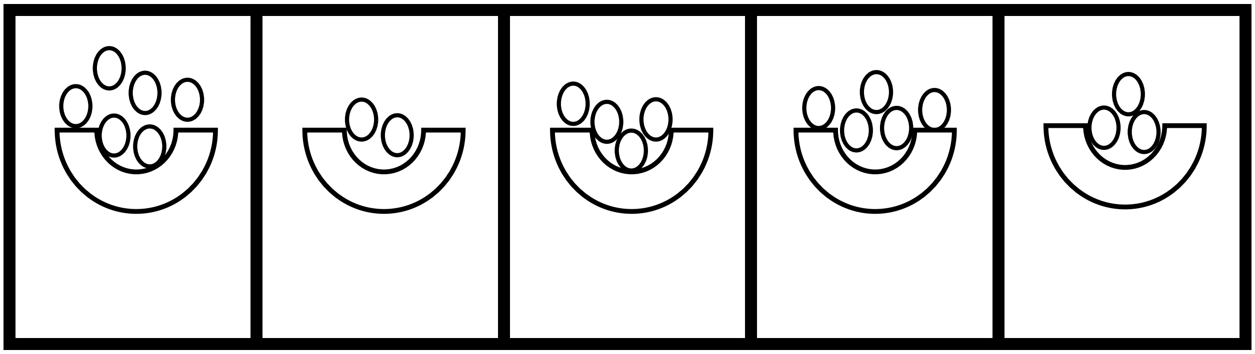

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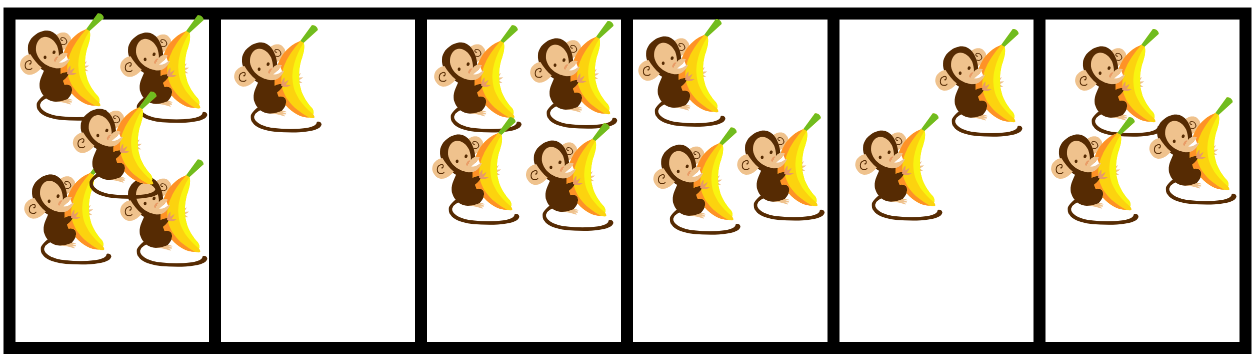

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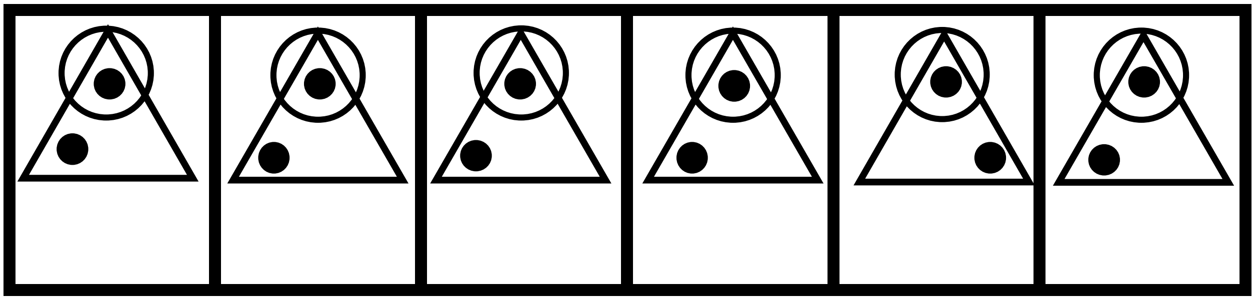

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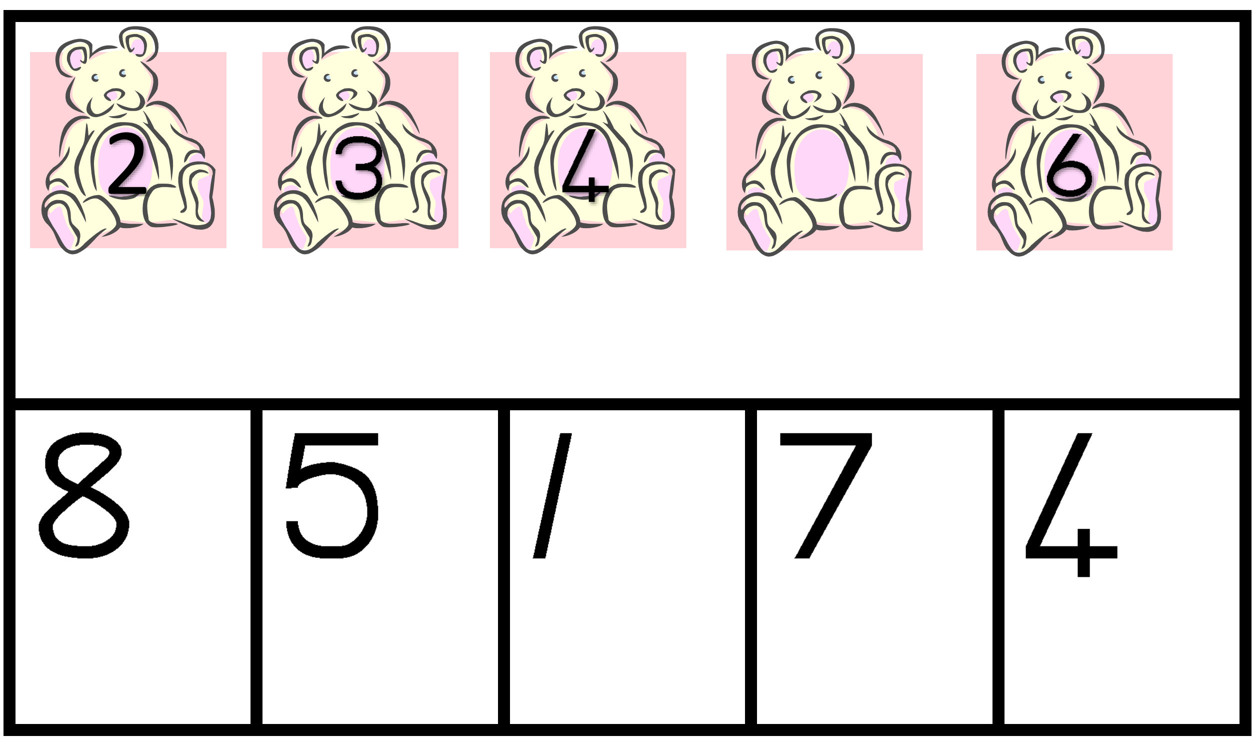

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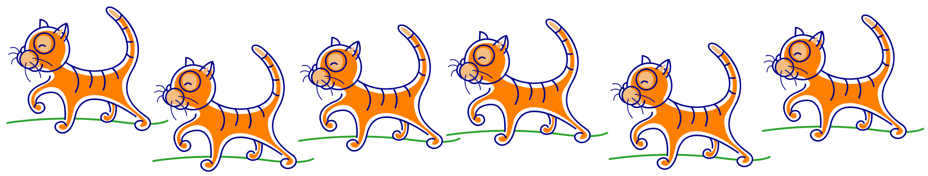

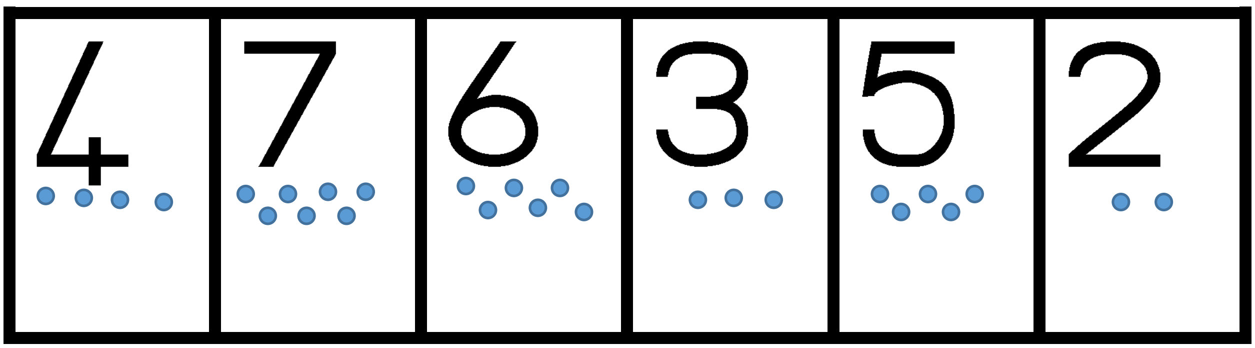

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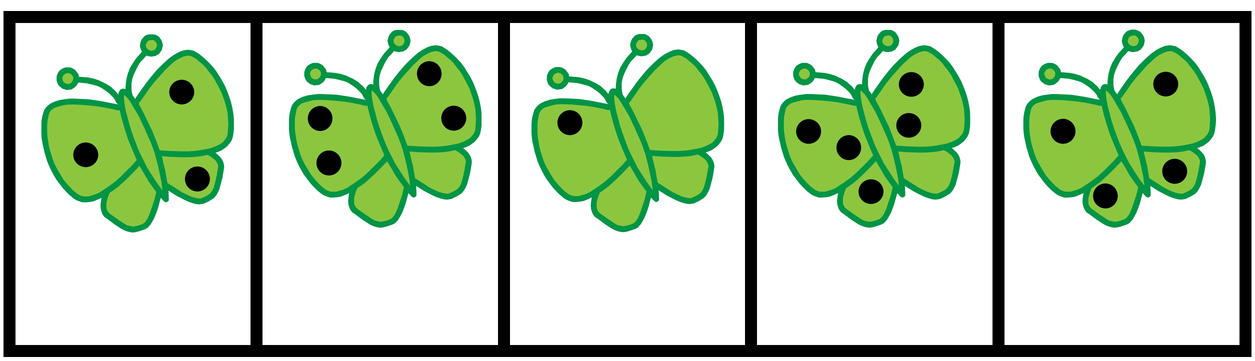

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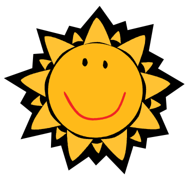	5	8	6	3	4

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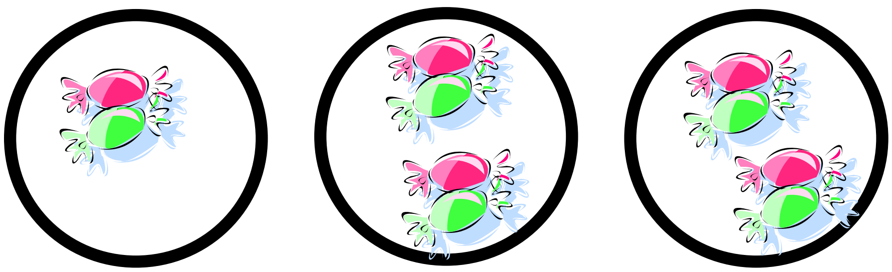

4	8	2	9	3	6

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			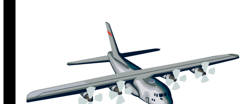	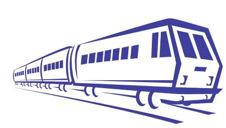

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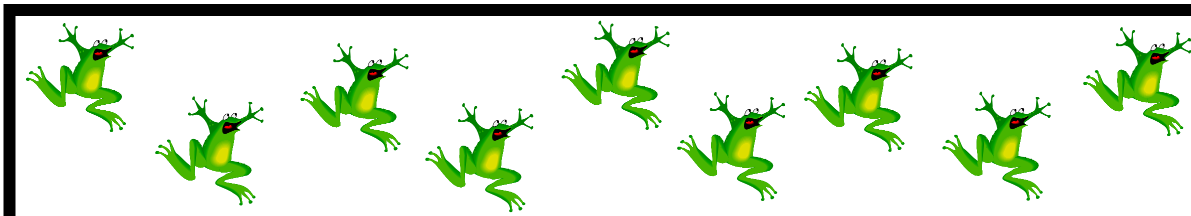

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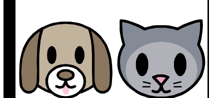	8	6	2	9	3

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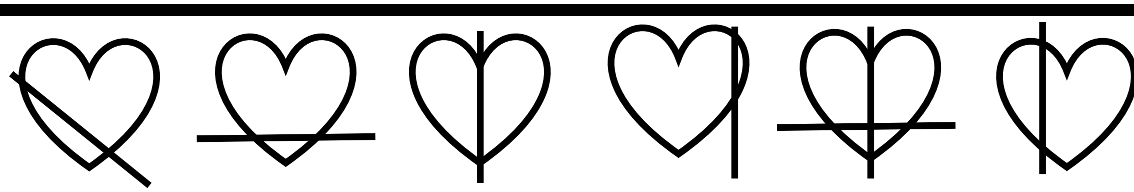

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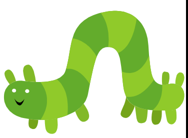	7	2	0	4	1

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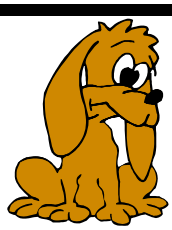	3	2	7	4	5

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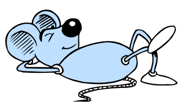	6	2	9	4	7

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7	2	3	4	8	5

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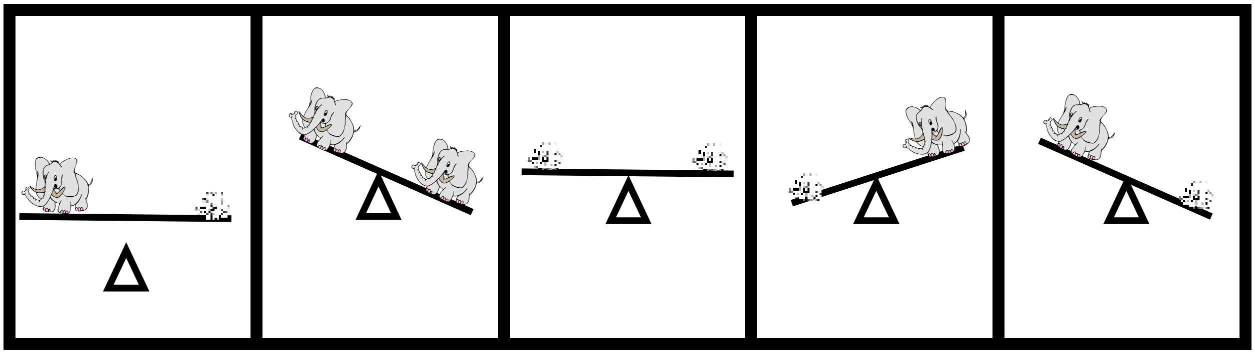

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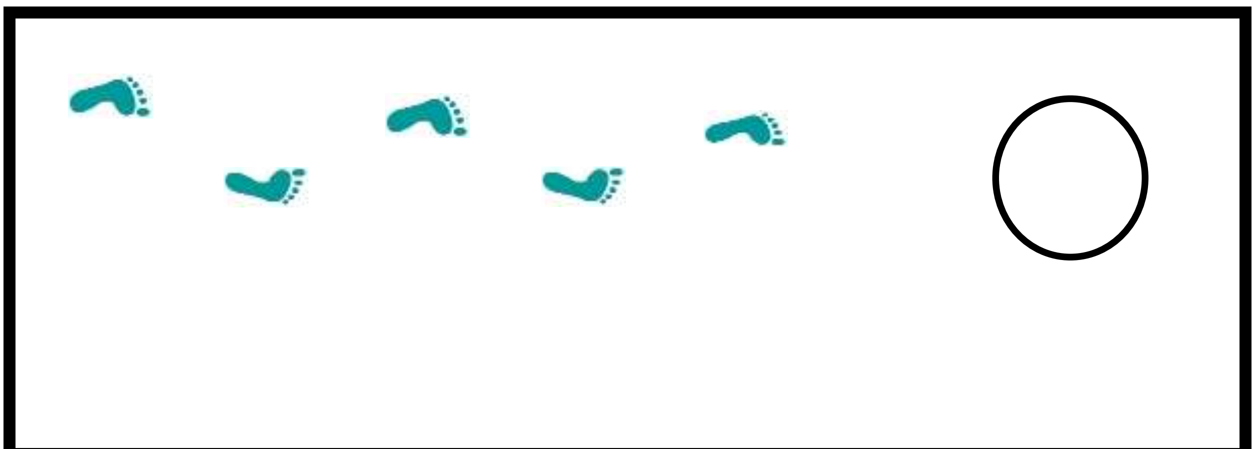

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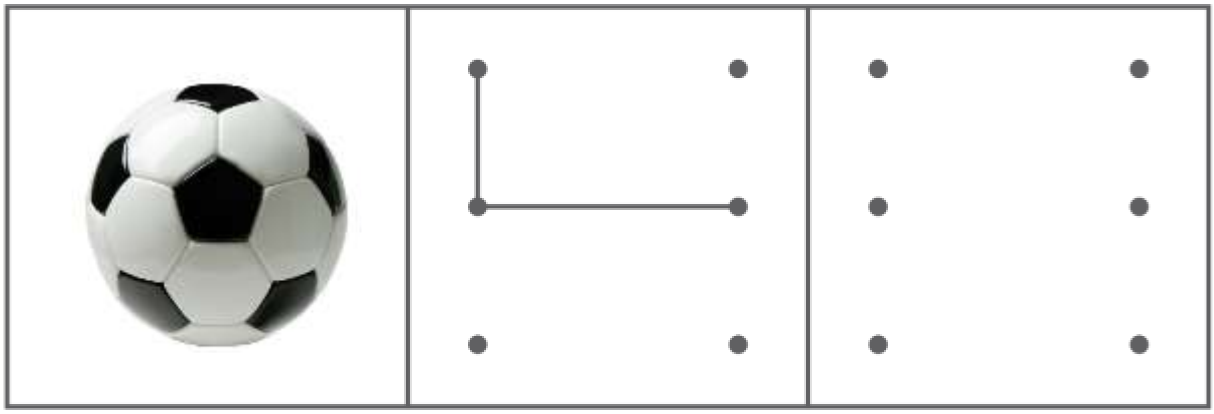

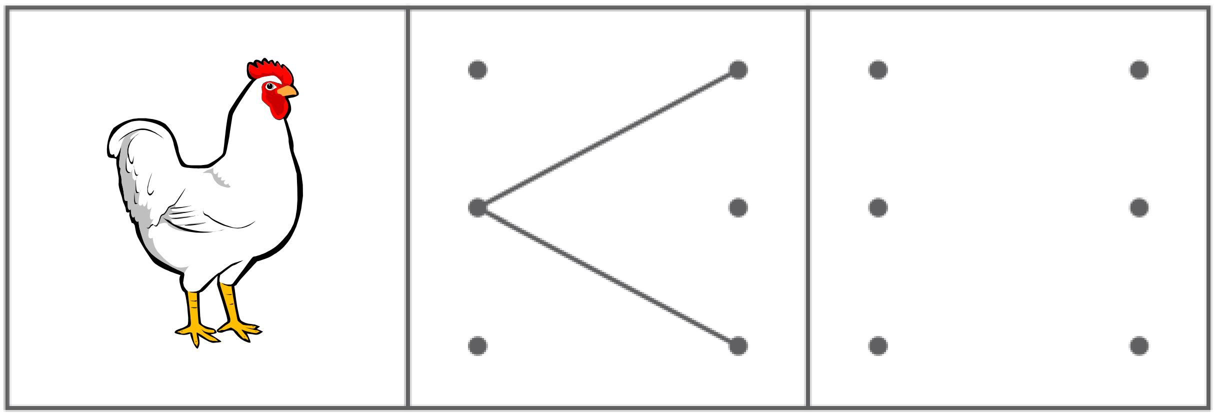

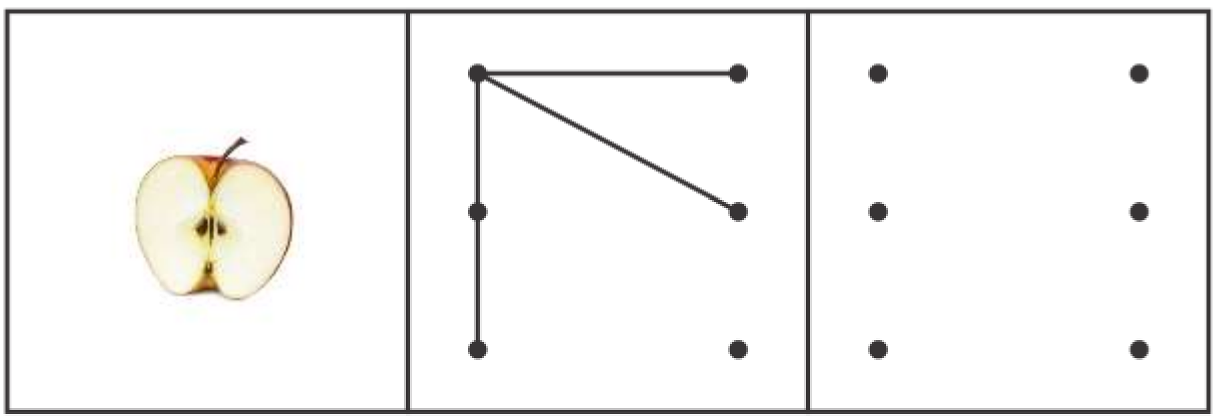

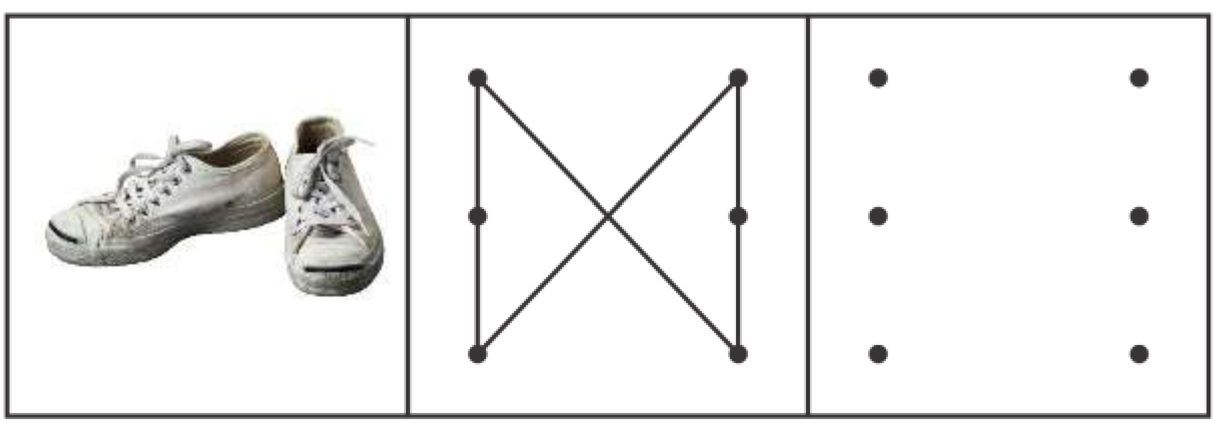

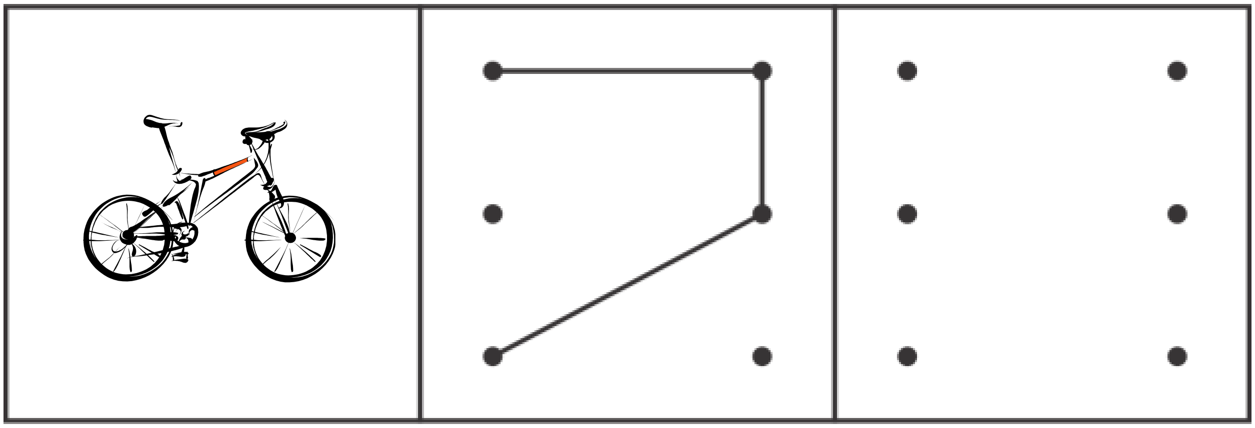

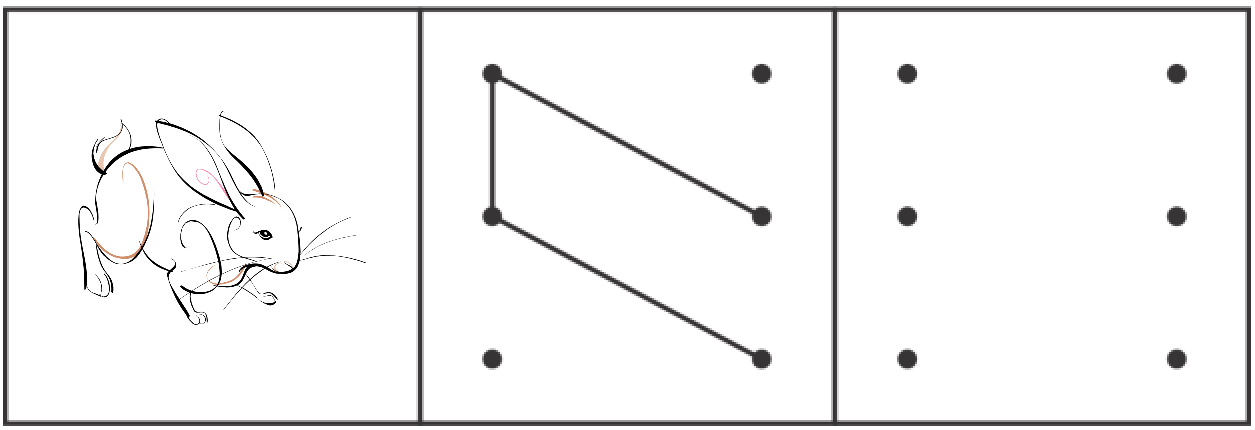

ADDENDUM C CONTINUED

Grade R Mathematics Test Questions

- Instructions must be read twice. They may be repeated after this, as many times as required if necessary.
- Children may be given counters if requested, as well as pencils and paper as concrete tools to assist with any question.
- Tester-pupil ratio should be 1:12. It may be higher if the tester uses adult assistants. Before each question is answered, children must place their finger at the correct corresponding picture of the question. Testers and assistants must ensure that the child is at the correct place for each question.
- The tester begins the test by first demonstrating how to draw a line through a correct answer (use the apple picture at the top left of the first page as the sample).
- The tester confirms that if a child recognises a mistake they have made they put up their hand and the tester will sign the correction

1. Do you see the box with all the fish in it? Next to it is a box of numbers. How many fish do you see? Draw a line through the correct number of fish.
2. I am building towers of blocks. My first tower had one block (point). My second tower had two blocks (point). The next tower had three (point) and the next had four (point). Can you draw the next tower that I would draw in the open space at the end (indicate).
3. Draw a line through the car that will come third in the race?
4. Draw a line through the bowl that has the least number of eggs in it?
5. Which <u>two</u> boxes have the same number of monkeys in them? Draw lines through both boxes.
6. Next to the strawberry are numbers. Draw a line through the number that is bigger than 4 but smaller than 6.
7. Can you see the triangles? Which picture is different from the rest? Which picture doesn't belong?

8. Count all the socks and count all the shoes. Are there enough socks for me to put one sock in each shoe? If the answer is yes, draw a line through the man saying yes. If the answer is no, draw a line through the man saying no.
9. Each teddy bear has a number on his tummy, but one lonely one doesn't. Choose a number in boxes underneath that you think we should write on the lonely teddy's tummy. Draw a line through it. You may also write the number on the teddy's tummy if you like.
10. If half the cats ran away, how many would be left? Draw a line through the number of that you think will be left?
11. Which two butterflies have the same number of dots? They might not look the same, but they have the same number or amount. Draw lines through both two butterflies. Remember that you have to draw lines through <u>two</u> butterflies that have the same amount of dots on their wings.
12. Next to the sun are some numbers. Draw a line through the number that is more than or bigger than 6?
13. Can you see my three circles with sweeties? If I eat all the sweets from the first two circles – how many did I eat altogether? Draw a line through the number.
14. Can you see the car, the house, the bicycle, the aeroplane and the train? Which picture should not be there? Which one doesn't belong with the others.
15. (First demonstrate drawing lines through sample balls on a board). Draw lines through 5 frogs. Mark any five frogs.
16. Can you see the pattern. It's a triangle, circle, square, heart, triangle, circle, square, heart. Can you finish the pattern to the end of the block?
17. If my dog is 5 years old and my cat is 1 year older. How old is my cat?
18. Draw a line through the heart that has been cut in perfectly in half.
19. Next to the lion are some numbers. Can you write those numbers again in the open box under the lion, but start with the lowest/ smallest number and end with the highest/biggest one. That means you must start by writing the little number – the smallest one – straight under the lion, then next to it (point) write the one that's a bit bigger, then (point) the one that's a bit bigger and end with the biggest one (point)!
20. The worm likes to eat leaves. He sees 5 leaves on the tree but only eats 4. How many leaves are left on the tree?

21. Next to the aeroplane are numbers. Which of these numbers come straight after 8?
22. A boy feeds his puppy two bones this morning, and two bones this evening. How many bones did his puppy eat today?
23. Next to the sleepy mouse are numbers. Draw a line through the smallest number next to the mouse.
24. Two boys are going to share these cakes at a party. If they are fair, how many cakes will ONE boy get?
25. In which picture do the two elephants weigh the same? (Note to marker: there are two possible correct answers to this question – selecting either of the two pictures with a straight see-saw will earn a mark)
26. Guess how many more footsteps I need to take before reaching the circle? Don't count the footsteps I have already taken! Just tell me how many footsteps are missing to get to the middle of the circle – how many more must I take?

The following question was added to ensure that testing conditions had not caused undue stress amongst children…

What do you think about answering questions like these? Do they make you feel happy, sad or scared? (Note to marker – this question is not for marks. It's a qualitative research question and does not count as part of the aptitude test).

27 – 30. Copy the pictures into the open blocks next to each one. (Demonstrate a simpler one on the board before allowing children to begin. Work slowly and ask them to complete the one next to the rabbit. Check that this is done before you ask them to complete the one next to the chicken etc.) (Note to marker – the first two questions are sample questions and are not marked. One mark is awarded for a completely correct drawing touching all relevant dots with no breaks in lines, overshoots of more than 2mm or sharp direction changes in lines).

ADDENDUM D

Teacher Interview Questions

Name of teacher: ____

Highest academic qualification obtained: ______________________________

Name of school: ____

1. How long have you been teaching Grade R
2. On average, how much time do you spend daily, just teaching mathematics?
3. How much time do you spend preparing for mathematics teaching every week?
4. What are your THOUGHTS about mathematics teaching in Grade R in South Africa (how is maths going – do you think it is a good thing or a bad thing)?
5. What are your most dominant FEELINGS about teaching Grade R mathematics (referring to how you teach it right now)?
6. What do you think your Grade R children think about mathematics?
7. How do you think your pupils will cope next year in Grade 1 mathematics?
8. Do you think you have been adequately prepared or trained to teach mathematics in Grade R (professionally or otherwise)?
9. Do you have enough resources in your school to teach mathematics?
10. If your school is teaching mathematics, which method you use most often?
11. Which method do you believe is the most effective for teaching mathematics Grade R (even if you aren't using it)?
12. Do you like teaching maths?
13. What sometimes scares you the MOST about teaching maths?
14. Do you think your children have improved in their MATHS REASONING because of your mathematics teaching this year?
15. Has the mathematics programme of 2014 matched the level of children in your school (too hard/ too easy)?
16. How are you planning to teach mathematics next year? (Are you satisfied with the way you are teaching now?)

17. Where do you believe we are MOST “going wrong” in teaching maths in Grade R South Africa – if we are? What advice would you give the DoE?
18. What have learned about teaching mathematics this year (summarise for me)?
19. What is difficult or not enjoyable in your current maths syllabus?
20. What problems do you think that you might be facing that other Grade R teachers aren’t?
21. What do you like the most about your maths syllabus right now?
22. How do you think we should teach maths in grade 1?
23. What do you think of the test?
24. Open comments… (anything you might want to add)

ADDENDUM E

Actual Sample of Recorded Teacher Interview

Name of teacher: _____________________confidential _________________

Highest academic qualification obtained: _____Diploma in accounting - UCT (and a matric)____________

Name of school: _________confidential ______________________________

How long have you been teaching Grade R 3 years	**On average, how much time do you spend daily, just teaching mathematics?** 1 hour 30 minutes
How much time do you spend preparing for mathematics teaching every week? 35 minutes	**What are your THOUGHTS about mathematics teaching in Grade R in South Africa (how is maths going – do you think it is a good thing or a bad thing)?** I think we're trying but are not there. Once – I went to a workshop (DoE) but it did nothing. We still needed more. We are confused as teachers.
What are your most dominant FEELINGS about teaching Grade R mathematics (referring to how you teach it right now)? Great. I've got great results from children that have never attended school. They can count now and have number recognition.	**What do you think your Grade R children think about mathematics?** They love it. Especially 6 in group - we call it small group play.
How do you think your pupils will cope next year in Grade 1 mathematics? I think they will do very well. It will be easy for them because we've laid such a good foundation.	**Do you think you have been adequately prepared or trained to teach mathematics in Grade R (professionally and extra)?** Yes. Not professionally – but after the play-based programme I am fine. It is so interesting.

Do you have enough resources in your school to teach mathematics? Now – yes. Before the programme – no.	**If your school is teaching mathematics, which method you use most often** Play-based.
Which method do you believe is the most effective for teaching mathematics Grade R? Play-based. It has good results.	**Do you like teaching maths?** Yes.
What sometimes scares you the MOST about teaching maths? Nothing anymore.	**Do you think your children have improved in their MATHS REASONING because of your mathematics teaching this year?** Yes - a lot
Has the mathematics programme of 2014 matched the level of children in your school (too hard/ too easy)? It was easy. I did revision with my slower ones in my spare time.	**How are you planning to teach mathematics next year?** The same programme I used. I won't change.
Where do you believe we are MOST "going wrong" in teaching maths in Grade R South Africa? Giving more resources. Qualified teachers. More training – especially in maths. Make it more FUN. Everyone will love it if it's more fun and enjoyable and friendly.	**What have learned about teaching mathematics this year (summarise for me)?** I am doing a good thing for them. Maths is more than counting. Kids must think for themselves and be independent thinkers.
What is difficult or not enjoyable in your current maths syllabus? Nothing. I wouldn't change. I would add on more things.	**What problems do you think that you might be facing that other Grade R teachers aren't?** I have no ceiling in my class. My class is sometimes too small for the programme. I would

	like to use my class's space more to work around this.
What do you like the most about your maths syllabus right now? Everything. I love wordsums. They're tricky but they make one think.	**How do you think we should teach maths in grade 1?** The same as grade R. Play based. It must be the same.
What do you think of the test? It was disappointing. I wanted my children to perform much better. The questions were fine. I don't like pen and paper idea.	

Open comments:

To start with I am glad this day came. I have waiting a long time for this day. I wish you well in your research and I am happy that we are finally getting results. I want to know what the results are like.

ADDENDUM E

cumlaude
languagepractitioners

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DECLARATION OF LANGUAGE EDITING

I, Christina Maria Etrecia Terblanche, hereby declare that I edited the article entitled:

Teacher directed play as a tool to develop emergent Mathematics concepts – a neuro-psychological perspective

for Erika G. Helmbold for the purposes of submission as a postgraduate dissertation. No changes were permanently affected and were left to the discretion of the student.

Regards,

CME Terblanche

Cum Laude Language Practitioners (CC)

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