Gr R teachers' understanding and implementation of the mathematical content knowledge of space and shape

by

Justine Mclachlan

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Supervisor: **Prof C.G. Hartell**
Co-supervisor **Dr. L. Bosman**

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DEDICATION

I dedicate this research to Our Heavenly Father, for providing me with the strength and determination to conquer any challenge…

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ABSTRACT

Globally, the importance of teaching mathematics to young children has rapidly increased. The concepts of space and shape are one of the mathematical content areas of mathematics that young children should explore, and Grade R teachers ought to understand and implement. Numerous theorists, researchers and authors have provided valuable insights and research on why Grade R teachers should be effectively teaching the mathematical content of knowledge of space and shape in their classrooms.

In South Africa, several influences and contributing factors make it a challenge for Grade R teachers to implement the mathematical content knowledge of space and shape. This study sought to gain an insight in how Grade R teachers understand and implement the mathematical content knowledge of space and shape.

The conceptual framework was developed from existing theories and research literature. A constructivist approach was followed. The framework comprised six levels to explain how Grade R teachers' mathematical and pedagogical knowledge develops. The framework assisted in formulating questions and methods for the data collection process. The collected data was organised, transcribed and analysed.

The study employed a qualitative case study design to generate data from five Grade R teachers' experiences, views, ideas, opinions and perceptions on teaching the mathematical concepts of space and shape. Data were collected from the five teachers through participant observations, semi-structured interviews, documents and keeping a journal. The data analyses and findings support the themes and subthemes to answer the research questions.

The findings from the research revealed that teachers should implement various innovative teaching approaches to facilitate active participation, so that the children could make their own meaning and understanding of the mathematical content of space and shape. Age-appropriate content and materials that scaffolds on children's prior knowledge were found to be important strategies for effective teaching and learning. Teachers and their schools have a responsibility to establish positive learning environments as well as positive learning experiences for the children. The teachers in the study raised their concerns about the Curriculum and Assessment Policy Statements as they felt that they lacked creativity and guidance. Various factors with a negative impact on teaching and learning were identified and recommendations were made for improvement. The study concludes that Grade R teachers would benefit from gaining an in-depth understanding of the effective implementation of the mathematical content knowledge of space and shape.

Key Terms: Gr R teacher, understanding the mathematical content knowledge of space and shape, implementing instructional approaches and activities, scaffolding children's development for learning space and shape concepts, CAPS curriculum, learning environment

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Translating.Writing.Editing

Hester van der Walt
HesCom Communication Services
Member: Professional Editors' Group

+27 84 477 2000
+27 12 379 2005
Fax2mail 086 675 9569

hester@hescom.co.za
hmvanderwalt@telkomsa.net
PO Box 30200
Wonderboompoort 0033
633 Daphne Ave
Mountain View
0082

LANGUAGE EDITING STATEMENT

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- Has been edited for language correctness and spelling.
- Has been edited for consistency (repetition, long sentences, logical flow)
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The edit has been done in tracked changes in Word, and the final responsibility for correctness rests with the client.

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LIST OF ABBREVIATIONS

ANA	Annual National Assessments
CAPS	Curriculum and Assessment Policy Statements
CDE	Centre for Development and Enterprise
DBE	Department of Basic Education
DoE	Department of Education
DHET	Department of Higher Education and Training
2-D	Two-dimensional
3-D	Three-dimensional
ECE	Early Childhood Education
FP	Foundation Phase
Gr R	Reception Year
IIE	Independent Institute of Education
MCK	Mathematical content knowledge
NCTM	National Council of Teachers of Mathematics
NEEDU	National Education Evaluation and Development Unit
PCK	Pedagogical Content Knowledge
TIMSS	Trends in Mathematics and Science Studies

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INTRODUCTION AND ORIENTATION TO THE STUDY

"To teach is first to understand" (Shulman 1987:14)

1.1 Introduction

Teaching mathematics effectively to young children is not a new concept, but it remains critically important. National and international "educational policy documents outline the mathematical concepts that young children should acquire in the early primary grades of their formal schooling" (Steyn 2014). "The teaching and learning of Foundation Phase (Gr R-3) (FP) mathematics involve more than just acquiring the knowledge of several notions and skills" (Ministry of Education 2012). Numerous researchers have found that "the teaching and learning of mathematics during the reception year (Gr R) demand specific pedagogical approaches, which allow children to construct their own mathematical knowledge and to communicate, investigate and solve mathematical problems posed to them" (Billstein Libesking & Lott 2013; Van de Walle, Karp & Bay-Williams 2013). Mathematical teaching "includes different types of knowledge, such as mathematical instructional approaches, mathematical content knowledge (MCK), knowledge of children, knowledge of the curriculum and the mathematical language that teachers use when teaching the MCK of the concepts of space and shape" (Bahr & De Garcia 2010). Furthermore, MCK "is concerned with the knowledge of the mathematical concepts, rules and procedures of doing mathematics" (Hill 2010; Van de Walle *et al.* 2013).

In the South African setting, the Curriculum and Assessment Policy Statements (CAPS) comprise a policy document that offers guidelines for teachers to teach knowledge, skills and strategies from Grade R-12 (DBE 2011). CAPS for the Foundation Phase (Grade R-3) was implemented in 2012 and has been used ever since. The CAPS document specifies that learning and teaching in Gr R should focus on four subjects (Home Language, First Additional Language, Mathematics and Life Skills). Mathematics comprises of five content areas with detailed outcomes for knowledge, concepts and skills, namely numbers, operations and relationships; patterns, functions and algebra;

space and shape; measurement; and data handling (DoE 2011). In the content area of space and shape, Gr R teachers are required to focus on teaching the properties, relationships, orientations, position and transformations of two-dimensional (2-D) shapes and three-dimensional (3-D) objects as stipulated in CAPS (DoE 2011). Space and shape constitutes an important part of young children's mathematical development. Teaching of this content area should be spread out over each week's programme, with some focused episodes under the guidance of the teacher, and countless opportunities for construction, sand and water play by the children (DBE 2011:37).

In this study, space and shape is also referred to as geometry. "It comprises one of the initial mathematical content areas of mathematics that young children instinctively review and explore, and teaching should focus on this facet" (Frobisher 2007:6). Geometry refers to the "study of shapes, their relationships, and their properties" (Bassarear 2012:463). Furthermore, "geometry deals with the spatial relationships between real things. Knowledge of geometry and geometrical reasoning is not acquired through passive consideration, but rather through active interaction with and exploration of shapes" (Clements & Sarama 2000).

Frobisher *et al.* (2007:19) comment on children's learning: "In their learning of shapes and space children experience and understand the connections between knowledge, concepts and skills in the different facets of geometry". Battista (2007) adds that "teachers should be mindful of a child's environment and employ a more practical approach (play-based) to teaching geometry that draws on a child's sense of space (or spatial sense). Spatial sense is defined as the understanding of shapes by describing their characteristics and their relations to each other".

Space is a multifaceted area of learning to define. Space can be described by classifying objects in two categories. These categories consist of positions and movement. Objects can be labelled in relation to their position, such as inside or outside, on top or underneath, in front or behind, as well as left or right (Ramollo 2015). Shapes and spaces are originated from objects found in nature, such as plants, leaves, tree trunks and rocks. However, these objects are seen as 3-D objects, rather than 2-D objects. In contrast, the familiar 2-D shapes studied in geometry are triangles, rectangles, and circles. Even though geometric shapes can be described informally and children can be taught the names of some prototypical examples, these shapes have mathematical definitions, which teachers should know (Ramollo 2015).

"Spatial sense consists of two important components of geometric knowledge. The first is spatial visualisation (the ability to visually compare shapes that have changed position on the plane for 2-D shapes or in space for 3-D shapes), which is essentially transformation geometry" (Bassarear 2012). The second is "spatial orientation, which operates when a fixed object is viewed from different points or when the position of an object is acknowledged (Battista 2007). "These two components of geometrical knowledge play an important role in children's ability to understand shapes and their properties through geometric reasoning and visualising the images, their properties and physical representations. With well-reasoned and well-executed instruction, children can use geometric reasoning – defined as "the invention and use of formal conceptual systems to investigate shapes and space" (Battista 2007:843) – to solve geometric problems as they develop their understanding of geometry. Spatial sense is informed by spatial reasoning, which, according to Bahr, Bahr and De Garcia (2010:390), is "at the heart of all mathematical strands" and comprises of "the ability to think and reason by comparing, manipulating and transforming a mental picture".

The term shape in this study will therefore mention the different parts and features of an object that can be observed and analysed. According to the CAPS document (DBE 2011), "the study of space and shape improves understanding and appreciation of the pattern, precision, achievement and beauty in natural and cultural forms. It focuses on the properties and relationships, orientations and positions, and transformations of 2-D shapes and 3-D objects" (DBE 2011).

Teachers should supply the children with activities and resources/materials that will inspire their curiosity and provide the means for making sense of mathematical concepts. Play provides children with the opportunity to learn more about mathematics. At the Grade R level, play can be designed into free play and focused play (Naudé & Meier 2014:203).

Throughout play, children should enjoy the activity and feel safe, and it ought to improve their self-esteem (IIE 2017). Also, "during play, children can repeat and rehearse reality until they are able to comprehend" (Naudé & Meier 2014). Children in the FP are highly energetic and enjoy playing (IIE 2017). It is, however, important that geometry should be taught effectively so that children can understand the concepts of space and shape. This study therefore investigated how Gr R teachers understood and implemented the MCK of space and shape.

1.2 Problem statement

In "recent years, questions have been raised about the effectiveness of the teaching and learning of mathematics in a South African context" (Kruger 2011; Rademeyer 2014; Van der Merwe 2014). "The international literature states that the teaching and learning of certain mathematical concepts are challenging for mathematics teachers and children" (Charlesworth & Lind 2013; Cockburn 1999; Dunphy 2009; Holmes 1985; Orton & Wain 1994; Van de Walle & Lovin 2006).

South Africa is fact facing a mathematics crisis from as early as preschool. Several reports such as the National Education Evaluation and Development Unit (NEEDU), the National Report Summary (DBE 2012b) and the Report on the Annual National Assessments (DBE 2012a) disclose that FP children perform poorly in both international studies (Trends in Mathematics and Science Studies) and national tests such as the Annual National Assessments (ANA). The reports explain that South African children perform "below acceptable levels in reading, writing and counting" (DBE 2011; 2012:6 et seq.). It would seem that if children struggle with counting, they would struggle with basic geometry too. Furthermore, "a study by the Centre for Development and Enterprise (CDE) (2013) specified that teaching and learning of mathematics" in South Africa was "amongst the worst in the world as teachers themselves struggle to respond to questions that they are teaching from the curriculum, and expecting the children to answer". Green (2011) also states that "teachers lack mathematical knowledge". Therefore, it could be assumed that this might be why teachers have difficulty in understanding and implementing the MCK of space and shape in Gr R. The study thus sought to understand how Gr R teachers understood and implemented the MCK of space and shape. It explored the relevant literature and theories and examined teachers' experiences, perceptions, understanding and approaches to the teaching of the MCK of space and shape. The factors that influence the teaching and learning of space and shape were also identified and discussed.

1.2.1 Research questions

The research study was grounded on a primary research question and four sub-questions.

Primary research question

How do Gr R teachers understand and implement the mathematical content knowledge of space and shape?

Secondary research questions

In order to answer the main research question, four sub-questions guided the study:

- How do Gr R teachers perceive the importance of space and shape?
- How do Gr R teachers explain the mathematical content knowledge of space and shape?
- How do Gr R teachers scaffold children's development of the mathematical content knowledge of space and shape?
- What is the gap, if any, between policy and practice in the teaching of the mathematical content knowledge of space and shape in Gr R?

1.3 Rationale of the study

I started teaching as a reception year (Gr R) teacher in 2013. In my first year of teaching, I realised that teaching mathematics in a primary school setting was important, but also more complicated than it seemed. My interest in space and shape (geometry) was sparked by the outcomes of the lessons I had planned and presented for this content area. Furthermore, the fact that many higher education institutions did not yet offer a qualification for Gr R teachers made me curious; I wanted to investigate how teachers understood the topic under study and what really happened during the prescribed allocated time for geometry in different Gr R classrooms in South Africa. Some teachers do not regard space and shape as a significant content area that could enhance learning for better overall results in mathematics (NAEY, NCTM 2010). CAPS allow teachers to use different instructional approaches to teach the MCK of space and shape (Luneta 2014). I therefore wanted to investigate how teachers taught mathematics.

After I had reviewed various studies (Luneta 2014; Wilmot & Schäffer 2015; Steyn 2014; Botha 2012; Smith 2015 and Ramollo 2015) in the literature on early childhood mathematics, I realised that in recent years, the focus has been mainly on researching mathematics as such. However, not much attention has been devoted to research on the teaching of space and shape before children start with formal schooling (Gr R). This motivated me to investigate Gr R teachers' practical implementation of the MCK of space and shape. I was also curious about how teachers perceive and implement the CAPS document. In the CAPS document, the weighting of Space and Shape (Geometry) for Grade R is only 15%, whereas the content area of Numbers, Operations and Relationships is the main focus of Mathematics in the FP which is 55% (DBE 2012a).

Therefore, because space and shape is such an important area for children to understand in their everyday life situations, the purpose of this study was to investigate Gr R teachers' experiences of their understanding and implementation of teaching space and shape.

1.4 Significance of the study

The study indicated that the teaching and learning of mathematics in the FP appears to be a crucial part of the South African curriculum. Because it was a qualitative study the results cannot be generalised to all school in South Africa, but the study does reveal some scientific evidence significant to Gr R teachers, such as how important geometry is for children's later mathematical success. It also provides empirical evidence of the nature of Gr R teachers' understanding and implementation of the MCK of space and shape.

The findings and recommendations of the study could therefore motivate Gr R teachers to adapt their approaches to teaching the content area of space and shape.

Grounded on the findings of the study about how the MCK of space and shape is understood and implemented by teachers teaching in Gr R classrooms in South Africa, recommendations are offered to the Department of Basic Education, principals and Gr R teachers to inform them about the approaches, factors and challenges that influence teachers and the significance of space and shape in mathematics.

1.5 Purpose of the study

The purpose of this study was to explore how Gr R teachers understood and implemented the MCK of space and shape in their classrooms. Teachers' perceptions, views and opinions were examined to gain an insight in their understanding when teaching space and shape to children and assist their learning in their school context.

Particularly, the study has aimed to:

- gain insight in the importance and understanding of space and shape teachers need to have through a literature review.
- identify the factors that in Gr R teachers' views influence the teaching of the MCK of space and shape.
- explore the teaching of space and shape concepts through interviews and observations to identify different instructional approaches.
- explore the use and understanding of the correct mathematical language when teaching space and shape at Gr R level.

1.6 Concept clarification

To improve the general understanding and application in the context of this study, key concepts are discussed and explained. The concepts are Foundation Phase, mathematical content knowledge, teaching space and shape, and understanding the mathematical concepts of space and shape.

1.6.1 Foundation Phase

In the South African context, “the FP is the initial phase of the General Education and Training band” (Steyn 2014). The FP has been sectioned into four grades, i.e. Gr R, 1, 2 and 3. Conferring to the Department of Basic Education (DBE) (2011), “children in this phase are aged five to nine years. In this study, the emphasis has been on Gr R teachers and how they teach five- to six-year-old children”.

Reception year (Gr R)

Grade R is also termed the Reception year. It is the year before a child starts with formal schooling in Grade 1, hence “Grade R is the final year of the preschool phase” (Excell & Linington 2015). The Reception year includes children aged five to six years.

Grade R teacher

Gr R teachers teach children aged five to six years. In this study, the emphasis was on Gr R teachers and how they understood and implemented the content area of space and shape in mathematics. According to Excell and Linington (2011), “Gr R teachers are teachers who should be able to demonstrate a comprehensive understanding of the many theoretical perspectives that inform early childhood education (ECE), including how children learn”. Gr R teachers should also create a suitable early-learning environment, and implement the play-based curriculum documented in CAPS.

1.6.2 Understanding the mathematical content knowledge of space and shape

Understanding is defined by the Oxford Dictionary Online (2014) as: “knowledge, awareness, insight, and skill”. The term *understanding* is “a part of knowledge that represents teachers’ personal experiences and beliefs” (Steyn 2014).

Even though Grade R children are not engaging in mathematics in a formal setting, their teachers require a thorough understanding of what mathematics is. “Teachers also need to understand how children learn mathematics, to plan activities that will stimulate their curiosity and enable them to make sense of mathematical concepts” (IIE 2017).

Mathematics are contextualized when teachers' pose everyday problems for children to solve using their mathematical skills (Naudé & Meier 2014). An attribute that teachers can benefit from when introducing formal mathematics is children's curiosity and the fact that they tend to have a natural inclination to discover and make sense of their world. "Mathematics is therefore a vital part of the young child's world" (Excell & Linington 2015).

Children need to interact with objects or materials that are concrete, which they can touch, see, smell, feel and taste. It is important for them to be actively and playfully involved in the process. "When teachers initiate learning, they should not only focus on the MCK, or what the child should know, but also on how the child will obtain and apply this knowledge" (Steyn 2014). Olsson (2009:184) states that "teachers need to be well *informed* to initiate learning" and to give children as "many perspectives as possible on the content knowledge". Effective learning of mathematics transpires when a challenging environment joined with the curious nature of the young child requires children to test mathematical ideas for themselves with hands-on experiences (Naudé & Meier 2014). In this study *understanding*, *understand* and *understands* refer to Gr R teachers' knowledge, comprehension and interpretation of the mathematical content of space and shape.

1.6.3 The implementation of the mathematical content knowledge of space and shape

For the purpose of this study, the term *implementation* refers to how Gr R teachers handle the teaching and learning of the MCK of space and shape. It refers to the habits in which the mathematical concepts of space and shape are put into effect by Gr R teachers.

Mathematics

In this study, FP mathematics refers to the subject Mathematics, in which Gr R teachers teach the mathematical content of space and shape in a South African context. According to the DBE (2011), mathematics teaching in the FP should focus on developing children's confidence in mathematical knowledge that they can use daily. Space and shape is one of the five content areas of the FP mathematics. The additional four content areas are numbers, operations and relationships, patterns, functions and algebra, measurement, and data handling.

1.6.4 Mathematical content knowledge

MCK is concerned with what teachers and children know about the "concepts, rules and procedures of doing mathematics" (Hill *et al.* 2008; Van de Walle *et al.* 2013).

Pedagogical content knowledge

"Pedagogical content knowledge (PCK) refers to how teachers transform their knowledge of the mathematical content of space and shape into a form that is accessible to children" (Ramollo 2015). Furthermore, it contains the "knowledge of how to use resources, representations or analogies for teaching mathematical ideas and how to break down ideas to explain concepts to children" (Rowland *et al.* 2010).

Pedagogical knowledge

In this study, pedagogical knowledge refers to the broad knowledge that teachers require for effective classroom practices (Ramollo 2015). This knowledge "includes content knowledge, knowledge about how to teach, methods, approaches and knowledge about the curriculum and knowledge about the discipline and classroom management" (Brijall & Isaacs 2010).

Curriculum and Assessment Policy Statements

"CAPS is a single, comprehensive, and concise South African school curriculum policy document, which stipulates the depth and breadth of MCK, skills and values children should learn in each grade in South Africa" (DBE 2012a).

Learning through play

The Oxford Dictionary Online (2014) defines learning as: "acquiring knowledge, realize, be aware, discover". *Learning through play* means that children learn something when participating in playful learning activities that consist of physical, cognitive, social and emotional development (Nicolopoulou *et al.* 2010). Affording to Ochiogu (2013), "learning through play can be put into effect by teachers who notice their own role in children's play.” To become familiar with and fluent in mathematics, children need to experience meaningful, interesting and worthwhile activities. In Grade R, “the child is part of an informal setting and the focus should be on learning through exploration and play” (Naudé & Meier 2014).

1.6.5 Space and shape (geometry)

Space and shape (geometry) comprises one of the first mathematical content areas of mathematics that FP children spontaneously and explore, and teaching should focus on this facet (Frobisher *et al.* 2007:6). Geometry refers to the “study of shapes and space, their relationships, and their properties” (Bassarear 2012:463). Furthermore, “geometry deals with the spatial relationships between real things. Knowledge of geometry and geometrical reasoning is not acquired through passive consideration, but rather through active interaction with and exploration of shapes (Clements & Sarama 2000). In this study, the concept of *space and shape* is encapsulated in the term geometry.

1.7 RESEARCH METHODOLOGY

The research methodology is described in the following order: research approach and design, selection of participants, data collection methods and data analysis.

1.7.1 Research approach and design

“The study employed a qualitative research approach using a case study design within an interpretive paradigm” (Maree 2010). McMillan and Schumacher (2010) describe qualitative research as an analysis of people’s individual and collective social actions, beliefs, thoughts and perceptions that is primarily concerned with understanding social phenomena from the perspectives of participants. Merriam (2009) believes “that in a qualitative research design, the researcher is regarded as the main source of data collection and analysis.” I interviewed teachers and observed their lessons to investigate how they understood and implemented the MCK of space and shape (Creswell 2012). This study had the following characteristics (Yin 2011:7):

- It represented the interpretations and viewpoints of teachers in the study.

- It enclosed the contextual condition within which the teachers teach MCK of space and shape.
- It provided insights into existing or emerging concepts that helped to explain how teachers understood and implemented the MCK of space and shape.
- It employed multiple case studies rather than depending on a single source.

The qualitative research approach was used since it allowed for and presented a body of in-depth, rich and descriptive data about the experiences and views of teachers about the phenomenon under investigation, instead of merely validating my own assumptions (Creswell 2012). The purpose was to investigate five Gr R teachers in their natural (school) setting. Interviews were conducted and audio-recorded in English in each teacher's classroom (Merriam 2009). Moreover, the aim was to obtain a "deeper understanding" of the instructional approaches that teachers used when teaching the mathematical content area of space and shape (Nieuwenhuis 2007:75).

A multiple case study design was chosen to form a "detailed, holistic and contextualised account of the dynamics underlying the group processes" (Fouché & Schurink 2011:322; Maree 2010:75-76). According to Yin (2014:16), "a case study is an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life contexts." In addition, Yin (2014:10) states that "multiple case study methods are particularly appropriate when research questions start with "how?" or "why?" Yin (2009) also argues that case studies are used to understand a real-life phenomenon in depth; however, such an understanding encompasses important contextual conditions, because these conditions are highly pertinent to the phenomenon or phenomena explored in various research studies.

Furthermore, the study employed multiple data collection methods. These methods encompassed participant observations, semi-structured interviews with each teacher at the three primary schools at which the Gr R teachers taught, and document analysis. These data collection methods helped to investigate and understand teachers' experiences, perceptions, views and opinions when teaching the MCK of space and shape.

1.7.2 Sampling procedure

The study adopted purposeful sampling to select five Gr R teachers from three different primary school settings according to “a specific criterion that allowed the researcher to obtain an understanding of the research problem” (Strydom & Delport 2011:392). Duncan and Noonan (2007) state that “purposeful sampling has elements of theoretical sampling and identifying people who fit the criteria for desirable participants”.

The samples were selected grounded on the following characteristics:

- The primary schools should offer Gr R facilities.
- The primary schools should have access to the basic teaching resources for teachers to impart the MCK of space and shape.
- The Gr R teachers had to be able to provide evidence of activities they planned or implemented when teaching the MCK of space and shape in their classrooms.
- The Gr R teachers had to be proficient in English as the language of learning and teaching (LoLT).
- The Gr R teachers should have three years or more of teaching experience.
- The teachers should have a qualification in early childhood development (ECD) at an accredited institution.
- The three primary schools should be situated in a residential area in Pretoria, Gauteng.

1.7.3 Data collection process

After obtaining my ethical clearance certificate in January 2017, I collected and analysed the data. The objective was to collect contextually rich data over a period of one to two months. The data collection consisted of four phases. In Phase 1, I contacted the primary schools and Gr R teachers asking permission to conduct research at their respective schools. This phase included informing the teachers of the data collection methods and ethical considerations.

Phase 2 entailed observations that were documented by means of field notes. This phase included visiting the primary schools and observing the three Gr R teachers in their natural settings while teaching a lesson based on the MCK of space and shape. The parents concerned had to give their consent for their children to be present in the classroom, but no information about the children is discussed in this study. Photos were taken of the manipulatives (objects) and the process of the lessons, presented in chapters 2 and 4. Each photo was captioned to explain the manipulatives and representations of the activities during the lessons observed.

In Phase 3, the participants were invited to participate in individual semi-structured interviews. Teachers were asked predetermined questions formulated to answer the research questions of the study. The interviews were conducted at a time and date most convenient to the teachers, and lasted between 30 and 45 minutes. The semi-structured interviews were audio-recorded in English and field notes were made during each one.

In Phase 4, the last phase, the collected data were transcribed and analysed into a number of categories that were afterwards divided into a few manageable themes and subthemes (Ryan & Bernard 2003). Table 1.1 depicts the four phases.

Table 1.1: Phases of data collection

PROJECTION OF DATA COLLECTION			
PHASE		DATA COLLECTION STRATEGY	OBJECTIVE
PHASE 1	Administration	Ethical clearance	Obtain permission to conduct research
		Contact participants	Establish relationships
		Correspondence with participants	Explain nature and intent of study
PHASE 2	Observations	Data were collected through participant observations and document analysis from five Gr R teachers teaching at three different primary schools in the region of Pretoria, Gauteng	To obtain rich data, as part of Gr R teachers' individual experiences and their understanding and implementation of the MCK of space and shape
PHASE 3	Semi-structured interviews	Data were collected by means of semi-structured interviews with five Gr R teachers teaching at three primary schools that had Gr R classes	To explore Gr R teachers' understanding and implementation of the MCK of space and shape
Phase 4	Analyse collected data	Analyse data	To establish themes and subthemes to answer the research questions posed in the study.

1.7.4 Data collection instruments

The data collection instruments used in the study were participant observations, semi-structured interviews, document analysis and journal-keeping (field notes).

"Participant observation is observing the actions of research participants" (Henning *et al.* 2004). The observations in this study were undertaken in the participants' classrooms (Petty *et al.* 2012; TerreBlanche & Durrheim 1999). Participant observations enabled me to assess the teachers' understanding of concepts and of teaching approaches in Phase 2 (Table 1.1).

Delport, Fouché and Strydom (2007:292) define semi-structured interviews as "being organised around areas of particular interest". I therefore used the semi-structured interviews to collect data from teachers about their understanding and implementation of the MCK of space and shape. The participating teachers were also asked about their perceptions and opinions of other teachers in terms of the teaching of the MCK of space and shape. They met other teachers at the Department of Basic Education workshops and cluster meetings and therefore had information about their colleagues and their challenges and performance. The individual interviews were guided by open-ended questions. The semi-structured interviews were audio-recorded and transcribed. In addition, these interviews guided the study by "eliciting in-depth responses, because the teachers were made to feel comfortable" (Mills *et al.* 2010). They were reassured that the recordings could be paused at any time if they wanted to and that they could withdraw at any time should they wish to do so.

The relevant literature and theories were reviewed to establish a comprehensive literature background of the topic under study and to construct a conceptual framework that guided the research process. According to Petty, Thompson & Stew (2012), "document analysis includes written work, drawings and pictures". "Document analysis formed part of this study and served to triangulate evidence from different sources" according to (Steyn 2014). CAPS were the primary document consulted in the study (DBE 2011). It provides guidelines to teachers on the content of subjects and how it should be taught to enhance children's learning. I also took photos and teachers provided me with their lesson plans.

Journal keeping (field notes) was used throughout the data collection process of this study. McMillian and Schumacher (2006:359) state that fieldnotes are "detailed descriptive recordings of events, actions and objects in settings". This method was used to collect notes of all the site visits.

1.7.5 Data analysis

Bromley, as cited by Maree (2007:75) states that multiple case study research is a "systematic inquiry into an event or a set of related events, which aims to describe and explain the phenomena of interest". The teachers were purposefully selected according to the characteristics required in this study (Strydom & Delport 2011:392). The data collected from the observations, semi-structured interviews, documents, and journal keeping revealed what needed to be analysed. De Vos, Delport, Fouché and Strydom (2011) propose an integrated process for qualitative data analysis. Data analysis is a creative and logical process of gathering and arranging data into themes and subthemes so that the analytical scheme becomes obvious (Walker, Cooke & McAlister 2008). In this instance, it revealed how Gr R teachers understood and implemented the MCK of space and shape.

Ryan and Bernard (2003:85) state that analysing text involves several tasks:

- discovering themes and subthemes (on Gr R teachers' understanding and implementation of space and shape)
- examining themes to select a manageable few
- linking themes into theoretical models related to the topic of this study

The body of collected data was consequently transcribed, coded and analysed to obtain themes and subthemes.

1.8 Ethical considerations

Ethical guidelines serve as a standard and a basis upon which researchers should evaluate their conduct during their research process. Standards should be internalised into the personality of researchers (De Vos *et al.* 2011). Five Gr R teachers were the participants. The research setting consisted of three primary schools. The primary school principals were asked in writing for permission to conduct the research at their respective primary schools. Consent letters were given to the participants, asking their consent to participate in the study and informing them about the procedures and purpose of the study. Participants were informed of their right to withdraw from the research process at any time, should they wish to do so. The consent letters were given to the participants before the research process began. The procedures that the researcher would follow were clearly communicated. The privacy of the participants was respected and confidentiality was ensured, thereby gaining the trust of the participants. The participating teachers were given pseudonyms. They were assured that their names would not be used in the study and that they would remain anonymous.

The following principles guided the process of confirming ethical conduct during the proposed research study:

- **Informed consent**

  Duncan and Noonan (2007) stipulate that participants (the Gr R teachers in the proposed study) should be informed of the nature and purpose of the research, possible risks and benefits, through consent letters. The participants were kept informed and consulted during every step of the research process. This strategy ensured a good relationship between myself and the participants.

- **Voluntary participation**

  The Gr R teachers were informed about the research procedures, and assured that participation was voluntary and that they could withdraw at any time during the study, with no negative consequences (Strydom 2011b:115).

- **Confidentiality and anonymity**

  The participants were assured that the data collected during the research process would remain anonymous and confidential and that none of the data would be exploited or published without their consent.

- **Privacy**

  During the research process, the researcher made sure that no harm befell the teachers or other parties involved. The aim was to resolve any conflict as soon as possible. The rights and welfare of the participants were protected at all times (McMillan & Schumacher 2001). The participants were treated with dignity and respect.

- **Safety**

  The teachers were never at risk of being harmed.

- **Trust**

  I gained the trust of the participating Gr R teachers by always presenting myself as a professional researcher with professional standards. I took full responsibility for my behaviour and tried to avoid any conflict of interest that could have led to harm if it was not dealt with in the correct manner. By complying with these ethical considerations, I established and maintained a relationship of trust between myself and the participants throughout the research process.

1.9 Chapter outline

In conclusion, the following outline of the study summarises the content of each chapter.

Chapter 1

Background and orientation of the study

Chapter 1 provided a framework for the reader, describing the background to the study and its problem statement, rationale, significance and purpose, together with a brief discussion of the research methodology. The key concepts were discussed.

Chapter 2

Literature review

Chapter 2 discusses the literature review. The literature focuses on the research questions posed in this study. The review of the literature has offered a wide spectrum of relevant theories and literature. A conceptual framework has been designed that guided the analysis of the data.

Chapter 3

Research methodology

In Chapter 3, the research methodology of this study is discussed. It explains why certain research methods and approaches were used to answer the research questions of the study. This chapter outlines the chosen qualitative research approach using a multiple case study design within an interpretive paradigm.

Chapter 4

Data analysis and findings

Chapter 4 consists of the results and findings of the five cases, describing the teachers' understanding and implementation of the MCK of space and shape. In this chapter, five cases of teachers understanding and implementing the MCK of space and shape is presented.

Chapter 5

Chapter 5 provides a discussion of the research process supported by a graphical representation. A comparative analysis of the research findings of the study with the relevant concepts and theories from the literature are discussed here.

Chapter 6

In Chapter 6, a synopsis of the study is provided and the research questions are answered. Recommendations, limitations of the study and a conclusion complete the study.

CHAPTER 2:
LITERATURE REVIEW

2.1 Introduction

Chapter 2 consists of a comprehensive review of the relevant literature on the teaching of the MCK of space and shape. The literature review focuses firstly on the theoretical perspectives within this study, which provide an insight into how children learn and Gr R teachers teach the mathematical content knowledge of space and shape. Secondly, it reviews the different teaching and learning components, including the mathematical and PCK that Gr R teachers need to teach the mathematical concepts of space and shape. Thirdly, it outlines the factors that influence the development and importance of mathematical processing skills. Lastly, the factors influencing the implementation, learning and teaching the mathematical concepts of space and shape are discussed, followed by the conceptual framework of the study.

2.2 Theoretical framework

The study reviewed the several aspects of the constructivist theoretical perspective deriving from the work of Jean Piaget (1896−1980) and Lev Vygotsky (1962), as well as the Van Hiele model of geometric thought for the development of a mathematical understanding of space and shape (Van Hiele 1986; 1999), as points of departure. These theories emphasise teachers' and children's active participation in teaching and learning, as prescribed in the South African curriculum statement, (DBE, 2012a). The Van Hiele model of geometrical thought is a suitable theory for this study and is a framework that teachers can employ in their classrooms.

2.2.1 Constructivism and teaching mathematical content

Constructivism is entrenched in the cognitive institute of psychology and in the theories of Piaget (Von Glasersfeld 1995) and Vygotsky (1962). Wood (1989:39) states that constructivism "brings aspects of Piaget's and Vygotsky's work together". The theory focuses on "the way in which knowledge is constructed by actively building new ideas and concepts through experience" (Powell & Kalina 2009:241). According to Naudé and Meier (2014), "it is an important theory for mathematics learning and teaching." In this study, it focused on the content area of space and shape. According to the Department of Education (DoE) (2011:3) in South Africa, one of the aims in the curriculum is to "find foundation in constructivism − when teaching in Gr R, therefore, teachers must start with what children know and then build on it". Naudé and Meier (2014:5) note that constructivism is concerned with "how we come to know" what we know. The work of Jean Piaget and Lev Vygotsky has been fundamental to the development of constructivism.

According to Hmelo-Silver (2014:1), constructivism is defined as follows:

> *Constructivism, as a perspective in education, is based on experimental learning through real-life experience to construct and conditionalize knowledge. It is problem-based, adaptive learning that challenges faulty schema, integrates new knowledge with existing knowledge and allows for the creation of original work or innovative procedures.*

The next section discusses the historical background to constructivism based on the theories of Piaget and Vygotsky. Hmelo-Silver (2014:2) "traces the historical origins of constructivism to early philosophers, such as Socrates, who believed in guiding children to construct their own meaning instead of allowing the teacher to "download" information to them" (Ramagoshi 2015).

2.2.1.1 Jean Piaget (1896-1980)

Ramagoshi (2015:72) cites Hmelo-Silver (2014:2), around 1896-1980 Piaget discovered that "the way a child learns and thinks changes as they grow" (Ramagoshi 2015). Piaget (1952) believed that knowledge does not only exist in the outside world or in an adult but is inherent in a child. Additionally, constructivists believe that learning is affected by the context in which an idea is taught as well as by children's beliefs and attitudes (Piaget 1954; Ramagoshi 2015). Piaget (1954) believed that children construct knowledge of the world through assimilation and accommodation, but emphasised that biological maturity is necessary. According to Piaget, the child learns through experiences, and the teachers' role is therefore to ensure that the environments in which children learn are interesting and stimulating, to enable them to learn and to develop intellectually. Cobb (1996:13) states that the "theoretical basis of social constructivism is largely inspired by the work of Vygotsky". According to Van de Walle and Lovin (2006), Piaget encouraged teachers to focus on children's prior knowledge, while Vygotsky suggested that children should socially interact with the environment, which in turn will promote mathematical understanding. Teachers who are seeking instructional approaches could benefit from studying social learning theories to understand how children actually learn through social interaction (learning from each other). Thus, both theorist propose that children will not attain a conceptual understanding of space and shape if Gr R teachers teach children by telling them, using a teacher-centred approach. Piaget identified four stages of cognitive development (Table 2.1).

Table 2.1: Piaget's four stages of cognitive development

Stage of cognitive development	Stage of cognitive development	Age
Stage 1	Sensorimotor period	Birth to two years
Stage 2	The pre-operational stage	2−7 years
Stage 3	Period of concrete operations	7−11 years
Stage 4	Formal operational period	Adolescence

The pre-operational stage is the second stage of cognitive development and applies to young children between the ages of four and seven years, which includes children in Gr R. According to Piaget (1952), "children in this stage do not yet think logically and they are only starting to learn about mathematical symbols". As children advance through this stage, they develop language to express their thoughts and to solve problems (Piaget 1952). Piaget (in Woolfolk 2004) believed that "children's thinking in the pre-operational stage" is characterised by:

- egocentrism (the inability to consider another person's point of view)
- animism (the capability of attributing life and thinking to inanimate objects)
- irreversibility (the inability to mentally reverse a sequence of events)
- centration (the tendency to centre on only one aspect of a situation, while ignoring others)
- lack of conservation (the belief that two equal quantities remain equal even if the appearance of one has changed)

2.2.1.2 Lev Vygotsky (1962)

According to Ramagoshi (2015:72), citing the work of Vygotsky (1962), social constructivism means that "meaning and understanding grow out of social interaction and that cultural and social influences affect cognitive development." Social interactions with teachers, peers, the indoor and outdoor environment and manipulatives will therefore most likely develop children's understanding and implementation of the MCK of space and shape.

Vygotsky (1962) emphasised that "meaning and understanding grow out of social encounters." Vygotsky likewise trusted that learning is a dynamic, social process free of the phases of improvement and that kids will have the certainty to take an interest in classroom exchanges and numerical exercises on the off chance that they encounter an effective result in the wake of finishing assignments. "Vygotsky therefore maintained that the higher mental processes, like problem-solving, self-regulation and memory, are co-constructed during activities shared by children and other people." In this social setting, forms are disguised and moved toward becoming piece of the child's psychological advancement (Woolfolk 2010:43). Vygotsky's theory utilises the concept of 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 relatively equipped to accomplish by themselves" (Papalia & Feldman 2011:34). "Children performing mathematical tasks in this zone can almost, but not quite, perform the task on their own" (Hembold 2014). With the correct guidance, the child can be successful and the responsibility for learning gradually shifts from the adult to the child. "The ZPD is a dynamic, changing space in which the child and teacher interact and understandings are exchanged" (Woolfolk 2010:47). Inside this zone, children can grow better approaches of thinking, internalise new skills and reach new levels of potential advancement. When a "new level of thinking is reached, it becomes their actual developmental level, and the cycle starts again" (Bohlin *et al.* 2012:124). Vygotsky's theory is concerned with scaffolding children's learning processes. Similar to the provisional stages used to firm and support the construction of a structure, scaffolding refers to the brief social support obtainable to children to help them achieve a task. Parents, teachers or others support a Gr R child to do a task until the child is able to do the task unaided (Papalia & Feldman 2011:34). "Scaffolding children in their geometrical skills acquisition involves using rich geometric language and playing games with them" (Brown 2009:476-477). Teachers in Gr R classrooms can scaffold children's learning through employing Van Hiele's model of geometrical thought.

This study is embedded in the Van Hiele model for the development of a mathematical understanding of space and shape. In the next section, I discuss Van Hiele's model of geometrical thought and show how it relates to Piaget's stages of cognitive development and the CAPS curriculum.

2.2.2 Van Hiele model of geometrical thought for the development of mathematical understanding

The Van Hiele model was developed by two Dutch mathematics teachers, Pierre van Hiele and his wife Dina van Hiele-Geldof. The model these two mathematics teachers developed explains how children develop spatial geometrical concepts (Van Hiele 1986; 1999, Crowley 1987). Van Hiele's (1986) theory of geometric knowledge focuses on geometrical reasoning and has been allied to Piaget's four stages of children's development of representational thinking about space and shape, in relation to the role children play in learning the concepts of space and shape in Gr R (Pusey 2003).

Piaget (1952) argued that "children's geometric understanding develops with age and that in order for children to create ideas about space and shapes, they need to interact physically with their environment and objects. Clements *et al.* (1999:193) asserted "children's representation of space is constructed through the progressive organisation of the child's motor and internalized actions". Van Hiele (1986; 1999), on the other hand, examined various aspects of learning geometry, such as "teachers trying to communicate at the same levels as the children they teach. Van Hiele agreed with Piaget that "children think geometrically at different levels during their cognitive growth" (Pusey 2003). However, Van Hiele's levels of geometric knowledge are "not age-specific, whereas Piaget's stages of cognitive development are age-dependent." This advocates that "children's progression from one level to the next rest on the effectiveness of the teaching and content acquisition opportunities that Gr R children are exposed to" (Frobisher *et al*. 2007). This study is interested in how children's geometrical understanding develops. Van Hiele's model is relevant to this study since it helps to determine Gr R children's level of geometrical understanding. The model furthermore serves as a framework for Gr R teachers to "design activities with a specific level in mind, and to ask questions that are below or above a particular level" (Van de Walle 2004).

Van Hiele's theory of geometrical thought (see Figure 2.1) postulated that "there are five sequential levels of geometric thought" (Bahr *et al*. 2010; Musser, *et al.* 2011). According to Van Hiele, "children progress and develop their knowledge of geometry (space and shape) in accordance with the developmental course suggested by these levels" (Luneta 2013).

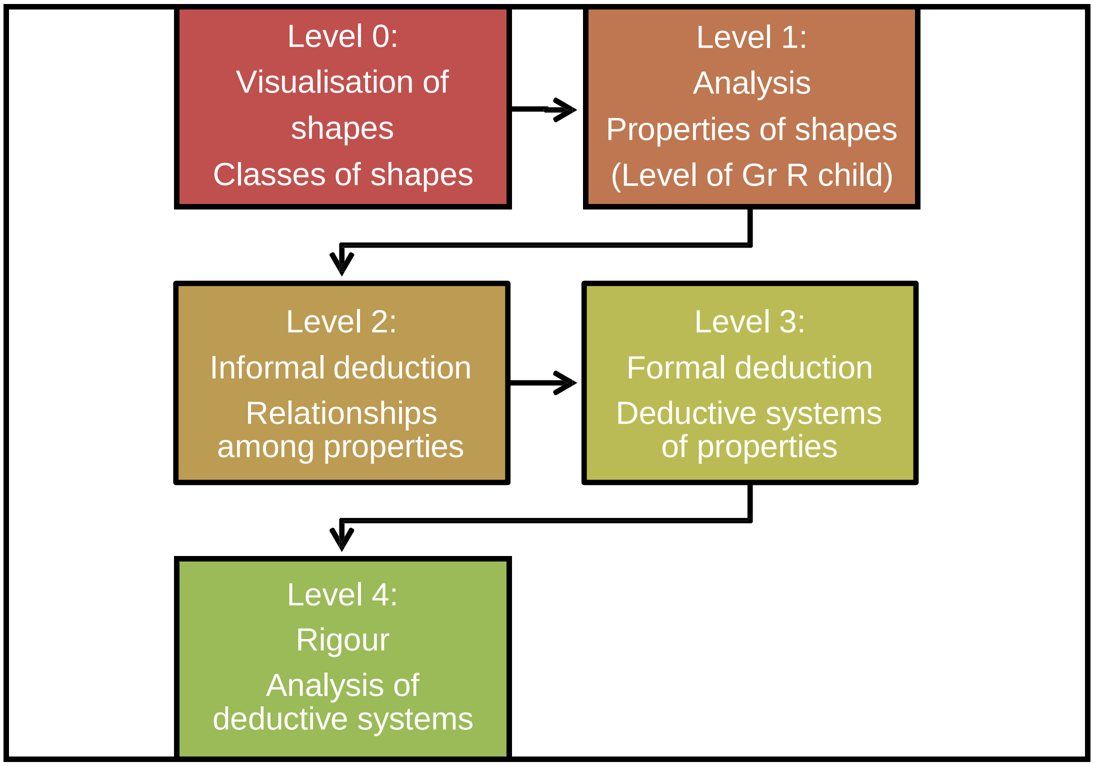

Figure 2.1: Van Hiele's theory of geometric thought (adapted from Van de Walle 2004:347).

The terms or words used in each of Van Hiele's levels define the type of thinking in which children have to participate in at each individual level. According to this model, "children move from the most basic level (visual), through to the most advanced level (rigour); teachers can help by giving the children suitable experiences at each level. Very few children in high school can operate at Van Hiele's level 4" (Crowley 1987).

The next section discusses each of Van Hiele's levels of geometrical thought for a better understanding of where Gr R children should be functioning. The levels are labelled *visualisation, analysis, informal deduction, formal deduction and rigour*. This revealed the characteristics of the thinking process (Burger & Shaughnessy 1986). Van Hiele's theory of geometrical thought helped me to observe whether the teachers in my study applied age-appropriate approaches in their lessons.

Level 0

Visual Level

At Level 0 (visualisation/recognition), children are capable of identifying a shape, but they are incapable to list the shape's properties. The children typically critic the shape by its appearance and not by the shape's properties. Children at this level additionally have a straightforward concept of space. "At this level, young children are able to identify different shapes, as they associate the shape with what they already know. According to Burger & Shaughnessy (1986), children see these shapes as a whole, without being able to analyse the shapes properties."

Level 1

Analysis Level

At Level 1 (analysis), which is a mainly the descriptive level, children are able to identify the properties of particular shapes, but not in a logical order. Furthermore, "children are able to analyse shapes in terms of their parts and properties but are not able to make any connections between different shapes" (Halat 2016). A child at this level ought to have the ability to perceive that a square has four sides and four angles that are all equal and that the diagonals of a square are equal and opposite bisectors of each other. However, children set at this level may have an incomplete comprehension of how the properties of shapes identify with each other. Level 1 represents the level at which Gr R children operate according to the assessment standards stipulated in the CAPS document (2012). For this study, "this level of the Van Hiele type of experience was aligned with the expected outcome of CAPS" (adapted from Bleeker 2011) (see Table 2.2.1).

Level 2

Informal Deduction Level

At Level 2 (abstraction/relationships), which is an informal deductive level, children can combine shapes and their properties to give an exact definition and to relate shapes to different shapes. Children can likewise exhibit a logical ordering of the properties; these are derived from each other, but they will most likely be unable to make another confirmation starting without no assistance.

Level 3

Formal Deduction Level

At Level 3 (formal deduction), children apply formal deductive arguments such as proofs and theorems within an axiomatic system. At this level, children are able to comprehend and use the ideas of formal geometry. Children understand how important deduction is, and can use it to build up a geometric theory based upon axioms and proofs in the identical method that Euclid used it. Children at this level learn how to do formal proofs and understand the importance of terminology, definitions, axioms and theorems in Euclidean geometry.

Level 4

Rigour Level

Level 4 (rigour/axiomatics), likewise known as the metamathematical level, is characterised by "formal reasoning about mathematical systems by manipulating geometric statements such as axioms, definitions, and theorems" (Van de Sandt 2007:1). Children at this level of geometric thought can also "compare systems based on different axioms and can study various geometries in the absence of concrete models" (Burger & Shaughnessy 1986:31). Children are therefore able to perceive geometry in an abstract manner. However, primary school children are not.to operate at this level.

"The first three levels show the development of procedural fluency in geometry and the last two the development of conceptual understanding" (Kilpatrick, Swafford & Findell 2001). Schneider and Stern (2010:178) describe conceptual knowledge as "providing an abstract understanding of the principles and relations between pieces of knowledge in certain domains". Star (2002) and McCormick (1997) similarly explain that procedural fluency is the "know-how-to-do-it knowledge" of mathematical knowledge, which involves the ability to quickly recall and accurately execute procedures. According to Danley (2002), it involves "engaging in practice with procedures and the manipulation of numbers."

Research on space and shape has "long focused more on procedures rather than concepts, but numerous studies indicate the importance of conceptual understanding to facilitate the application of procedural knowledge and to accomplish long-term retention of procedural competence" (Wolfaardt 2016). In addition, Wolfaardt (2016) states that "the use of physical and visual representations to facilitate conceptual understanding assists children in mastering and maintaining mathematical competence" on the mathematical content of space and shape in Gr R (see section 2.3.2.2).

In recent years, Van Hiele's model of geometric thought has been look upon as "the best framework known for teaching and learning geometry" (Mayberry 1983; NCTM 2000; Wu & Ma 2006), as it can be adapted to each geometrical level to align with the outcomes for teaching space and shape from Gr R to 12 in schools.

2.3 Teaching and learning components of the mathematical concepts of space and shape in Gr R

Turnuklu and Yesildere (2007) contend that Gr R teachers "should acquire PCK as well as MCK to enhance children's conceptual understanding of the mathematical concepts of space and shape". PCK consolidates knowledge about children's learning processes, as well as knowledge of mathematical instruction, while mathematical knowledge is subject-specific (Steyn 2014). The PCK in this study incorporates the knowledge of content and children. Gr R teachers should realize that children are "diverse, have different learning styles, are active problem solvers and are ready to build their own mathematical knowledge, and that children are capable of learning mathematics" (Charlesworth & Lind 2013). Figure 2.2 outlines the teaching and learning components of the mathematical concepts of space and shape in Gr R

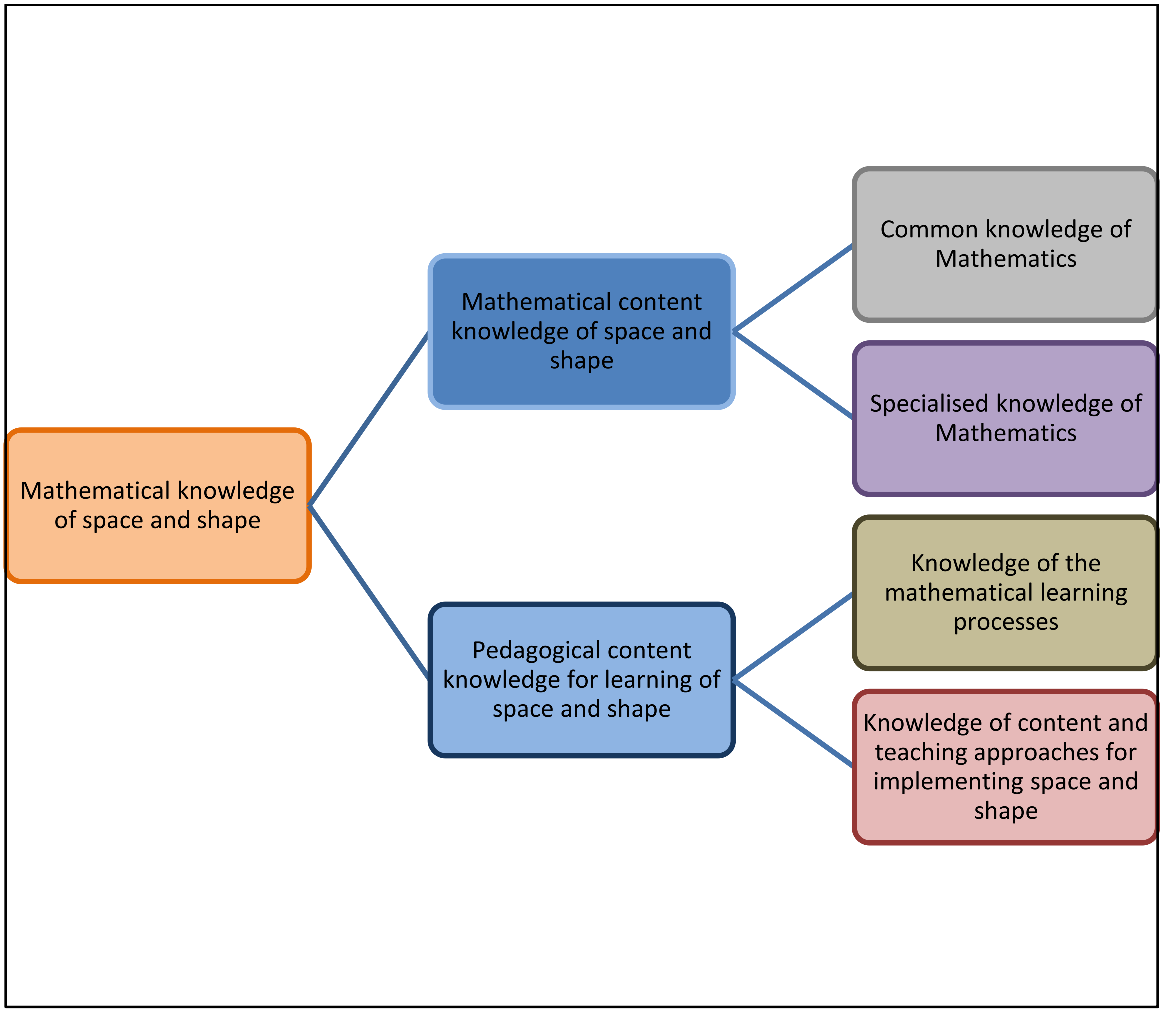

Figure 2.2: Teaching and learning components of the mathematical concepts of space and shape in Gr R, adapted from Ball *et al.* (2008)

Figure 2.2 illustrates that MCK and PCK, the components of mathematical knowledge, are interrelated. According to Ball *et al.* (2008:3), these components are linked, to ensure that "discussions of content are relevant to teaching and that discussions of teaching retain attention to content" on the topic of geometry (space and shape). In addition, Steyn (2014) states that: "it is therefore necessary for teachers to acquire common knowledge of the mathematical concepts of space and shape to identify a wrong answer, whereas specialized knowledge and knowledge of mathematical learning processes are required to identify the nature of problem-solving in mathematics". Steyn further posits that: "Deciding on how to best remediate problem-solving may require knowledge of" mathematical instructional approaches for Gr R teachers to successfully understand and implement the MCK of space and shape in their classrooms (Ball *et al.* 2008:11; Steyn 2014).

In the next sections, I discuss each component of the teaching and learning of the mathematical concepts of space and shape, since the aim of this study is to gain a better understanding of how Gr R teachers understand and implement the MCK of space and shape. The components include MCK, mathematical conceptual understanding, and PCK, as explained by Steyn (2014). I will now explain each component.

2.3.1 Mathematical content knowledge

Research suggests that "mathematical knowledge is constructed relationally" (Arzarello *et al.* 2005; Bransford *et al.* 2000; Rudd *et al* 2008; Van de Walle 2007) and that "new knowledge is learnt more effectively when it draws on real and relevant contexts – re-enforcing the idea of building on children's prior knowledge" (Barnes 2004; Freudenthal 1971). Content knowledge is knowledge of the subject matter, which, according to Hill *et al.* (2008:78) is divided into "common content knowledge" (CCK), commonly held as mathematical knowledge that anyone who knows mathematics would possess, and "specialised content knowledge" (SCK), or mathematical knowledge specific to the teaching of the subject as "the experiential knowledge and skills acquired through classroom experience" (Lee & Luft 2008). "Teachers need to know the mathematical content they teach and children need to understand the mathematical content" (Ball *et al.* 2008). Therefore, it is essential to define what MCK means in the context of this study. Ball *et al.* (2005) propose that "the MCK for the teaching and learning of geometry (space and shape) consists of two key elements: common knowledge of the MCK of space and shape and specialised knowledge of the MCK of space and shape". Each of the key elements is discussed below. In this study, aspects of common knowledge are found in the national curriculum (CAPS).

2.3.1.1 Common knowledge of mathematics in the CAPS document

Common knowledge of mathematics includes knowledge of the mathematical concepts of geometry (space and shape) or the strands prescribed in the "curriculum and the knowledge pertaining to the organising structures of the teaching of the MCK of space and shape" (Ball *et al*. 2008). Space and shape is part of the geometrical strand of the mathematics curriculum (CAPS), which should be developed "in a sequential manner through geometrical experiences" (Charlesworth & Lind 2013). The CAPS document proposes concepts and strands for the teaching of the mathematical content in Gr R. Lattuca and Stark (2009:4-5) define a curriculum "as a plan that teachers use as the foundation of their lessons". In addition, the curriculum includes "purpose, content, sequence, learners' instructional processes and resources, evaluation and adjustment", which forms part of common knowledge.

In South Africa, the current curriculum is referred to as the "National CAPS curriculum" (Wolfaardt 2016). CAPS are a "policy document that provides the skills, values and knowledge that children should acquire in their schooling years" (Ramollo 2015). Furthermore, CAPS offer guidelines for MCK, resources, instructional strategies that teachers should teach and use in each grade (DBE 2012a). All aspects of Gr R, including the classroom environment and teaching and learning practice, should promote the holistic development of the child (DoE 2011:13). Development that is an integral part of emergent numeracy includes cognitive development (problem-solving, logical thought and reasoning, language development (the language of mathematics) and perceptual-motor as well as emotional and social development.

"The approach to learning mathematics should be based on the principles of integration and play-based learning" (DoE 2011:13). "Learning the mathematical concepts of space and shape can be developed through activities such as stories, songs, rhymes, finger games, and water play, educational toys including board games, construction and exploration activities, imaginative play and playground games". It can therefore, be assumed that various kinds of games and play could include aspects of numeracy. In other words, the acquisition of emergent mathematics and related mathematical concepts should, like all good teaching, adhere to the following learning principles where children move through three stages of learning:

- the kinaesthetic stage (experience concepts with body and senses);

- the concrete stage (3-D, using a variety of different objects such as blocks, bottle tops, twigs and other objects in the environment);
- paper and pencil representation (semi-concrete representations using drawings, matching cards etc.).

"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). Movement is a way for children to grasp concepts that are regularly taught only two-dimensionally or auditory-visually, using additional tactile modalities (Gallahue & Donnelly 2003:110-111). This implies that Gr R teachers should incorporate movement when teaching the mathematical concepts of space and shape. A Gr R teacher should try to integrate physical movement into academic lessons and academic lessons into physical movement as "physical education context presents plentiful opportunities to challenge children to employ critical thinking strategies" (Gallahue & Donelly 2003:671). In this regard, Gr R teachers can apply movement to enhance the learning of space and shape, especially during the kinaesthetic and concrete stages of learning. By providing physical activities that children would not generally pursue on their own, educational experiences are created that positively influence perceptual-motor and cognitive concept learning (Gallahue & Donnelly 2003:118). "At a practical level, though, even if mathematics lessons incorporating movement are not possible, allocating short physical activity breaks to children during the day can significantly improve their reading and mathematics results" (Erwin 2012b).

According to CAPS "Gr R, teachers are provided with a timetable called the daily programme", which consist of three main components, namely:

- Teacher-guided activities
- Routines
- Child-initiated activities or free play

The emphasis throughout should be on using these aspects of the daily programme to promote the acquisition of emergent numeracy in a fun and spontaneous context (DoE 2011:13). One of the aspects that seems relevant and integrated with the teaching and learning of space and shape is creative arts, especially in Gr R. According to the DoE 2011:13) “creative art activities could also have a mathematical emphasis, for example, using geometric shapes such as circles and squares to make a collage or designing a pattern to frame a picture”. The teacher’s knowledge could make the most of children’s learning potential.

“The Gr R teacher should be proactive, a mediator rather than a facilitator” (DBE 2011). “A mediator makes the most of the incidental learning opportunities that arise spontaneously during a range of child-centred activities such as free play in the fantasy corner or block construction site, sand and water play activities as well as teacher-guided activities that focus on different mathematical concepts such as space and shape” (DBE 2011).

The allotted time for Mathematics within the FP in terms of CAPS (DBE 2011) is 30% of 23 hours of formal teaching per week.

Table 2.2: Weighting of content areas in Mathematics for Gr R (DoE 2011)

Content areas	GR R
Number, Operations and Relations	55%
Patterns and Functions	7,5%
Space and Shape	15%
Measurement	15%
Data Handling	7,5%
Total	**100%**

The CAPS Assessment Standards match the activities described by Crowley (1987) as "those that would facilitate the acquisition of the first level of Van Hiele's model, namely visualisation" (Bleeker 2011). Table 2.3 on page 37 compares the types of experiences described by Van Hiele and advocated by Crowley (1987) for Level 1 (visualisation) (that of Gr R children) with the Assessment Standards in the CAPS document.

According to CAPS (DoE 2011), Gr R children should be able to do the following in the content area of space and shape:

- Focus on three-dimensional (3-D) objects, two-dimensional (2-D) shapes, position and directions.
- Explore the properties of 3-D objects and 2-D shapes by sorting, classifying, describing and naming them.
- Draw shapes and build with objects.
- Recognise and describe shapes and objects in their environment that resemble mathematical objects and shapes.
- Describe the position of objects, themselves and others using the appropriate vocabulary.
- Follow and give directions.

Table 2.3: Alignment of Van Hiele's type of experience with CAPS (adapted from Bleeker 2011)

Van Hiele type experiences (Crowley 1987)	Assessment Standards CAPS Gr R
1. To manipulate, colour, fold and construct geometric shapes	1. Build three-dimensional (3-D) objects using concrete materials (e.g. building blocks, construction)
2.To identify a shape or a geometric relation In a simple drawing In a set of cut-outs or other manipulatives In a variety of orientations Involving physical objects that are part of everyday life Within and in relation to other shapes	2. Recognise, identify and name three-dimensional objects in the classroom and in pictures, including Boxes (prisms) Balls (spheres) Describe one three-dimensional object in relation to another (e.g. "in front of" or "behind")
3. To create shapes by using cut-outs. Tracing paper, dot paper, grid paper, and geo-boards By drawing figures By constructing shapes with sticks, straws, pattern blocks etc.	3. Build three-dimensional objects using concrete materials (e.g. building blocks)
4. To describe geometry shapes verbally using the appropriate standard and non-standard language Comparing shapes e.g. these shapes have the same number of "corners" Contrasting shapes	4. Describes, sorts and compares physical three-dimensional objects according to: Size Objects that roll Objects that slide
5. To solve problems using shapes	5. Follows directions (alone and/or as a member of a group or team) to move or

Van Hiele type experiences (Crowley 1987)	Assessment Standards CAPS Gr R
Investigating making squares and rectangles, using triangles Covering a given area using different shapes	place self within the classroom (e.g. “at the front” or “at the back”)
	6. Recognises symmetry in itself and own environment (with focus on front and back)

The focus of the CAPS document in the FP (Gr R–3) in the study of space and shape (geometry) is on practical experience for children. In Gr R, the child should be given the opportunity to work with objects and be involved in cutting out and drawing activities. The object used at this phase is to “enable children to recognise and describe objects and shapes in their environment while using the appropriate language and expanding their vocabulary” (Bleeker 2011).

2.3.1.2 Specialised knowledge of the mathematical content knowledge of space and shape

According to Steyn (2014) Gr R teachers “need specialised mathematical knowledge to effectively teach the mathematical concepts of space and shape to interpret and evaluate children’s development of mathematical understanding” according to the Van Hiele model. Shulman (1986) regards “content knowledge as the main knowledge base that a teacher must possess to be effective”. With this kind of knowledge, Gr R teachers must be able to assess children on their understanding of space and shape.

Specialised mathematical knowledge of the MCK of space and shape will enable Gr R teachers to:

- interpret errors made by children
- link representations to underlying ideas

- evaluate children's explanations
- respond to children's questions
- explain mathematical rules and terminology related to the MCK of space and shape in Gr R (Ball & Bass. 2005; Ball et al. 2008).

2.3.2 Pedagogical content knowledge for learning of space and shape

PCK is regarded as "specialised knowledge for teaching" and described as the capacity teachers have to transform the content knowledge they possess into forms that are pedagogically efficacious and yet adaptive to the differences in ability and background presented by children (Shulman 1987:15). PCK therefore "plays an important role in the teaching of the mathematical concepts of space and shape" (Turnuklu & Yeslidere 2007).

Pedagogical learning is viewed as a multifaceted combination of mathematical knowledge, which includes "pedagogy, how children learn the concepts of space and shape, theories, curriculum and content knowledge" (DHET 2011; Zazkis & Zazkis 2010). Gr R teachers' PCK should employ various principles for the effective teaching of space and shape. These principles and guidelines are discussed in Table 2.3.

Table 2.4: Adapted principles of effective teaching (Anthony & Walshaw 2009)

Principles of effective teaching of space and shape in the Gr R classroom	How Gr R teachers can enhance the principle
Arranging children into groups	Teachers should create opportunities for children to work as individuals or in small groups.
Building on children's thinking	Activities developed for space and shape should be play-based and built on children's experiences and interests.
Worthwhile mathematical tasks	Children should be able to make sense of space and shape concepts and become broad-minded. They must be able to justify their solutions.
Making connections	Children should be able to apply what they have learnt to their own life situations.
Assessment for learning	Informal assessment of space and shape should aim at diagnosing learning issues and inform teaching and learning decisions.
Mathematical communication	Children should be engaged in using various ways of finding the answers rather than finding the correct answer.
Mathematical language	The use of correct language is encouraged, which includes the use of the correct mathematical terminology of space and shape. The teacher is expected to explain the terminology to learners for a better understanding of the concepts.
Tools and representation	Teachers should use appropriate resources, mathematical models (2-D and

Principles of effective teaching of space and shape in the Gr R classroom	How Gr R teachers can enhance the principle
	3-D objects) and technology to support learning.
Gr R teachers' knowledge	Substantial content knowledge and PCK of teachers should assist children to develop a grounded understanding of space and shape concepts. Teachers should be able to respond to children's mathematical needs using their knowledge.

2.3.2.1 Knowledge of content and constructivist instructional approaches for implementing space and shape

Anthony and Walshaw (2009) are of the opinion that "instructional approaches combine all activities in and out of the classroom, such as organisation and planning of lessons, arrangement of learners, delivery of lessons based on children's experiences, effective communication using appropriate language and tools/materials, as well as lesson assessments based on the outcome of the lesson". Mansfield and Happs (1996) note that "traditional instructional approaches do little to promote teachers' understanding of the children's level of mathematical thought". Van Hiele (1986) specifically states that the "inability of many teachers to match instruction to children's geometrical understanding is a contributing factor to teachers' failure to promote meaningful understandings of this topic".

Effective instructional approaches should promote increasing insight into the mathematical concepts of space and shape (Kwon 2004; Orton 2004). Thus, according to Steyn (2014), a knowledge of mathematical instructional approaches combines knowledge of how to promote, plan and assess learning and knowledge about the mathematical concepts of space and shape. The four instructional approaches proposed by Ramagoshi (2015) are integrated with the constructivist design and relate to this study.

They are “case-based learning, discovery learning, inquiry-based learning and problem-based learning”.

Case-based learning

Case-based learning comprises real-life experiences, which the children attempt to solve while at the same time building new knowledge. Children should be able to apply what they have learnt about space and shape to their own life situations. The teacher facilitates small groups, who come up with specific analysis techniques and work towards solutions of an open-ended problem. According to D’Angelo (2014:7), “children benefit from this type of instruction because they are given an opportunity for decision making as part of their learning process and because they experience and address different viewpoints”. Children get the opportunity to discuss a case using their knowledge, prior experiences and perspectives to solve the problem. They will engage in arguments based on the interpretation of the case. This, in turn, develops their understanding of the case they are trying to solve.

Discovery learning

Mayer (2004) and Papert (1980) assert that “in discovery learning, the teacher gives children a problem to solve”. If children use this approach to learning, they are able to explore and formulate solutions to a problem. In discovery learning, the teacher facilitates and guides the children to develop problem-solving skills. In addition, D’Angelo (2014:7) believes that “discovery learning assumes that children are able to retain knowledge if they discover the knowledge themselves”. Children should be able to make sense of space and shape concepts and become progressive. They must be able to validate their solutions.

Inquiry-based learning

According to Edelson, Gordin &Pea (1999), “inquiry-based learning entails that the children are solely responsible for the content they want to learn, the learning process and the assessment of learning”. Teachers pose questions to guide children if they use inquiry- based learning. In doing so, the facilitator (teacher) helps children to build their knowledge from the answers they receive and through the interactions they have with other children. Furthermore, the use of correct language is encouraged, which includes the use of the correct mathematical terminology of space and shape. The teacher is expected to explain the terminology to learners for a better understanding of concepts. Children benefit greatly from this approach because "they develop metacognitive learning skills and research skills upon which they can build towards future educational experiences" (D'Angelo 2014:7).

Problem-based learning

Problem-based learning is similar to inquiry-based learning, in the sense that children are provided with a problem, which they need to solve themselves. In this instructional approach, children must deal with "real-life" experiences, and critically analyse a problem and find solutions for it. Problem-based learning is perceived as a constructivist approach because it includes three instructional goals, listed by Burrows (1985); construct flexible knowledge, develop effective collaborators and become motivated to learn. Problem-based learning is project-based and assists children to create their own meaning. Teachers should use appropriate resources, mathematical models (2-D and 3-D objects) and technology to support learning. These projects could include reports, physical models, computer models, exhibitions, websites and other concrete products that give opportunities to children to show their understanding.

The four instructional approaches could be useful to Gr R teachers to implement in their classrooms when teaching the MCK of space and shape as they are relevant to the context of this study. Effective approaches to geometry require teachers to develop sound teaching approaches and knowledge of useful resources and activities (Ding & Jones 2006). Effective mathematics teachers reflect on their connected mathematical knowledge bases and fluidly combine them with their experience and understanding of geometry when teaching (Luneta 2013).

2.3.2.2 Knowledge of mathematical learning processes

Knowledge of mathematical learning processes is a combination of how Gr R children learn and what Gr R children need to know about the MCK of space and shape. Another theorist who shared multiple aspects of Piaget's theory of constructivism was Jerome Bruner (1960:7). According to Finesilver (2006), Bruner theorised that children develop an understanding of concepts through active learning experiences. Bruner's theory consists of three learning stages, namely enactive, iconic and symbolic. Steyn (2014) proposed that enactive learning involves direct experiences with concrete materials. The second stage is iconic learning, which suggests that learning is based on the use of visual representations of concepts (Steyn 2014). Lastly, symbolic learning experiences, according to Finesilver (2006), include "the use of language as well as mathematical symbols". Du Plessis and Webb (2011) state that Bruner's learning stages incorporate an active process of acquiring and applying mathematical knowledge and a strong element of constructivism (Steyn 2014). In the process of acquiring and applying mathematical knowledge, children encounter important skills to encourage lifelong learning in mathematics (Botha 2012; Singapore Ministry of Education 2012; Steyn 2014).

Evidence also shows that high-quality ECE programmes can make a difference in enhancing learning (Clements & Sarama 2009). Early childhood teachers, in particular, play a crucial role as one of the primary vehicles through which children learn mathematics (National Research Council 2009). Children, who have a strong spatial sense do better in mathematics (Clements 2004). Children need to manipulate, draw, compare, describe, sort, and represent shapes in a variety of ways to develop their ideas about shapes (Charlesworth 2005; Clements 1999).

This study focused on the use of manipulatives, representations of mathematical concepts of space and shape, the language used for teaching the mathematical content and cooperative learning to highlight how teachers could ensure children's learning processes and their growth of mathematical process skills (Figure 2.4). The factors include four interrelated skills and are comprised of manipulatives, representations, language and cooperative learning. In the next section, these factors are discussed.

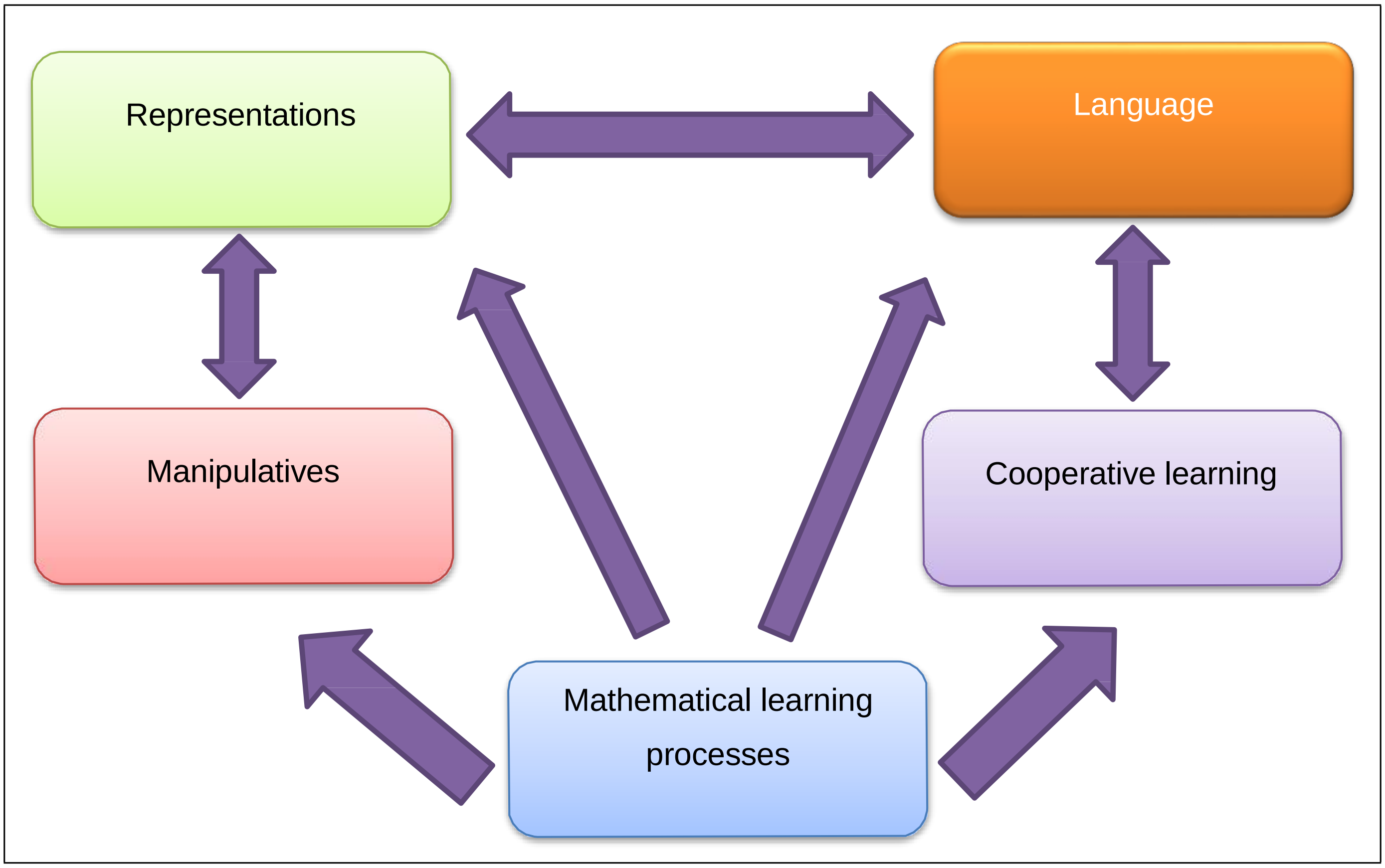

Figure 2.3: Factors influencing the development of mathematical process skills, adapted from Finesilver (2006) and Steyn (2014)

Manipulatives

Maria Montessori and Simmonds (1917) was one of the first teachers to develop manipulatives (materials) specifically designed to initiate mathematical concepts. Van de Walle *et al*. (2013:27) describe manipulatives as "physical objects used to illustrate mathematical concepts". According to Laski & Siegler (2015) "manipulatives are concrete materials used to demonstrate a mathematical concept or to support the execution of a mathematical procedure". 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" section 2.2.1.1). "The pre-operational child should use concrete referents when developing mathematics concepts, because according to Piaget, even a child as old as 11 years is still not fluent in logical, abstract thought" (Woolfolk 2010:34). The idea that the environment should be "a stimulating field for developing cognitive skills is supported by Piaget's and Vygotsky's work" (Botha *et al*. 2005:701).

According to the Singapore Ministry of Education (2012:3), "interactions with manipulative objects allow children to construct logical arguments" and to "connect mathematics with the real world". A variety of stimulating manipulatives like blocks and art materials should be used to facilitate the acquisition of geometrical knowledge, which in turn will support overall language and cognitive development (Brown 2009).

Representations

Children's own representations according to Van de Walle *et al*. (2010) "will probably improve their understanding and retention". Olsson (2009) asserts that "young children should be encouraged to apply their mathematical knowledge in different contexts". Various researchers (Freudenthal 2010; Slaten 2006; Van Oers & Poland 2007; Steyn 2014) write that "visual representations include pictures, drawings, gestures, diagrams and photographs, which represent children's mental images of mathematical concepts". "Children 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).

Figure 2.4: Visual representations of teaching the concepts of space and shape in Gr R classrooms

In Gr R, children are naturally curious and explore the world around them. They also love to learn through play. Gr R teachers can build on this to support mathematical development. In doing so, teachers need to ensure that appropriate toys and other resources are available for children to play with. Furthermore, teachers need to recognise the mathematical potential of these toys and resources. “Teachers observe children interacting with the resources and provide additional resources or play alongside children, using appropriate vocabulary and asking appropriate questions to maximise their potential” (Taylor 2013).

Language

“Language is a vehicle for communication, and mathematics is a specialised language used to communicate and model real-life situations” (Kodisang 2015). The literature supports the use of the home language as a medium of instruction and state that children learn effectively when they learn in their home languages (Langer 2013; Mashiya 2011; Skovsmose & Greer 2012; Skutnabb-Kangas 2009). The language of instruction in the teaching and learning of space and shape (geometry) is described by Atebe and Schäfer (2008:50), who cite Van Hiele:

> *People reasoning at different levels, speak different languages and the same term is interpreted differently. The mismatch between instructions and children's cognitive levels in geometry is caused largely by teachers' failure to deliver instructions to the children in a language that is appropriate to children's thinking level.*

The language of learning geometry in mathematics is regarded as a tool of communication that cultivates interaction and conceptual understanding (Vukovic & Lesaux 2013). Mathematical language focused on space and shape involves specialised terminology (Simmons & Singleton 2008). Gr R children would refer to the vertex of a pyramid as the point and the angle of a square as the corners (Bleeker 2011). Bleeker (2011) says that "it is impossible for any curriculum to prescribe or predict the precise dialogue most suited for a particular learner or context to best facilitate the development of abstract concepts". Such documents can therefore only offer guidelines. According to the CAPS document, "children should develop the following language skills in learning various concepts in mathematics," such as the concepts of space and shape:

- Number vocabulary, number concept and calculation and application skills;
- Listening, communicating, thinking, reasoning logically and applying the mathematical knowledge gained;
- Investigating, analysing, representing and interpreting information (DBE 2012:8).

"These skills indicate the impact language has in teaching and learning mathematics" (Ramollo 2015). However, for this study the focus was on "the language skills needed by Gr R teachers teaching the mathematical concepts of space and shape". According to Steyn (2014), "language use in the classroom encourages active engagement of children in mathematics". In addition, it also inspires cooperative learning, which will enhance children's communication, connecting, problem-solving, representation as well as reasoning process skills (Steyn 2014). Scaffolding children in their geometrical skills acquisition is a “combination of using rich geometric language and playing games with children” (Brown 2009:476-477).

Cooperative learning

Cooperative learning comprises “instructional methods in which teachers organize students into small groups, which then work together to help one another learn academic content” (Slavin 2011:344). Kessler (1992) emphasises that “cooperative learning focuses on structured groupwork in which child-child interaction plays a big role”. The application of cooperative learning to classroom teaching started in the 1970s when Israel and the United States began to study cooperative learning models for the classroom (Bilen 2015). Because this study employed a constructivist approach and the work of Piaget, Vygotsky and Van Hiele’s levels of geometrical thought, cooperative learning is “crucial as it supports interaction with peers and teachers” (Kheong 2009). Knowledge of the mathematical learning processes focuses mostly on children’s learning; however, teachers implement various instructional approaches to engage children in the learning process of mathematics on space and shape. “Cooperative learning has been reported to improve students’ academic achievement” (Beck & Chizhik 2008; Sousa 2006; Zain *et al.* 2009). Teaching should therefore focus on ensuring that cooperative teaching forms part of teachers’ daily teaching practices, as this might have a positive impact on the teaching and learning of space and shape in Gr R classrooms.

2.4 Factors influencing the implementation of learning and teaching the mathematical concepts of space and shape in Gr R

In this section, the following factors are discussed that could influence the implementation of the MCK of space and shape. These factors are:

- Teacher training and qualifications
- Learning environment for teaching the concepts of space and shape
- Working conditions
- Gender differences

- The LoLT of mathematics.

2.4.1 Teacher training and qualifications

"Teachers are fundamental to the development of young children's mathematical abilities" (Greenes 1999:46). Unfortunately, as in most developing countries, in-service training opportunities for many South African Gr R teachers are limited (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 (DBE 2012:32). Botha (2012) concurs: "the quality of teacher education programmes is concerning" in South Africa. As increases in teachers' knowledge and skills, as well as changes in classroom practice, are related to sustained and intensive professional development (Garret *et al.* 2001:936; Brendefur *et al.* 2013:193), quality teacher training workshops could have a direct influence on effective preschool mathematics instruction in our country, a notion that needs serious further investigation. Consequently, Gr R teachers' knowledge or understanding of the MCK of space and shape "might be influenced by their lack of effective teacher training and qualifications" (Smith 2015). Professional development must be promoted that will empower Grade R teachers to teach more effectively in the classroom.

In South Africa, there is a consensus that "getting basic education right' is foundational for the future of this country". When the Minister of Basic Education, Angie Motshekga, spoke about the importance of the Grade Reception Phase (R) programme for five- and six-year-old children on 9 February 2013, she focused on the teachers as deliverers of the programme:

The DBE (2013) recognises the challenges of teacher training and working conditions and of the short supply of skilled teachers. The department accepts the task of ensuring that Grade R teachers are paid well and know what they are supposed to do. In 2011 the Department of Basic Education (DBE) published 'The minimum requirements for teacher education qualifications' (2011a). In this document, the DBE sought to raise the minimum qualification requirements of Gr R teachers, while drawing them more strongly into the FP domain:

> *All new entrants intending to become (FP) teachers (qualified to teach from Gr R-3) should register for a Bachelors of Education degree (BEd) rather than for a Gr R Diploma, provided that they meet the requirements for entry into the BEd (Andrich et al. 2015).*

"From 2014 the DBE proposed that Gr R training be compulsory for Gr R teachers. It furthermore stated that Gr R teachers with ECD level 4 and 5 qualifications were set to be excluded from teaching Gr R" (Andrich *et al.* 2015). For Gr R teachers to be competent, "they need to act reflectively in their teaching practice to ensure that learning the concepts of space and shape are taking place and that children are learning from teachers' actions and words" (Excell & Linington 2008). Walsh and Petty (2007) state that "if teachers act reflectively in their teaching practices, they may find new, playful ways to enhance children's learning by focusing on eliminating the frustrations, disillusionment and feelings of failure that children may experience when they are learning the mathematical concepts of space and shape".

Bredekamp (2011:14) explains:

> *Well-qualified teachers are needed to plan and implement an engaging curriculum and teach effectively. Similarly, positive relationships among teachers and children are more likely to be established when the size of the group and ratio of adults is relatively small. An age-appropriate, well-equipped, and organized physical environment is needed to protect children's health and safety to promote active learning.*

2.4.2 Learning environment for teaching the concepts of space and shape

According to Casey (2005:57), "the learning environment is not just a physical setting, but is made up of everyone in it, the weather, seasons and events in the lives of the children and the community". The learning environment does not just consist of physical features but of the atmosphere as well, which can influence children's play significantly" (Van Heerden 2012). Casey (2005:30) further stipulates that "the physical environment can portray the message that it is a *space* for children, for instance by means of soft landscaping, dimensions, appealing equipment and ample things with which to interact. It will be an implicit invitation to children to use fully in learning the mathematical concepts of space and shape".

The environment plays a vital role in children's learning about space and shape because "the environment we are in affects our moods, ability to form relationships, effectiveness in work and play – even our health" (Bullard 2010:3). Thus, Gr R classrooms should be exciting to children, inspirational, generating enthusiasm and creating an appetite for learning about the MCK of space and shape (Drake 2009 [2010]:1).

Van Heerden (2012) is of the opinion that "the hardwiring of the brain that occurs during the early years is affected by among others the learning environment". According to Strong-Wilson and Ellis (2007:43), "there are two important reasons why children's development and learning are seriously affected by the learning environment". The first is that "young children's brains are developing rapidly and the second that the environment in which they find themselves either helps to build and form connections or to prune away synapses that are not used" (Van Heerden 2012). Gr R teachers should ensure that the teaching and learning of space and shape concepts are positive experiences, as it will support the children in this process. "Inadequate surroundings can limit children's experiences and thus vitally influence the way the children's brains develop" (Strong-Wilson & Ellis 2007:43). In turn, this could place a damper on the manner in which teachers teach and the way in which children learn in their Gr R classroom environments.

The second reason is that the amount of time that children spend in these environments plays a strong role in children's development (Van Heerden 2012). Bullard (2010:3) explains:

> *In the past, many teachers believed that play was the only catalyst for learning. However, most teachers now realize that children's learning through play is profoundly affected by the social and physical environments they are in. If teachers want to prevent boredom and help children meet outcomes primarily through play, we need to intentionally design environments tha provide children with materials, tools and*

> *challenges that allow development to flourish. For children to gain the most from play, we need to be available to scaffold children's learning … Quality environments are the foundation upon which a quality play-based curriculum is built.*

Bullard's remarks here (2010:3) are relevant to this study, as the Gr R curriculum is play-based. The differences between children, for example the way they learn, need to be taken into consideration (Sanders 2002:8; Walsh et al. 2006:202).

2.4.3 Working conditions

Teachers who are faced with harsh working conditions may struggle to implement the MCK of space and shape in Gr R classrooms. On the other hand, teachers who have a reasonable number of children in their classrooms could promote positive working conditions for teachers. The DoE (2005:38) points out: "[T]here has been much discussion regarding the 'ideal' learner-teacher ratio". However, the DoE adds that South Africa's "learner-teacher ratio is an average of between 35 and 40 learners per teacher". Excell and Linington (2008) concur, emphasising the necessity of an adequate number of teachers and explaining that "teacher shortages may lead to overcrowded classrooms". Gr R teachers' understanding and implementation of mathematics in general may be negatively influenced by their experiences of teaching the content and concepts of space and shape in overcrowded classrooms. Gr R "teachers work long hours with little rest or vacation time, causing them to become physically drained and unable to teach Mathematics effectively" (Excell & Linington 2008; Sumsion 2003).

"Teachers could become negative if they have to deal with adverse working conditions, such as personal differences with co-workers, not being respected or rewarded for the work they do" (Smith 2015), and the resources that they are provided with for teaching various concepts. These issues need to be addressed, as they may obscure their commitment towards child-centred learning in their classrooms. Flottman *et al.* (2011) point out that "teachers need departmental, professional and parental support".

Teachers are often faced with working conditions in which they are offered little support to implement the MCK of space and shape (Smith 2015). Eventually, these "teachers may even leave the teaching profession, as they feel that their passion and enjoyment are outweighed by the constant negativity they have to face" (Flottman *et al.* 2011; Sumsion 2003; Smith 2015).

2.4.4 Gender differences and their influence on spatial abilities

"Spatial ability plays a vital role in our daily interaction with the environment, assisting with navigation, recognising and manipulating objects, and academic tasks and recalling locations. Spatial ability is one of several relatively independent human intellectual competencies and is considered essential to mathematics" (Gardner 1983). Boys and girls show different outcomes in different learning environments when they learn geometry (Casey *et al.* 2008b; Friedman 1995). Gender differences in spatial ability are well recognised in the scientific literature (Coluccia & Louse 2004; Halpern 2004, Kimura 1999; Levine *et al*. 2005; Voyer *et al.* 1995). "Early researchers in this area have traditionally reported a male advantage over female on standard tests of spatial ability after adolescence" (Maccoby & Jacklin 1974). Recent research, however, showed that gender differences emerge around the time children enter preschool or begin formal schooling (Grade 1), which may be as early as children can reliably perform tasks that access visuospatial abilities. Levine *et al.* (1999) found that, on average, preschool boys are more accurate than girls at spatial tasks. According to Yang and Chen (2010), "gender differences and spatial abilities are critical to geometrical learning". Additionally, Battista (2007) states that "spatial reasoning forms the foundation of geometrical reasoning". Becky (2010) argues that "adults and children attach a certain stigma to the construction of gender". Consequently, it is crucial for Gr R teachers to impart the mathematical concepts of space and shape in such a way that children are enabled to develop good spatial abilities regardless of their gender.

Gender has not received adequate attention in terms of preschool-age children's mathematical learning. The existing research has focused primarily on language skills, with mixed findings. Some studies have suggested that "gender differences have a minimal effect on language and mathematics skills (Hyde & Linn 1988; Valiente *et al.* 2010), while other studies have shown that a difference exists, favouring boys in mathematical learning" (Herbert & Stipek 2005; Valiente *et al.* 2007; Valiente *et al.* 2008). Because the role of gender in mathematics has not received the attention it requires, teachers may not realise its importance, which could negatively affect the teaching and learning of mathematics in Gr R classrooms.

2.4.5 Language of learning and teaching in mathematics

Mathematical language has an important influence on arithmetic, but differences between cultures and the home and school contexts play a significant role (Dowker 2005:207). If mathematical language is not clearly explained to the child, or if a child cannot reason with it, mathematics will be "full of incomprehensible mumbo-jumbo" (Dowker 2005:207). It would therefore seem that mathematical language and language acquisition for Gr R children are two of the most critical factors to include in a young learner's mathematics programme (Botha *et al.* 2005:706). It would appear that the quality of the dialogue between teachers and children, and between children, is of great importance if it is to have a significant influence on learning and educational attainment (Mercer & Sams 2006:525).

2.5 Conceptual framework

According to Maxwell (2013), a conceptual framework is a system of concepts, assumptions, expectations, beliefs and theories that shape one's research. Maxwell (2013) also states that the function of a conceptual framework is to help the researcher to assess and refine their goals. The conceptual framework in my study consisted of six different interrelated levels that affect what teachers teach and how it influences the Gr R child's learning of the MCK of space and shape.

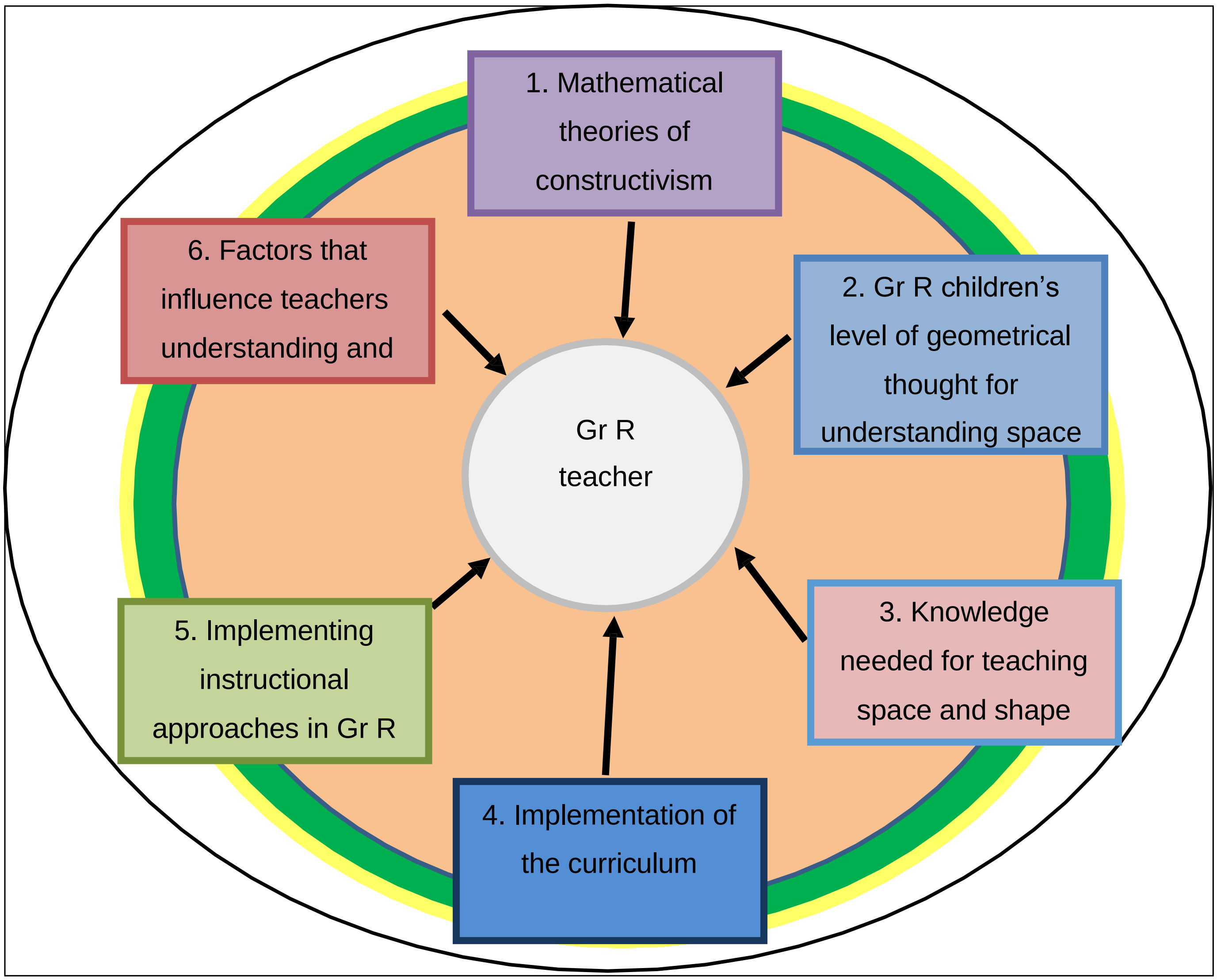

Figure 2.5: The developing conceptual framework for understanding and implementation of the mathematical content knowledge of space and shape (Adapted from Steyn 2014)

The conceptual framework in Figure 2.5 outlines the six components that need to be investigated to explain teachers' understanding and implementation of the mathematical concepts of space and shape. The grey circle puts the Gr R teacher in the centre of the conceptual framework because Gr R teachers' understanding and implementation are influenced by the six components.

The interconnected yellow line illustrates that even though the six components are illustrated and discussed in numerical order, the process is non-linear. Additionally, this explains that Gr R teachers can move between the six components to develop a comprehensive understanding of the MCK of space and shape. The dark green circle represents the external environment while the pale green area represents the school and classroom environment. Both these environments play an important role in the implementation of the MCK of space and shape. Teachers in this study had a stronger focus on practical teaching in the classroom.

The first component explains that constructivism finds its roots in the cognitive school of psychology and in the theories of Piaget (Von Glasersfeld 1995) and Vygotsky (1962). Wood (1989:39) agrees that constructivism "brings aspects of Piaget's and Vygotsky's work together". It is a theory that focuses on the way in which knowledge is constructed through a process where one actively builds new ideas and concepts through experience (Powell & Kalina 2009:241). Scaffolding children in their geometrical skills acquisition entails the use of rich geometric language and playing games with children (Brown 2009:476-477). Teachers in Gr R classrooms can scaffold children's learning through employing Van Hiele's model of geometrical thought.

The second component of the conceptual framework therefore explains R teachers' level of geometrical thought for the understanding and implementation of space and shape and hence the effect that teachers' level of geometrical thought has on the child. It is directly related to the third component, namely the knowledge teachers need for teaching the MCK and PCK of the concept of space and shape. It is relevant in the context of this study as illustrated in Figure 2.3 because the components of MCK and PCK are interrelated in mathematical knowledge. According to Ball *et al*. (2008:3), these components (MCK and PCK) are linked, to assure that "discussions of content are relevant to teaching and that discussions of teaching retain attention to content" on the topic of geometry (space and shape).

Steyn (2014:26) adds, "it is therefore, necessary for teachers to acquire common knowledge of the mathematical concepts of space and shape to identify a wrong answer, whereas specialized knowledge and knowledge of mathematical learning processes are required to identify the nature of problem-solving in mathematics". She further posits that: "deciding on how to best remediate problem-solving may require knowledge of" mathematical instructional approaches for Gr R teachers to successfully understand and implement the MCK of space and shape in their classrooms (Ball *et al.* 2008:11).

The implementation of the curriculum is the fourth component. In this study, space and shape was part of the geometrical strand of the Mathematics curriculum, which should be developed "in a sequential manner through geometrical experiences" (Charlesworth & Lind 2013). The CAPS for Mathematics describes the purpose, concepts and strands for the teaching of the mathematical content in Gr R. Lattuca and Stark (2009:4-5) define a curriculum as a plan that teachers use as the foundation of their lessons. In addition, the curriculum includes "purpose, content, sequence, learners' instructional processes and resources, evaluation and adjustment". CAPS is a policy document that describes the skills, values and knowledge that children should acquire in their schooling years (Ramollo 2015). Furthermore, CAPS offer guidelines for MCK, resources and the instructional strategies that teachers should teach and use in each grade (DBE 2012). All aspects of Gr R, including the classroom environment and teaching and learning practice, should promote the holistic development of the child (DoE 2011:13). The aspects of development that are integral to emergent numeracy include cognitive development (problem-solving, logical thought and reasoning, language development the language of mathematics) and perceptual-motor as well as emotional and social development.

The approach to learning Mathematics should be based on the principles of integration and play-based learning (DoE 2011:13). Learning the mathematical concepts of space and shape can be developed through activities such as stories, songs, rhymes, finger games and water play, educational toys such as board games, construction and exploration activities, imaginative play and "playground games".

Hence, the fifth component of this framework refers to the instructional approaches teachers could employ in their classrooms when they are teaching. This component explains that the children have a direct impact on Gr R teachers' instructional approaches.

This is especially important for the environment in which children gain new knowledge for learning about space and shape.

Anthony and Walshaw (2009) are of the opinion that “instructional approaches combine all of the actions in and out of the classroom, such as organisation and planning of lessons, arrangement of learners, delivery of lessons based on children’s experiences, effective communication using appropriate language, tools and materials, as well as lesson assessments based on the outcome of the lesson”. Mansfield and Happs (1996) note that “traditional instructional approaches do little to promote teachers’ understanding of children’s level of mathematical thought”. Van Hiele (1986) points out that “the inability of many teachers to match their instruction to children’s geometrical understanding contributes to their failure to promote meaningful understanding of this topic”.

Effective instructional approaches should increase insight into the mathematical concepts of space and shape (Kwon 2004; Orton 2004). According to Steyn (2014), “a knowledge of mathematical instructional approaches should therefore combine the knowledge of how to promote, plan and assess learning, and knowledge about the mathematical concepts” of space and shape. The four instructional approaches proposed by Ramagoshi (2015) that were integrated with the constructivist design in this study include case-based learning, discovery learning, inquiry-based learning and problem-based learning (see section 2.3.2.1).

Component 6 is the last level of this framework and pertains to the factors that influence the implementation and understanding of space and shape. Six factors have been identified. They include:

- teachers’ training and qualifications;
- the learning environment for teaching the concepts of space and shape;
- the competence of Gr R teachers;
- working conditions;
- gender differences and the influence these have on children’s spatial abilities and

- the LoLT of mathematics. The factors are described below.

Teacher training and qualifications

Botha (2012) explains “the quality of teacher education programmes is concerning”. Increases in teacher knowledge and skills together with changes in classroom practice are related to sustained and intensive professional development (Garret et al. 2001:936; Brendefur *et al.* 2013:193). Quality teacher training workshops could have a direct influence on effective preschool mathematics instruction in South Africa, an aspect that needs serious further investigation. Consequently, Gr R teachers’ knowledge or understanding of the MCK of space and shape might be influenced by their lack of understanding and implementation on the mathematical content thereof (Smith 2015).

The learning environment for teaching the concepts of space and shape

The environment plays a vital role in children’s learning about space and shape because “the environment we are in affects our moods, ability to form relationships, effectiveness in work and play – even our health” (Bullard 2010:3). Gr R classrooms should therefore be exhilarating to children, inspirational in generating enthusiasm and creating an appetite for learning about the MCK of space and shape (Drake 2009 [2010]:1).

Competence of Gr R teachers

The DBE (2013) recognises the challenges of teacher training, working conditions and ensuring a supply of skilled teachers. The department has accepted the task of ensuring that Grade R teachers are paid well and know what they are supposed to do. In 2011, the DBE published a document titled ‘The minimum requirements for teacher education qualifications’ (2011a).

Working conditions

Teachers who have to cope with harsh working conditions might struggle to implement the MCK of space and shape in Gr R classrooms. Excell and Linington (2008) stress that an adequate number of teachers is essential and explain that teacher shortages may lead to overcrowded classrooms. Gr R teachers' understanding and implementation of mathematics in general may be influenced by their experiences and interest in teaching the content and concepts of space and shape in overcrowded classrooms. Gr R teachers work long hours with little rest or vacation, causing them to become physically drained and not being able to teach Mathematics effectively (Excell & Linington 2008; Sumsion 2003).

Gender differences and the influence it has on children's spatial abilities

Recent research has shown that gender differences emerge around the time children enter preschool or begin formal schooling (Grade 1), which may be as early as children can reliably perform tasks that assess visuospatial abilities. Levine et al. (1999) found that, on average, preschool boys are more accurate than girls at spatial tasks. According to Yang and Chen (2010), gender differences and spatial abilities are critical to geometrical learning.

Language of learning and teaching in Mathematics

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 Gr R children is one of the most critical factors to include in a young learner's mathematics programme (Botha *et al.* 2005:706).

Consequently, Gr R teachers should consider how these factors positively and negatively affect their teaching abilities in their classrooms. If teachers, correctly implement all the levels, as described above, children should understand the concepts of space and shape taught, and lastly, teachers should be able to reflect on their teaching practices.

2.6 Conclusion

Chapter 2 provided a comprehensive study of the literature related to Gr R teachers' understanding and implementation of the MCK of space and shape. Figure 2.3 outlines the teaching and learning components of the mathematical concepts of space and shape that are crucial for Gr R teachers. The knowledge and skills that teachers should have for the effective teaching of the mathematical concepts of space and shape are comprehensively discussed. The literature review encompasses the components and other aspects such as the theories, curriculum implementation, instructional approaches, mathematical processing skills and the factors influencing teaching and learning. The chapter furthermore discussed the CAPS document and instructional approaches to its implementation. In addition, it describes the mathematical processing skills that may assist Gr R teachers and the factors that hamper their implementation of the mathematical concepts of space and shape. Lastly, a conceptual framework has been developed from the literature review to formulate and answer the research questions on the understanding of space and shape.

The data that was collected and analysed is discussed in Chapter 4, and the findings and recommendations are made in Chapter 5. Chapter 3 discusses the research methodology.

CHAPTER 3:
RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

In Chapter 2, I discussed the theoretical perspectives and literature relevant to the topic under study. Chapter 3 presents detailed descriptions of the research paradigm and design and methods employed to investigate teachers' views, ideas, opinions and perceptions of the implementation of the mathematical concepts of space and shape in the Gr R classroom.

The chapter describes the study's qualitative research approach, the research paradigm and design and the research context in which the study was conducted. I discuss the sampling procedures, research sites and sampling selection, followed by the data collection strategies. Thereafter, analytical methods are described, and a review of how I ensured trustworthiness for this study. Lastly, the ethical measures I took are outlined.

3.2 Research approach

Since the research intended to obtain a deeper insight into how teachers understand and implement the MCK of space and shape in the context of their Gr R classrooms, I employed a qualitative research approach. According to McMillan and Schumacher (2010), "a qualitative approach is an analysis of people's individual and collective social actions, beliefs, thoughts and perceptions and is primarily concerned with understanding social phenomena from the perspectives of participants". Harwell (2011:158) states: "Qualitative research is usually described as allowing a detailed exploration of a topic of interest in which information is collected by a researcher through case studies, ethnographic work, interviews, and so on." Terell (2012:277) explains in qualitative research," I (the researcher) should record fully, accurately and in an unbiased way what I see and hear from the participants". Denzin and Lincoln (2005:10) note that "qualitative studies emphasise the natural settings, entities and processes that are not experimentally examined or measured in terms of quantity, amount or intensity. In this study, I included multiple case studies". In addition, I made use of participant observations, semi-structured interviews, document analysis and Journal-keeping (field notes) to gather information-rich data and gain an insight into teachers' teaching experiences and understanding of the mathematical concepts of space and shape.

This research approach allowed me to interact with and observe the participants in their schools, focusing on their way of understanding the topic under study, and in doing so, gaining in-depth knowledge of the meaning that the topic has for the participants (Niewenhuis 2007a:51). Nieuwenhuis (2007a:51) adds that qualitative research focuses on describing and understanding a phenomenon within its naturally occurring context, with the intention of developing and understanding the meaning(s) imparted by participants – "seeing through the eyes of participants" – so that the phenomena can be described in terms of the meaning that they have for the participants (Hannaway 2014).

By using a participant observation approach, I was able to observe Gr R teachers at three selected schools to discern their instructional approaches, views, ideas and perceptions in teaching the mathematical concepts of space and shape. I was able to gather first-hand information about their experiences of the teaching approaches under investigation while making field notes. During the observations, I also took photographs as an explanation of the teachers' perceptions and experiences of the mathematical concepts of space and shape, visually presented in Chapter 4.

Patton (2002:225) states that in qualitative research, direct quotations and excerpts from interviews can be cited as they present the participants' perceptions. In the semi-structured interviews, the five selected participants responded to predetermined questions. Consequently, I was able to gather rich narratives by making field notes about their experiences, views and perceptions on the mathematical content of space and shape while teaching Mathematics. According to McMillan and Schumacher (2010:321-324), there are nine key characteristics of qualitative research data present in the majority of qualitative studies. Table 3.1 highlights each characteristic and explains how it relates to this research study.

Table 3.1: Nine key characteristics of qualitative research (McMillan & Schumacher 2010:321-324) and how they relate to this study (adapted from Bruwer 2014)

Characteristic of qualitative research	How it relates to and features in this study
Behaviour is studied as it occurs in **natural settings**.	Data was collected at research sites chosen by the participants, namely their own **Gr R classrooms.**
Context sensitivity is needed in order to interpret behaviour.	**The constructivist theories of Piaget, Vygotsky and Van Hiele** were employed to explain the direct and indirect influences of different contexts on teachers who teach the concepts of space and shape in Gr R classrooms.
Researchers **collect data directly** from the source through direct interactions with participants.	Data was collected through **observations and semi-structured interviews** with Gr R teachers at the three selected schools.
Rich narrative descriptions are necessary for an in-depth understanding of a complex phenomenon.	The semi-structured interviews were **recorded and transcribed** to form a detailed data analysis.
Process orientation – researchers focus on the *how* and *why* of behaviour and not just the outcomes.	The focus of this study was on **how** teachers understood and implemented the MCK of space and shape.
An **inductive data analysis** enables the researcher to work through the data progressively and generate a new understanding of the phenomenon.	The analysis of the data revealed new insights into the topic under study and recommendations were made for improvement.
Researchers use the **perspectives of their participants** to reconstruct reality.	The purpose of this study was to explore how teachers' understanding and implementation of the MCK of space and shape affect their **teaching Gr R children, as seen through the eyes of Gr R teachers**.

Characteristic of qualitative research	How it relates to and features in this study
Emergent design – changes in the research design might be necessary after the data have been collected.	No changes were made.
Understanding and explanation of a complex phenomenon need to be equally **complex** in order to capture its true meaning.	Since the **MCK of space and shape is a multidimensional construct with various different mathematical concepts**, a detailed explanation was required to understand it; I furthermore realised that it was impossible to "account for all of the complexity" (McMillan & Schumacher 2006:324) of this topic.

The purpose of this study was to gain an in-depth understanding of how five Gr R teachers experienced the teaching and learning of the mathematical content knowledge of space and shape in their classrooms. In this study, I therefore employed an interpretivist view as a point of departure. Interpretive studies attempt to generate an understanding of the phenomenon under investigation by analysing the meaning provided by the participants in the study (Niewenhuis 2007:59).

3.3 Research questions

The research questions are given below, followed by the research paradigm and design that was utilised to answer the questions. Creswell (2008) advises that a good primary question narrows down the purpose of the study and helps the researcher to focus on the phenomenon of interest. However, this question should also be general and open-ended to ensure that it provides for the exploratory nature of a qualitative study (Creswell 2008:143-144). Jansen (2007:3) adds that a good research question will also direct the researcher to appropriate literature and keep him/her focused during the data collection process. Jansen (2007:12) further states that the secondary research questions are more specific and should add to the focus of the primary research question. I used the following questions to guide this study of teachers' understanding and implementation of space and shape:

Primary research question

How do Gr R teachers understand and implement the mathematical content knowledge of space and shape?

Secondary research questions

In order to answer the main research question, four secondary questions guided this study:

- How do Gr R teachers perceive the importance of space and shape?
- How do Gr R teachers explain the mathematical content knowledge of space and shape?
- How do Gr R teachers scaffold children's development of the mathematical content knowledge of space and shape?
- Is there a gap between policy and practice in the teaching of the mathematical content knowledge of space and shape in Gr R?

3.4 Research context

3.4.1 Interpretive paradigm

The underlying research epistemology in this study was interpretive, from a qualitative approach (Burton & Bartlet 2009:18). The hermeneutics and the phenomenology (Brown & Heggs 2005:293) of the study were positioned in the qualitative, interpretivist paradigm. Maree (2010) posits that a paradigm involves the beliefs a researcher holds. Maree (2007:47) states that a paradigm is a "set of assumptions or beliefs about fundamental reality which gives rise to a particular view". Denzin and Lincoln (2011) and Nieuwenhuis (2007) describe an interpretivist paradigm as one that attempts to understand a phenomenon being studied by analysing the meanings generated by the participants in a study. “Interpretivist seeks to uncover meaning and understand the deeper implications revealed in data about people” (Somekh & Lewin 2005:346). According to Creswell (2010:59), interpretivism attempts to understand phenomena through the meanings that people assign to them and is based on the assumptions that there is not only one reality but many. Interpretivist researchers carry out their studies in natural contexts to attain the best possible understanding (Creswell 2007:37). I therefore did not attempt to manipulate the phenomena of interest (Norris & Walker 2005:132) and completed the research process in a “naturally occurring context and not in experimental situation[s]” (Creswell, 2010:51). In this study, the teachers were interviewed at their respective schools to ensure a natural context in which they were comfortable.

The aim was to understand as much as possible of the Gr R teacher participants’ teaching, knowledge and approaches of the topic under study and the environment (context) in which they found themselves, without consciously influencing them. Doing this allowed close interaction with the participants and provided insights into what they perceived to be environments conducive to perceptual development (Creswell 2007:297). As the researcher, I had to try and be thorough, precise, meticulous and accurate, even though the study was not generalisable (Burton & Bartlett 2009:21). A qualitative interpretivist study is not generalised to the larger population (Creswell 2007:294), but rather to adds to the research topic being studied.

In this study, an inductive approach was followed. Somekh and Lewin (2005:346) state: “Inductive refers to the process of constructing theories from empirical data by researching for themes and seeking to make meanings from evidence.” Furthermore, because the study was empirical and inclusive, the researcher collected data about Gr R teachers’ pedagogy and their school context using various data collection strategies (Somekh *et al.* 2005:1). As a qualitative researcher, I used instruments and techniques that were well suited to qualitative research methods and fitted into the interpretivist paradigm. According to Burton and Bartlett (2009:21), the methods favoured in interpretive studies are participant observations and semi-structured interviews, which allow the situation to be as “normal” as possible. Naturalistic unobstructive methods of data gathering were therefore chosen (Burton & Bartlett 2009:21; Creswell, 2010:77), which included face-to-face interviews and observations. To ensure the credibility and trustworthiness of the study, various data collection methods were employed (Creswell, 2010:80).

3.4.2 The role of the researcher

Maree and Van der Westhuizen (2007:41) explain that a qualitative researcher forms a collaborative partnership with their participants to collect the data needed and thereafter analyse the collected data to gain a better understanding of the phenomenon being investigated. In qualitative research, the researcher is seen as the "research instrument" in the data gathering process and it is said that researcher subjectivity cannot be eliminated (Niewenhuis 2007). Equally, a researcher is "naturally involved in a sustained and intensive experience with the participants" (Creswell 2014).

In this study, interactions between myself and the participants included observations and semi-structured interviews, during which the Gr R teachers exposed their approaches, views, ideas, opinions and perceptions about teaching the mathematical concept of space and shape in their classrooms. Accordingly, Creswell (2014:130) stipulates that researchers must recognise their own "biases, values and personal background (gender, history, culture and socioeconomic status)", as these could influence the researcher's thoughts and interpretation of the collected data.

Niewenhuis (2010) posits that the role of the researcher entails finding existing data of interest, before analysing and interpreting the data. For this reason, I was expected to be objective about the topic being studied, and remain unbiased during the observations and interviews to avoid influencing participants by my own views and perceptions. I had to document the procedures followed and ensure that permission had been granted to protect the participants' rights (Creswell 2014). The ethical considerations are clarified in Section 3.12 of this study.

Denzin and Lincoln (2003) explain that a successful qualitative researcher works towards creating a picture by utilising a wide variety of people's ideas and theories. Chapter 2 in this study reviewed various literature studies that revealed different perspectives on teaching space and shape and on discovering the positive and negative aspects that might influence teachers' teaching practices.

To find an answer to the primary research question, the role of a researcher includes sourcing existing data on the topic being investigated, and then studying and analysing the relevant information and data (Niewenhuis 2010). Moreover, the data collection process required the selection of participants that complied with the sampling criteria and would willingly participate in the data collection process. Nieuwenhuis (2010:51) states that after all the data has been collected, the researcher should transcribe, analyse, and interpret it while remaining unbiased and emotionally uninvolved. In Section 3.8, the data collection process is discussed in detail.

3.5 Research design

A research design is an overall strategy that one chooses for systematically carrying out a research study (Creswell 2009:3). Terell (2012:258) describes a research design as a road map that determines the most appropriate route for carrying out the study.

In this study, I used a multiple case study research design. I focused on five Gr R teachers at three selected primary schools to investigate teachers understanding and implementation of the content of space and shape. Hancock and Algozzine (2006:15) explain a case study design as "conducting an empirical investigation of a contemporary phenomenon within its natural context using multiple sources of evidence". Nieuwenhuis (2007:75) regards a case study as a "systematic inquiry" into an event or set of related events that aims to describe and explain the phenomenon of interest. Case study research addresses a phenomenon by focusing on one or more cases that represent a group (Hancock & Algozzine 2006:15). A case study design is recognised as an effective qualitative design because it focuses on experimental knowledge and the social context of individuals (Hesse-Biber & LeFavy 2011:256). Yin (2014) explains that one needs to make sure that a case study design is best suited to one's study by comparing it to other research designs. I chose a case design for this study because I intended to collect in-depth, information-rich data about how Gr R teachers in purposefully selected schools understood and implemented the MCK of space and shape. The limitations of a case study design are highlighted by Niewenhuis (2007:76), who posits that the selected sample or samples cannot be seen as representative of an entire population.

From an interpretive perspective, the typical characteristics of multiple case studies are that they strive to provide a comprehensive (holistic) understanding of how participants in a specific context make meaning of the phenomenon under study (Bogdan & Bilken 2003:55). In this study, private schools (in urban areas) and a public school in a township were selected. This allowed me to document a range of findings from observations, interviews, and documentation on whether Gr R teachers understood and effectively implemented the MCK of space and shape in their classrooms.

3.6 Sample selection

Sample selection in qualitative research is a critical part of a study, as the quality of the data depends on it (Hancock & Algozzine 2006:40). Nieuwenhuis (2007:79) notes that sampling is “the process used to select a portion of the population for study”, and explains that purposive sampling is generally used for qualitative studies. This means that the research sites and participants are selected specifically for collecting the most suitable data to answer research questions. Researchers use purposeful sampling to select participants with a stated purpose in mind (Teddlie & Yu 2007:5). My purposeful sampling method consisted of selecting well-established schools and experienced teachers who were given good references by their principals and counterparts whom I consulted. According to Niewenhuis (2010:79), selecting specific participants involves sourcing people who have the qualities and knowledge pertaining to a study.

This study utilised a small sample size, involving five Gr R teachers from three schools – ensuring they would be information-rich cases – to answer the primary research question (McMillan & Schumacher 2010). By gaining the teachers’ views, ideas and perspectives, I was able to make sense of the topic being investigated. I examined the factors that could possibly influence (positively or negatively) the teachers’ teaching, such as the implementation of CAPS, working conditions, overcrowded classrooms, teaching and learning environments, and the language abilities of space and shape. Observing and interviewing the five teachers gained sufficient amounts of data for this study to be successfully completed.

Creswell (2014:150) asserts that "participants must be individuals who have all experienced the phenomenon being explored and can articulate their lived experiences". The participant group consisted of Gr R teachers with at least three years of teaching experience in the FP. The five teachers were selected from three different schools in the region of Pretoria (Gauteng). Teachers teaching at two private and one township school were included in the study. The private schools were better resourced than the township school. The purpose of using a township school was to gain an overall picture of the factors that influences the quality of instruction. For example, the difference in materials, differences in teaching approaches according to each individual teacher and respectively their qualifications and understand how the teachers implement mathematics. No government schools in urban areas were available, as their teachers were completing their assessments and felt that their academic programmes were full.

The participant Gr R teachers signed a letter of consent for this study. The parents of the children also had to sign such letters, to allow the children to be present in the classroom while I observed their teachers teaching a lesson based on the mathematical concepts of space and shape. The letters informed both the teachers and parents of their rights and the reason for conducting this study. The principals similarly signed letters of consent giving me permission to conduct research at their schools (Appendix A).

Duncan and Noonan (2007) state that purposive sampling combines the elements of theoretical sampling and identifying people who fit the criteria for desirable participants. McMillan and Schumacher (2010:378) suggest that purposeful samples can be stratified or nested by selecting particular units or cases that vary according to a key dimension. In this study, the cases of five teachers were selected according to a specific sampling criterion. The specific sampling criteria for the participating teachers are outlined in Table 3.2.

Table 3.2: Sampling criterion for Gr R classrooms and teachers

Sampling criteria for Gr R classrooms	Sampling criteria for Gr R teachers
The schools should have Gr R facilities.	Teachers who had obtained a qualification at a recognised tertiary institution.
The schools should have basic teaching resources for teachers to impart the MCK of space and shape.	Experienced teachers, with a minimum of three years' teaching experience at Gr R level.
Consent to conduct research from principals.	Voluntary participation in the study.

3.7 Research sites and participants

Creswell (2014) asserts "the idea behind qualitative research is to purposefully select research sites or participants that will help the researcher understand the problem and research question". Since the aim of this study was to determine teachers' understanding and implementation of the mathematical concepts of space and shape, I purposefully selected experienced teachers from different backgrounds to obtain views from different school contexts on the topic.

3.7.1 Research sites

According to Creswell (2014), the place where data is collected from is referred to as a research site. In this study, data were collected through participant observations, semi-structured interviews, document analysis and Journal-keeping at three schools. Private schools in South Africa are normally well resourced, like the two private schools selected for the study. Township schools are generally less well resourced, like the township school selected for this study. The purpose of including such different schools was to gain rich information and to understand the research problem in different school contexts.

The semi-structured interviews were conducted after school hours at times and on dates best suited to the teachers at the three schools listed in Table 3.3.

Table 3.3: Information on research sites

Research sites	Location	Number of Gr R classes	Number of children in each Gr R class	Language of instruction	Type of school
School 1	Pretoria (urban area)	4	22	English	Private school
School 2	Pretoria (township)	2	40	Setswana/English	Township school
School 3	Pretoria (urban area)	4	22	English	Private school

School 1 was a relatively new private school that had opened its doors in 1998. The school consisted of a preschool, primary school and a high school. There were twelve classrooms in the preschool, four of them Gr R classrooms, accommodating five- to six-year-old children. Each Gr R class catered for a maximum of 22 children per classroom, accompanied by a qualified teacher and a classroom assistant for each class. The classrooms were beautifully decorated and spacious, making good use of natural light. Each classroom was well equipped. The classrooms were surrounded by an attractive playground. This school's vision and mission statement stated that "learning takes place through exploration and discovery, to ensure that the children become independent and take responsibility for their own actions". I selected two participants from this school, naming them Participant A and Participant B at School 1 (S1).

School 2 was a township school funded by the state, with a feeding scheme. The school catered for children from Grade R to Grade 7. There were two Gr R classes, with qualified teachers and voluntary assistants. The classrooms accommodated up to 40 children per class (children aged 5-6). The classrooms were bright, but had few resources and a lack of space to create different learning areas. One teacher from this school participated in the research study, named Participant C at School 2 (S2).

School 3 was a newly built urban private school in Pretoria. The school was rapidly expanding and additional buildings were being constructed. The children had to share their outdoor space until the buildings were completed. The school consisted of a preschool, primary school and high school. They catered for children from Grade 000-12 (between the ages of 3 and 18 years). The classrooms were bright and had sufficient learning spaces, with designated corners, such as a fantasy play corner, reading corner etc. Each Gr R class had a maximum of 25 children, with two assistants shared between the four classes. All the teachers were qualified and experienced in teaching Gr R. This school's vision and mission statement was "teaching and learning takes place in a loving, nurturing environment where pupils are encouraged to become happy, confident and competent individuals". Two Gr R teachers from this school participated in the research study, named Participant D and Participant E from School 3 (S3).

3.7.2 Participants

According to McMillan and Schumacher (2010:138), purposive sampling is an approach where participants are selected because of the rich information they available, which is required to answer the research questions. The five teachers who were observed and interviewed were all females. All five participants used English as a medium of instruction, while one teacher repeated her instructions in Setswana when she felt it was necessary, because Setswana was their mother tongue/home language.as the children were all black.

Participants A, B, D and E (21, 15, 9 and 30 years' experience respectively) had many years of teaching experience, while participant C had the least teaching experience (4 years).

Table 3.4 summarises the background information of the participants.

Table 3.4: Background of participants

Participant	Gender	Home language	Years of teaching experience in Gr R	Type of school
Participant A School 1 (S1)	Female	English	21	Private school
Participant B School 1 (S1)	Female	English	15	Private school
Participant C School 2 (S2)	Female	Setswana	4	Township school
Participant D School 3 (S 3)	Female	English	9	Private school
Participant E School 3 (S3)	Female	English	30	Private School

3.8 Data collection strategies

Data collection is described as a series of interrelated activities with the purpose of collecting rich information relating to the research question (Creswell 2010:118). In this study, I employed various data collection strategies, which included participant observation, semi-structured interviews, document analysis and field notes for identifying patterns during the data collection process. Creswell (2012:212) suggests that the researcher should pose general, broad questions to participants and allow them to share their views relatively unconstrained by the researcher's perspective. Qualitative research data mainly consists of participant observations, semi-structured interviews and documents, and the generated quality data is presented in the form of printed words, images and audio-recorded data (Denzin & Lincoln 2000). I used multiple sources of information for context-rich data, which in turn answered the research questions and determined the essence of the topic being investigated. Creswell (2009:176) states that in qualitative data collection, the researcher builds patterns, categories and themes from the bottom up, by organising data into increasingly abstract units of information. A number of categories were identified and then reduced to a smaller and more manageable set of themes and subthemes (also see Chapter 4 and 5). Data were collected in four different phases, which assisted me to complete the study within a set time frame and to keep a record of the data collection process. Table 3.5 illustrates how the data collection process unfolded in the different phases.

Table 3.5: Phases of data collection

Time frame	Role of the researcher	Role of the participant
Phase 1	Approaching principals of three primary schools with permission letters (Appendix A). Arranging information meetings with principals and Gr R teachers to explain the study and research process in which the teachers would be involved. Inviting Gr R teachers to participate in the study. Explaining to participants what to expect during observations and semi-structured interviews. Visiting the primary schools for observations and recording notes in my journal (field notes). Keeping in contact with Gr R teachers and regularly visiting the primary schools.	Attending information meeting. Agreeing to participate in the study (voluntary).
Phase 2	Observing lessons presented by the five Gr R teachers. Keeping a journal of the observations of the research sites and teaching approaches.	Presenting a lesson on the mathematical concepts of space and shape.
Phase 3	Conducting semi-structured interviews with teachers, with a duration of 30-45 minutes per interview. Keeping a journal.	Participating in a semi-structured interview.
Phase 4	Analysing and interpreting data.	Researcher establishing themes and subthemes to answer the research questions posed in this study.

3.8.1 Participant observation

Participant observation is a way of observing the actions of research participants (Henning, 2004). The observations in this study were undertaken in the natural settings of the participants, their Gr R classrooms (Petty, *et al.* 2012; TerreBlanche & Durrheim 1999). Participant observations enabled me to assess teachers' understanding of concepts and processes in Phase 2 (Table 3.5). The five teachers were each observed in their classrooms to gain an in-depth understanding on how they understood and implemented the mathematical concepts of space and shape, as well as their views, ideas and perceptions on its importance. The observations were carried out before the interviews, to formulate predetermined questions on the instructional approaches and activities for the semi-structured interviews. Silverman (2008) suggests various questions that could be considered when a researcher uses observations while making field notes of what is being observed. These questions are:

- What are the participants doing?
- How exactly do participants go about doing this?
- How do participants characterise and understand what they are doing?
- What assumption do the participants make of this?
- Analytic questions: What does the researcher see during the observation? What can be concluded from these observations? Why did the researcher include these participants?

These questions were kept in mind during the participant observations with the Gr R teachers, as it assisted me developing a clear picture of teachers' understanding and implementation of the topic under study.

3.8.2 Semi-structured interviews

Creswell (2014:190) describes qualitative interviews as interviews that "involve semi-structured and generally open-ended questions that are few in number and intended to elicit views and opinions of participants". Yin (2009:106) claims that interviews are a “guided conversation rather than structured queries”, and that semi-structured interviews allow the researcher to enter the world of the participants while trying to gain an understanding of their experiences. Interviews were conducted to collect data and learn about the experiences, ideas, perceptions, beliefs, views and behaviours (Niewenhuis 2007:87) of Gr R teachers of the topic under study. The interviews were conducted in the participants’ classrooms, which ensured that the documentation was at hand if the teachers needed to refer to any documentation used in the data collection process. Semi-structured interviews required the participants to “answer a set of predetermined questions and allowed for the probing and clarification of answers”. This means that the teachers were not restricted in their responses to questions (Ramagoshi 2015).

Through semi-structured interviews, one can examine attitudes, interests, feelings, concerns and values that may not be obvious through observations (Gay *et al.* 2011:388). This allowed me to carefully examine each teacher’s attitude and feelings towards teaching the MCK of space and shape. The five interviews with the teachers lasted between 30 and 45 minutes each. The interviews were audio-recorded, while I made field notes. Creswell (2014:190) provides guidelines to keep in mind when conducting interviews. I employed these guidelines in my study, to ensure interviews were successful (Table 3.6).

Table 3.6: Guidelines for conducting interviews (adapted from Cassim 2016)

To keep in mind during interview	Implementing guidelines
Conversation should start in a friendly and non-threatening manner.	The topic was not of a sensitive nature, and interviews were therefore stress-free and occurred as regular conversations in a relaxed atmosphere.
Interview must generate rich data.	The literature review of this study guided my interview questions. This meant that I was confident of gaining information-rich data. The participants were selected according to specific criteria, which resulted in choosing participants which possessed the insight and knowledge required for this study.
Positive interaction between researcher and participant is key to gathering valuable data.	Friendliness and a hospitable environment enabled me to conduct interviews to investigate teachers' views, ideas, perceptions and beliefs on the topic under study. Probing questions ensured an in-depth understanding of the research topic.

3.8.3 Document analysis

Researchers Rule and John (2011:67) state that "document analysis is a useful place to start data collection in a case study, particularly if the research design includes other methods, such as interviews and/or observations". Yin (2011) advises the researcher to engage with documents as a data source because they provide scientific and valuable information from which a lot of detail can be elicited. When I collected relevant data for this study, the participants at the three schools provided me with the documents listed in Table 3.7.

Table 3.7: Documents used for data collection

Documents	Provided by	Used by schools
Policy documents (CAPS)	Department of Basic Education	1, 2 and 3
Lesson plans	Participants A, B, D and E	1 and 3
Worksheets	Participants D and E	3

It is clear from Table 3.7 that not all the teachers had lesson plans and worksheets. School 2 did not provide lesson plans or worksheets, while School 1 did not have worksheets. School 3 submitted all the documents requested. The document analysis gave me an indication of how the teachers understood and implemented the MCK of space and shape. School 3 was the only school that used age-appropriate worksheets during their observation lessons.

3.8.4 Journal-keeping (field notes)

Schwandt (2007) describes field notes as evidence to gain meaning and an understanding of the culture, social situation, or phenomenon being studied. In this study, I kept a research diary as part of the data collection process. Gambold (2010) claims that field notes could be used to describe a physical space, the mannerisms of people and the duration of events. I took the duration of events into consideration when I obtained information through field notes. Cohen *et al.* (2005:146) state that field notes can either be written *in situ* or away from the site or the study field. I used field notes from the start of the data collection process (Phase 1) when I arranged meetings with the teachers and principals of the schools. Cohen *et al.* (2005:146) suggest that observations are recorded field notes and to some extent include descriptions, such as a written description and explanation of the events and behaviour of the participants. During observations (Phase 2), I made use of field notes to describe teachers' attitudes, behaviour, understanding and implementation of the lesson on teaching the concepts of space and shape.

3.9 Summarising and interpreting information

Hancock and Algozzine (2006) state that in case study research, the researcher has to make sense of the information collected from multiple sources. It is a recursive process in which the researcher has to interact with the information throughout the investigative process. A checklist was utilised for implementing the case study design (Hancock & Algozzine 2006). This assisted me in summarising and interpreting the data obtained from teachers (Table 3.8).

Table 3.8: Checklist for implementation of a case study design (adapted from Smith 2015)

Secondary research questions	Required information	How information was obtained	Other information
How do Gr R teachers perceive the importance of space and shape?	I had to obtain knowledge of Gr R teachers' experiences, views, ideas, perceptions and understanding of teaching space and shape.	Information was obtained from the photos, the semi-structured interviews and field notes. Teachers presented a lesson on the content of space and shape, which I observed.	I observed teachers' perceptions of space and shape and the importance thereof, through the lessons they presented during Phase 2 of this study. Teachers were also asked about other teachers' views.
How do Gr R teachers explain the MCK of space and shape?	Information on teachers' understanding of the MCK of space and shape had to be obtained.	Information was obtained from the observations and the language teachers used when teaching. Additionally, it was obtained from the interviews and field notes.	I organised the data derived from the teachers into manageable themes and subthemes. This is presented in Chapter 4 of this study.
How do Gr R teachers scaffold children's development of the MCK of space and shape?	I had to establish what instructional approaches, mathematical process skills and activities teachers utilised to scaffold children's development of space and shape concepts.	I asked the teachers for their lesson plans of the lessons they presented during the observation. Photos were taken of the activities teachers used during these lessons as evidence and I researched various instructional approaches to obtain information in this regard.	Observations, semi-structured interviews and document analysis were very useful in obtaining sufficient information.
Is there a gap between policy and practice of space and shape in Gr R?	Information to determine whether teachers implemented the curriculum was	I studied the national curriculum (CAPS) and what is stipulated regarding the mathematical content of	Studied literature and site visits ensured an in-depth understanding of whether a gap existed between policy and

Secondary research questions	Required information	How information was obtained	Other information
	obtained through observations, interviews and document analysis. Factors that might influence effective teaching were also investigated.	space and shape. I also asked questions during the interviews with the teachers. Additionally, I reviewed literature that discussed possible factors to gain an in-depth understanding of this issue.	practice. Lesson plans and worksheets were also analysed to investigate how teachers understood the topic under study.

3.10 Data analysis

> *Qualitative data analysis is primarily an inductive process of organising data into categories and identifying patterns and relationships among the categories … general themes and conclusions emerge from the data rather than being imposed prior to data collection" (McMillan & Schumacher 2010:367).*

According to Creswell (2008), data in a qualitative study consists of a text base, which is analysed by describing the research site and participants, as well as screening the data for themes or broad categories representing the findings, and in doing so, enabling the researcher to gain a clear picture of the phenomenon under investigation. In addition, Creswell (2008:57) explains that this is followed by interpreting the meaning of the findings in relation to existing research, addressing the research questions and reporting the findings through writing a descriptive report which includes the personal experiences and reflection of the researcher.

Once data had been collected from the teachers, I transcribed the audio recordings of the semi-structured interviews and then reduced the data to smaller, more meaningful categories (Yin 2009). After the data was categorised into smaller parts, I coded it and merged it into themes and subthemes. Identifying the themes was a time-consuming and complicated process (Kodish & Gittelsohn 2011).

Implementing various qualitative data collection techniques helped to record the teachers' perceptions, views and opinions, thoughts and teaching approaches to offer a descriptive and contextually rich overview on why they acted in certain ways and what their feelings were about these actions (Mukherji & Albon 2010). De Vos *et al.* (2011) propose an integrated process for qualitative data analysis. I experienced the data analysis as a creative and logical process of gathering and arranging the data so that the analytical themes became obvious (Walker *et al.* 2008). It was important to keep Ryan and Bernard's (2003:85) views in mind, who state that analysing text involves several tasks:

- discovering themes and subthemes;
- winnowing themes to a manageable few;
- building hierarchies of themes or code books;
- linking themes to theoretical models.

Furthermore, the data analysis methods in my study merged Creswell's (2012:237) six steps frequently used in analysing qualitative data and the data analysis method for a case study research type, outlined below (Creswell 2007:156-157):

- I began with data management (Creswell 2007:157). I arranged the collected data in groups of observations, semi-structured interviews, document analysis and journal-keeping (field notes). Thereafter, I transcribed the audio recordings from the five teachers' interviews into text data. Creswell (2007) suggests that it involves reading and memoing data to be coded and describing each case study and its context.
- Further exploration of data was done by means of coding, also known as classifying (Creswell 2007).
- I employed codes to get an overall picture of the themes and subthemes. Creswell's (2012:236) question "What in the responses of the participants provide answers to my research question?" guided my observations, semi-structured interviews and document analysis.

- The findings were represented through in-depth descriptions of the cases (Creswell 2007) in Chapter 4).
- Another step in the data analysis was interpreting the collected data from the five participants and grouping the data into fewer and more manageable themes in Chapter 5 (Creswell 2007).
- Finally, strategies to validate the accuracy of the findings were employed. Triangulation of different data enhanced the accuracy of this study. Additionally, I consulted my supervisor to establish whether I had accurately interpreted and portrayed the Gr R teacher participants' perceptions and experiences of space and shape concepts in the subject of Gr R Mathematics.

Rule and John (2011:75) state that data analysis allows one to formulate thick descriptions, establish themes, produce explanations of thought stemming from the case and finally to theorise the case. Creswell (2007:75) maintains that when analysing the data from a multiple case study, the researcher should first offer a detailed account of each case and the themes or categories within the case (Table 4.1), known as "within-case analysis" and thereafter a thematic analysis across all cases, called "cross-case analysis" (chapters 4 and 5).

Identifying the themes and subthemes enabled me to link the relevant literature to the collected data (Patton 2002) and subsequent findings. The themes and subthemes were presented by making use of narrative logic (Murkherji & Albon 2010). Furthermore, in line with the guidelines of Murkherji & Albon (2010), I discussed each case study as one would tell a story, with one concept logically flowing into another.

3.11 Addressing trustworthiness

In qualitative research, the quality of the research is most important (Cassim 2016). According to Thomas (2010), this includes aspects such as the quality of the design, analysis and the judgements (inferences) made in a study. Creswell (2014) maintains that the validity and reliability of a study in a qualitative methodology are dependent on the thoroughness with which the researcher conducts the research. According to Maree

(2013:140), trustworthiness is "the way which data is collected, sorted and classified, especially if they are verbal and textual".

The trustworthiness of the procedures and methods of this study (Figure 3.1) was secured by implementing high standards of credibility (internal validity), conformability (objectivity), dependability (reliability) and transferability (external validity) (Loots 2016).

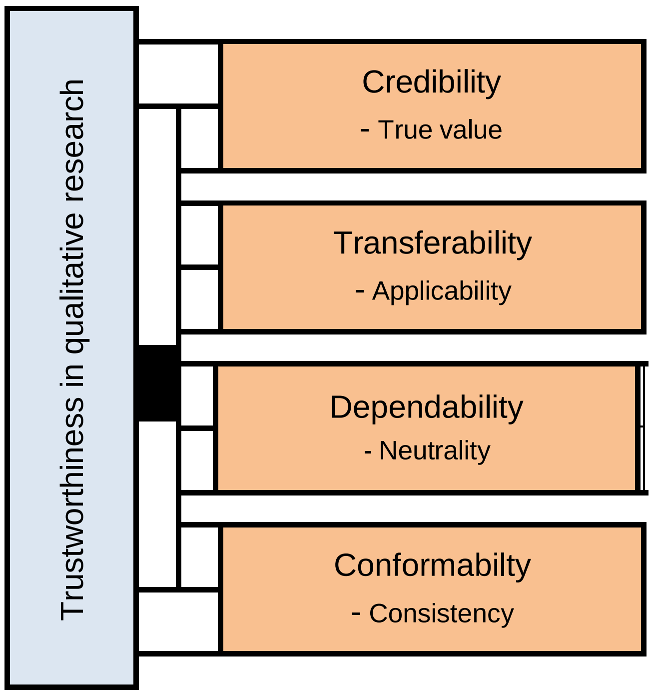

Figure 3.1: Trustworthiness

3.11.1 Credibility

"Credibility is one of the most important factors in establishing trustworthiness" (Shenton 2004). Similarly, credibility is the "idea of internal consistency, where the core issues is how we communicate to others" (Morrow 2005:252).

Marshall and Rossman (2011:54) mention that case studies rely on the worldviews of both the researcher and the participants. I therefore applied member checking to my research. According to Creswell (2008:267), in member checking the researcher asks the participants to confirm whether the transcribed data and interpretations thereof are accurate and reflect the meanings they intended to share with the researcher. Member checking can be done at different stages during the research process. It includes asking participants to clarify their answers during semi-structured interviews, taking transcribed interviews back to participants to be verified, asking participants to give their opinions on the findings and interpretation, and asking them to comment on a draft report of the study (Niewenhuis 2007:113-114).

I used an audio recorder and field notes to ensure that interviews were recorded and accurately interpreted and that nothing was left out in this phase of the data collection process. To ensure the credibility of the data, I asked the participants to confirm whether the transcribed data and interpretations thereof were accurate and reflected the meanings they intended to share.

3.11.2 Transferability

Creswell (2014) explains that transferability refers to the extent to which the findings in qualitative research can be shifted to similar settings. According to Trochim (2006), transferability relates to external validity and the extent to which the results of qualitative research can be generalised or transformed to other contexts or settings. “Given the usually small sizes and absence of statistical analyses, qualitative data cannot be perceived to be generalizable in the conventional senses”. This study investigated only three schools and the findings therefore cannot be transferred to other settings (Morrow 2005:253).

3.11.3 Dependability

Dependability is “the way in which a study is conducted so that it is consistent across time, researchers and analysis techniques” (Morrow 2005:252). Additionally, Morrow (2005) states that this is only possible if the researcher documents each step of the research design as it develops. I documented each step of this research design by using a journal to keep track of events and to establish categories and emerging themes. Another individual who is familiar with this field of study and reviews the study should be able to retrace my steps. The reasoning behind this is “if the same study was repeated in the same context, using the same methods and involving the same participants, similar results would be achieved" (Shenton 2004:71).

Shenton (2004:69) believes it is the researcher's responsibility to explain any changes in the research context and to document whether they have affected the research process since its start. Maree (2007) advises that trustworthiness can be addressed by looking for convergence between multiple and various sources. Denzin and Lincoln (2000:5) posit that employing participant observations, semi-structured interviews and document analysis as multiple data collection methods will assist in the crystallisation of the data collected. In this study, the themes were not analysed for generalising beyond the case under investigation, but rather for understanding the complexity of each individual case (Creswell 2012:75).

3.11.4 Conformability

Conformability is not objective (Morrow 2005:254). In this study, I referred to multiple sources on similar studies in the literature on the topic investigated. Thomas (2010) explains that conformability includes the researcher's consulting an external person to review the study and give feedback on the study's strengths and weaknesses. This role was fulfilled by my supervisor.

3.12 Ethical considerations

Ethical guidelines serve as a standard and the basis on which researchers should evaluate their conduct during the research process. Standards should be internalised into the personality of researchers (De Vos *et al.* 2011). Five Gr R teachers were the participants. The research setting consisted of three primary schools. The principals were asked permission to conduct research at their respective primary schools. The participants were also consulted to gain their consent to participate in the study. Consent letters were given to the participants. These letters asked participants' permission and informed them about the procedures and purpose of the study. Participants were informed on their right to withdraw from the research process at any time, should they wish to. The consent letters were given to the participants before the research was carried out. The procedures followed by the researcher were clearly communicated. The privacy of the participants was respected and confidentiality was ensured in gaining the trust of the participants.

The following principles guided the process of confirming ethical conduct during the research study:

Informed consent

Patton (2002:273) describes informed consent as a process whereby participants give their consent to participate in a research study after getting honest information about its procedures, risks and benefits. Duncan and Noonan (2007) stipulate that participants should be informed of the nature and purpose of the research and possible risks or benefits by means of consent letters. The participants who participated in the study were informed and consulted during every step of the research process. By employing this strategy, a good partnership between the participants and the researcher was ensured.

Voluntary participation

Gr R teachers were informed about the research procedures and assured that participation was voluntary and that they could withdraw at any time during the course of the study, with no negative consequences (Strydom 2011b:115), therefore, participation was voluntarily (Strydom 2011b:116).

Confidentiality and anonymity

The participants were ensured that the data collected during the research would remain anonymous and was handled confidentially and that none of the data were exploited or published without their consent. Christians (2005:145) suggests that it is the researcher's obligation to keep the respondents' identity and responses private. Patton (2002:412) contends that confidentiality means that no one has access to the participants' data or names in the possession of the researcher and that no one can match research information with the particulars of a participant.

Privacy

During the research process, I made sure that no harm befell the teachers or other parties involved. If any conflict occurred, the aim was to resolve it as soon as possible. The rights and welfare of the participants were protected at all times (McMillan & Schumacher 2001). The participants were treated with dignity and respect. According to Mak (2006), when the lived experiences of participants are muted and when they are deprived of their identity, it often translates into an insistence that their identity will not be concealed when reporting research findings, particularly when theses flow from collaborative research projects in which participants are co-researchers.

Safety

I had an obligation to respect the rights, needs, values and desires of informants. Participants should not feel threatened during any stage of the research process.

Trust

To gain the trust of the Gr R teachers, I always presented myself as a professional researcher with professional standards. I took full responsibility for my behaviour and tried to avoid any conflict of interest which might have led to harm if not dealt with in the correct manner. By complying with these ethical considerations, I ensured trustworthiness between the researcher and the participants

3.13 Conclusion

The purpose of Chapter 3 was to provide a detailed description of the research methodology applied to exploring Gr R teachers' understanding and implementation of teaching space and shape and the importance thereof. The intention was to employ a methodology that would help me to gain a "thick, detailed understanding (Morrow 2005:252) of how teachers understood the concepts and the instructional approaches employed in their teaching. Accordingly, a qualitative research approach was followed by conducting observations, semi-structured interviews and document analysis. The sampling strategy used is known as purposeful (also known as purposive) sampling, by which I selected Gr R teachers in the region of Pretoria, Gauteng. Participants were selected from private schools and a township school. In Chapter 4, I provide a detailed discussion of the analysis of the data and a clarification of the findings. The qualitative research paradigm, case study research design and data collection strategies were suitable for an in-depth research of the topic in this study. It helped me to obtain relevant findings to answer the research questions and to make recommendations in Chapter 5.

CHAPTER 4:
RESULTS OF THE DATA COLLECTION PROCESS

4.1 Introduction

Chapter 4 discusses the findings of the data collected. The data analysis of this study was guided by the main research question of how Gr R teachers understand and implement the MCK of space and shape. The primary research question and the secondary research questions were addressed by means of specific themes that were identified through the data analysis. The themes were established through studying the relationship between the conceptual framework of the study and the data collected. The case studies have been written in a narrative style, to explain each case study as descriptively as possible.

The chapter includes photos taken during the participant observations. The photos illustrated the materials used and activities implemented by the Gr R teachers. Only the most relevant photos were used for discussion.

The results of this study are presented in five case studies with each case study describing an individual Gr R teacher. The Gr R teachers' personal experiences of early childhood Mathematics and their teaching of the MCK of space and shape as well as their understanding and beliefs about the importance of space and shape in Gr R are described. The Gr R teachers' perceptions about the content provided in CAPS and their teaching practices are provided. The instructional approaches that the teachers employed during the observation lessons are described. Lastly, I discuss the factors that influenced the teachers' teaching of the mathematical content of space and shape. I will start by explaining the data analysis procedures.

4.2 Data analysis procedures

The data gathering tracked the procedures of a multiple case study design. Information was gathered from Gr R teachers – the purpose was to establish how each one understood and taught the mathematical content of space and shape in their classrooms.

Also, I was interested in their views, ideas and perceptions of the subject. Five participants at three different schools were observed and interviewed. Participant observation, semi-structured interviews and document analysis were conducted to gather relevant data. I followed Creswell's (2013:180) advice for the analysis of the data: "Data analysis in qualitative research consists of preparing and organising that data for analysis, then reducing the data into themes through a process of coding and condensing the codes and finally representing the data into discussion."

Creswell (2012:237) proposes six steps frequently used for analysing qualitative data. The steps are as follows:

- The data for the analyses were prepared and organised by categorising the data (i.e. the photographs taken during observations, observations of participants presenting lessons and interviews). Thereafter, I transcribed the audio-recordings collected from the five participants' interviews into text data.
- I coded the data for each of the five participants. Field notes from participant observations and interviews were documented. Creswell (2012) explains that to derive meaning from the data, it must be labelled and segmented by text to establish descriptions of the cases and identify themes.
- I implemented codes to create a holistic picture of the data.
- The data was presented as photographs, observations and interviews. This was done by sorting teachers' responses of their understanding, views, ideas, experiences and perceptions of the mathematical concepts of space and shape into categories.
- The results were interpreted by comparing the empirical findings with existing literature. (See Chapter 5 for a detailed discussion.)
- Finally, I validated my findings by consulting my supervisor and the participants to confirm whether I had accurately interpreted and portrayed the Gr R teachers' perceptions, experiences and the importance of understanding and implementing the MCK of space and shape in their classrooms.

4.2.1 Data analysis according to each primary school setting

Description of School 1 (S1)

S1 was a relatively new school that opened its doors in 1998. The school consisted of a preschool, primary school and a high school. There were twelve classrooms in the preschool, four of them Gr R classrooms accommodating 5-6-year-old children. Each Gr R class catered for a maximum of 22 children per classroom, accompanied by a qualified teacher and a classroom assistant for each class. The classrooms were beautifully decorated and spacious with a lot of natural light. Each classroom was well equipped. The classrooms were surrounded by a pleasant playground. The school's vision and mission statement said that "learning takes place through exploration and discovery, to ensure that the children become independent and take responsibility for their own actions". I selected two teachers (participants A and B) from S1 to participate in this study.

Description of School 2 (S2)

S2 was a state-funded township school with a feeding scheme. The school catered for children from Grade R to Grade 7. There were two Gr R classes, with qualified teachers and voluntary assistants. The classrooms accommodated a maximum of 40 children per class (children aged five to six years). The classrooms were bright, but have few resources and a lack of space for the children to move or play. PC in the research study taught at S2.

Description of School 3 (S3)

S3 was a newly built urban private school in Pretoria. It was rapidly expanding, constructing additional buildings. At the time of the study, the children had to share their outdoor space for the time being until the buildings were completed. The school consisted of a preschool, primary school and high school. The school catered for children from Grade 000 to Grade 12. The classrooms were bright, with sufficient learning spaces and designated corners, such as a fantasy play corner, reading corner etc. Each Gr R class had a maximum of 25 children, with two shared assistants between the four classes. All the teachers were qualified and experienced in teaching Gr R. S3's vision and mission statement stated that "teaching and learning takes place in a loving, nurturing environment where pupils are encouraged to become happy, confident and competent individuals". Participants D and E in the research project taught at S3.

4.2.2 Data analysis according to participants

Purposeful (also known as purposive) sampling was used to select five Gr R teachers, according to a specific sampling criterion teaching at three different primary schools in the region of Pretoria, Gauteng. In order to protect anonymity and confidentiality of the participants, their names were not disclosed and they were referred to as participants A, B, C, D and E (Table 4.1). The collected data was organised and identified by these pseudonyms to decontextualise it (Nieuwenhuis 2007b:104). In this section, the data is discussed according to each participant's information to highlight the codes, together with a detailed description of the data that was collected (Table 4.2 and Table 4.3). Firstly, a short description of each participant was given, followed by the analysis of the photos taken of the activities conducted and materials used in during the lessons I observed. Thereafter, the observations and interviews (including references made to document analysis where applicable) of each participant in this study have been outlined.

Table 4.1 provides the profiles of the five participants in this study.

Table 4.1: Profiles of participants

Participant	Gender	Age	Home language	Type of school
Participant A	Female	36	English	Private school
Participant B	Female	52	English	Private school
Participant C	Female	24	Setswana	Township school
Participant D	Female	30	English	Private school
Participant E	Female	51	English	Private school

Table 4.2 codes the participants and schools according to their pseudonyms. The codes are used to refer to each individual participant.

Table 4.2: Coding of participants and schools

Participant	Code
Participant A	PA
Participant B	PB
Participant C	PC
Participant D	PD
Participant E	PE
School 1, 2 and 3	S1 S2 S3

Table 4.3 outlines the type of data collection methods and the codes used to refer to each data type.

Table 4.3: Coding of data type

Data type	Code
Observations	Obs.
Semi-structured interviews	SSI
Document analysis	DA

4.3 Description of the findings of each case

This study comprised five individual cases. In this section, each case is presented with a description followed by an analysis of the observations, interviews and documents used for compiling the study.

4.3.1 Case of Participant A

PA taught at an urban private school (S1). She was a 36-year-old female teacher. Her home language was English. She was a passionate and experienced Gr R teacher, who had an interest in the learning and teaching of young children. She had taught Grade 3 for a few years before she started teaching Gr R. She had a pleasant personality, with a love for children. I observed her lesson in her classroom and the interview was conducted in her classroom after school hours (PA, SSI).

4.3.1.1 Observation lesson of Participant A

During PA's observation, she seemed confident in her teaching abilities. Evidently, she had a good rapport with the children in her class and taught the mathematical concepts of space and shape to children in a "fun" and interactive way. She taught a lesson on the properties of "circles" and "spheres". Her classroom was spacious, well planned and colourful (Figure 4.1). The children's artwork was neatly displayed on the classroom wall, and PA had a full-time teaching assistant. PA presented her lesson indoors (PA, Obs.).

Figure 4.1: **Learning about circles and spheres**

In Figure 4.1, the first photo shows the “crazy clay” the children used for making circles and spheres. The second and third photographs illustrate the children’s art, displayed according to a group. Some children were in the “rectangle group” and other children were in the “circle group”, etc. The last photograph illustrates a wall in the classroom that had “shape” pictures the teacher used when teaching the concepts of space and shape to the children in her Gr R class.

Introduction to the lesson

As an introduction, PA used her interactive whiteboard, by showing the children an age-appropriate video clip on the content of circles and spheres.

The children were *fixated on what was being explained in the video* (PA, Obs.).

Body of the lesson

Prior to the lesson, PA prepared the other materials she planned on using. She used moulding clay, from an educational store. After the video clip, the teacher said: "I have a surprise for you" and took the clay from the containers (each child received their own container). She asked the children "can you make a ball shape for me?" followed by asking "what do we call a ball shape?" The children responded a "sphere" (Obs.). PA continued by discussing the properties of circles and spheres. Thereafter, the children were allowed to experiment with the clay in bouncing the putty and rolling it (Obs.). Children were asked to take their "shapes" and hide them in a secret spot, to take home at the end of the day to show their parents (Obs.). PA utilised discovery learning and inquiry-based learning. PA allowed the children to explore with the clay and facilitated and guided the children to develop problem-solving skills. PA posed questions throughout the lesson to guide the children (Obs.).

Conclusion of the lesson

In the conclusion of her lesson, she said "you were so well behaved" and initiated a game, "I spy with my little eye". The children had to spot things in and around the classroom that had the properties of a circle or a sphere (Obs.). The children eagerly participated throughout the lesson and were at all times involved in the learning process. The teacher utilised frequently used words for teaching the concepts of space and shape, and it appeared as though she had a good understanding of the MCK needed by a Gr R teacher (Obs.).

4.3.1.2 Interview with Participant A

PA defined the term "geometry" correctly as follows:

> *Geometry is almost everything round us. It is different objects that take up a space in an environment, I also think it refers to the exploration of shapes* (PA, SSI).

What came to her mind when referring to the MCK of space and shape was:

> *Oh, goodness, I think it refers to how 2-D and 3-D concepts in Mathematics relate to one another. I, think it also refers to prepositions as up, down, left, right, inside and outside* (PA, SSI).

She understood the concepts of "geometrical reasoning" and "spatial reasoning" as follows:

> *Geometrical reasoning, I would say is how is someone would reason about the concepts of geometry, but I do not think it is applicable for the context of Gr R. According to my understanding, spatial reasoning relates to teachers and children being able to explain how objects fit into a space and the space around it* (PA, SSI).

PA scaffolded children's understanding of space and shape in this way:

> *I use a lot of activities to build on the kids' knowledge they have. I let children make shapes using their bodies, copy shapes from the environment, create shapes and use maps to explore directions* (PA, SSI).

The instructional approaches PA employed in her classroom included:

> *I like using movement when teaching, a lot of movement. I especially like children exploring and making shapes with their bodies. Groupwork is also good, I feel that is the best way in which children learn from each other.* (PA, SSI).

PA felt that her instructional approaches to teaching space and shape according to CAPS should include learning through play using various resources. She explained her opinion as follows:

> *I guess it is enough. I know the document says Gr R should be play-based. In my class, I encourage learning through play. We have so many resources, that the children don't easily get bored and I also put out different things for the next day. For space and shape body awareness and learning kinaesthetically is very important, and we teach a lot of that with our movement activities* (PA, SSI).

This type of instructional approach refers to case-based learning. According to Ramagoshi (2015), case-based learning involves real-life experiences that children try to solve while at the same time building new knowledge. The children could apply what they had learnt about space and shape to their own life situations through play.

Her perception of space and shape was vague, although she knew what CAPS expected of her:

> *I perceive space and shape, uhm, as just something we need to teach. Actually, I have never thought of it.* (PA, SSI)

PA was of the opinion that Gr R teachers in South Africa were optimistic about teaching the mathematical concepts of space and shape:

> *Positive perception, I would think* (PA, SSI)

She explained that geometry was interesting and exciting:

> *Well, I am positive about teaching it, as it is a fun area to teach, and there is so much that you can do with it. So, I would think most teachers would also perceive it in a positive light* (PA, SSI).

CAPS is not sufficient for teachers, according to PA. Her school arranged workshops that equipped them with the necessary knowledge and skills to teach the mathematical concepts of space and shape. She commented about CAPS:

> *Even though we follow CAPS, I don't know much about what is listed for the content of Mathematics or a matter of fact any of the content areas. I feel CAPS is not a guideline, but only a vague outline. It does not guide teachers on how to teach the concepts, to me it only lists what the outcomes of a lesson should be. I feel that the content should be more elaborated, and in a step-by-step instructional manual*. *Not just focused on CAPS, but at my school, we have so many courses and workshops, so it is easy to just add all the things we learn from it. It gives me a lot of ideas* (PA, SSI)

The CAPS guidelines were not substantial and affected the teachers' teaching practices. Therefore, according to PA:

> *Definitely has an impact, and I feel that teachers have to understand it, to teach it. Teachers need experience and should make it relevant to Gr R. I think guidelines for teaching in CAPS need to be revised, because it lacks creativity* (PA, SSI)

There were no time constraints, according to PA. She integrated space and shape in other areas such as movement and art. However, her opinion was focused on the perspective of how the teacher taught the mathematical concepts of space and shape:

> *I think it depends on the teacher, if a teacher enjoys teaching it, she will teach it more often, but if she doesn't enjoy it, she will not teach it enough. I teach it daily, by integrating it with my movement activities during morning ring and when doing art. The groups children are grouped according to in my class is according to a "shape" for example some are in the "square group" others are in the "triangle group" and so on* (PA, SSI).

From PA's viewpoint, the gap between policy and practice depended on the support a teacher received from the school and the DoE:

> *No, not really, it depends on the school and the teacher and the support the teacher receives that make the difference. I think it really just depends* (PA, SSI).

Factors that influenced PA's teaching of space and shape included:

Factor 1 ***Outdoors (Learning environment):***

She referred to the importance of teaching the MCK of space and shape through exploration, even outdoors. She enthusiastically elaborated her thoughts:

> *I think our playground is so well designed and that children enjoy playing outside. I think children learning space and shape through exploration, without even knowing what they are learning about. I use the outside environment for some art activities, I ask the children to go on a "hunt" and to go find leaves and stick etc. to add to their art pictures* (PA, SSI)*.*

Factor 2 ***Parental support (Demands of teaching space and shape concepts)***

Participant A had a positive regard for parental support. She highlighted this factor as a benefit to her teaching practices:

> *Very fortunate, the parents are very involved in their kids' lives and want the best for their children. It is sometimes challenging when you address concerns with*

> *parents, because they sometimes think you "picking" on their children, which is not true* (PA, SSI).

4.3.2 Case of Participant B

PB taught at a private school (S1). She was a 52-year-old female teacher. Her home language was English. She was an experienced Gr R teacher, who had a love for early childhood mathematics and how young children learn. She was a passionate teacher who dreamt of writing her own textbook based on teaching mathematics to young children. PB said:

> *I have been teaching Gr R for 21 years and has taught children from the ages of 2-14 years. I have a Bachelors Education degree (B.Ed.) in Foundation Phase and I have also completed a 2-year Diploma in School Readiness at the University of Johannesburg* (PB, SSI).

4.3.2.1 Observation lesson of Participant B

From PB's observation, it was clear that she had a good general understanding of space and shape, and that she enjoyed teaching young children mathematics. Additionally, she facilitated, assisting children to grasp new content without directly teaching it to them (face-to-face). She preferred facilitation to teaching (directly providing content to children face-to-face) because she wanted children to explore "what" they were learning about before she explained the concepts in a more formal manner. During the observation lesson, she utilised a lot of space and shape terms. She seemed comfortable using terms such as semi-circle, symmetrical, symmetry, prepositions and equal. When PB presented her lesson on the MCK of space and shape, she presented it indoors. Her classroom was spacious and had room for a lot of movement. PB portrayed that young children should be involved in the learning process and that children learn best about space and shape when the teacher is a facilitator rather a teacher (PB, Obs.).

Figure 4.2: Symmetry lesson and sorting of objects

Figure 4.2 shows that during PB's observation lesson, she utilised a lot of different materials, which included strings, hula-hoops, clipboards, different soft-shaped objects, sorting buckets, music and pencils to teach the concept of "symmetry", as illustrated in the photographs. It was clear that she had a lot of resources and that she was well prepared to use each resource effectively in the lesson to ensure that the children had "understood" using it and that she enjoyed teaching with it (PB, Obs.).

Introduction to the lesson

In the introduction of PB's lesson, she started with a morning ring (children gathering around the carpet) where she greeted the children and told the children who the "helpers" of the day were. She went on by taking the register and discussing the weather. Thereafter, she revised numbers, the concept that had been explained in the previous lesson. She gave each child a piece of string, she then told the children to take the piece of string (using one hand) to try and get it to "hang" equally. She continued her lesson, by saying: "What do you call it when both sides are the same?" The children were given the opportunity to answer. PB told the children to place the pieces of string in their lockers, "because we are going to use it later", she explained. She instructed the children to each take a hula-hoop. After all the children had taken a hula-hoop, she started singing a song called the "wheels on the bus", and the children joined in the singing. She instructed the children by saying: "Let us play a game, let us pretend we are bus drivers." The children had to pretend they were "bus drivers", and used the hula-hoops as their "steering wheels as they sang "the wheels on the bus go around and round"; they then pretended they were "helicopters", placing the hula-hoops above their heads, pretending to "hover" like helicopters. Afterwards, the children had to stand in front of the hula-hoop, behind the hula-hoop inside the hula-hoop etc. First, PB asked the girls to go and fetch a clipboard with a plain white paper and a pencil as well as the strings in their lockers, and then she asked the boys to do so. She instructed the children to sit inside the hula-hoop and place the clipboards in front of them before she continued with the body of her lesson. (PB, Obs.). The introduction was age-appropriate and relevant for the content that followed in the body of the lesson.

Body of the lesson

PB drew a big circle on the whiteboard, followed by drawing a dotted line through the middle of the circle, asking the children "what do you call it, when you can divide a shape into two equal sides?" and the majority of the children answered, "it's symmetry". PB went on to explain that "when a shape has two equal sides we say the shape is symmetrical". She then used differently shaped and coloured magnets, explaining the concept of symmetry to the children as “symmetry is very easy, what you do on the one side, you need to do on the other side”. The photographs in Figure 4.2 are a visual representation of how PB illustrated the concept of symmetry. After the concept was explained, she took out two containers filled with objects of different shapes, colours and sizes. She told the children to “choose an equal amount of shapes, remember, they should look the same, and, have the same colour and be the same size”. She asked the children to use their strings, divide their hula-hoops into two equal sides, and use the objects they chose to make their own symmetrical patterns (inquiry-based learning). After they had completed their symmetrical patterns practically, she asked the children to use their clipboards and pencils and to draw the patterns they created on their blank pages. She also told the children that when they were done drawing their patterns, they should turn their papers over and draw their favourite shapes (case-based learning) and write their names inside the shapes, before she moved on to the conclusion of her lesson (PB, Obs.).

Conclusion of the lesson

In her conclusion, PB assessed the children by asking them to take the objects they had used for creating a symmetric pattern and to sort the objects according to their properties (PB, Obs.).

4.3.2.2 Interview with Participant B

PB summarised the term “geometry” as follows:

> *Geometry is space and shape concepts. It is geometrical shapes and how we introduce it to children by making them aware, not just by identifying the shapes and naming them, but also by teaching the shapes, explaining its properties* (PB, SSI).

Children’s personal space and environment define the MCK of space and shape according to PB:

> *To me it defines the personal space of children and making them aware of the space, especially their environment* (PB, SSI).

When PB was asked what she understood under the term pedagogical content knowledge, it was clear that she was knowledgeable about the term, explaining:

> *I think it is what we want them to learn about the content being taught. For space and shape, it probably relates to the fact that teachers should explore the knowledge children have. I like to facilitate learning, it makes learning more inquisitive* (PB, SSI).

She understood the concepts "geometrical reasoning" and "spatial reasoning", explaining them as follows:

> *Firstly, geometrical reasoning is when children explore different shapes around them, and spatial reasoning is the space around you to "reason" if things fit or not* (PB, SSI).

PB was hesitant when questioned about how she scaffolded children's understanding of space and shape. She explained that it was important to start with what children already know and build on it.

She adequately replied:

> *Wow, umh, I think I scaffold children's understanding of space and shape by starting with the "basics" of geometry. First, I teach the properties of two-dimensional shapes (2-D), then I focus a lot on symmetry, by teaching the concepts practically. Three-dimensional (3-D) shapes, I only start teaching more formally at the end of term 1, beginning of term two. I think the important thing is to establish what each individual child "knows" and "understands" of what is being taught. I don't think it is fair to expect that all children will grasp each individual concept in the same amount of time, in comparison to that of another child. Some years you have kids that just "click" other years it is a bit more of a struggle … but yes, concepts should initially be taught as children progress* (PB, SSI).

The instructional approaches PB employed in her classroom were good, as they reflected the approaches provided in CAPS. Her approaches included:

> *I like to use various methods, the methods I use most when teaching probably is peer teaching, and teaching through exploration. I like to think that I am more of a facilitator in my classroom, than a teacher* (PB, SSI).

She also emphasised play-based learning and the use of music when she added:

I feel children learn better when they learn with music and by playing. This puts the "fun" into a lesson and, I think it is important for teachers to teach space and shape concepts to children in a "fun" way, this will help that children love it (PB, SSI).

PB was an experienced teacher and was confident that her teaching approaches were effective when she explained her instructional approaches to teaching space and shape according to CAPS:

Sufficient. I think that I incorporate all the methods, I sometimes even combine methods, if I feel it will benefit children's understanding of what is being taught. I like it when children learn through exploration. To me that's when they remember what they have learnt, and then they debate their own thinking (PB, SSI).

Her perception of space and shape was vaguely explained, but she noted that teachers should be motivated at all times to teach effectively:

Teachers should have a passion for what they are teaching, because if they lack enthusiasm, so will the content of the lesson. *My daughter recently started teaching, and she said, that they don't teach space and shape (geometry) to university students like they should* (PB, SSI).

PB explained that some teachers were scared of teaching the mathematical content of space and shape and therefore could have a negative perception of this content area.

She mentions the following:

Teachers are scared … they think the subject of Mathematics mostly consist of only numbers and some data handling, but if teachers focus more on space and shape concepts, children's number formation will improve and therefore, space and shape is crucial … (PB, SSI).

PB explained that CAPS did not sufficiently provide the content of the curriculum and that workshops were too superficial. She expressed her opinion about CAPS as follows:

The knowledge that I have gained in CAPS workshops have not been sufficient. It felt as though the workshop only provides a quick overview of what should be *taught, but specific content areas are not discussed individually. They also try and cram in the entire document and its context into one afternoon* (PB, SSI).

Additionally, she felt that:

Not enough emphasis is given to certain content areas of Mathematics (PB, SSI).

This led me to ask an additional question: Please elaborate which content areas? (PB, SSI). According to her, the focus is too much on other content areas:

For Gr R Mathematics in particular, I would say, we focus too much on numbers, operations, patterns and data handling, and too little on space and shape.

Moreover, PB, felt that the guidelines provided by CAPS influenced teachers' teaching practices significantly:

A big influence on Gr R teachers' teaching practices, because it guides us, how to observe children, on how children learn about space and shape through exploration (PB, SSI).

PB regarded the teaching of the mathematical content of space and shape as important and as the basis for Mathematics. When asked whether she felt enough time was spent on teaching the content of space and shape to children, she answered:

Definitely not, space and shape is integrated in other lessons, when teaching space and shape, it is seldom that space and shape is taught as an individual lesson. Teachers should definitely put more focus on the importance of shape and shape, because I believe that the mathematical content knowledge of space and shape is the foundation in early childhood Mathematics (PB, SSI).

PB confidently and comprehensively answered the question of whether she believed that there was a gap between policy and practice in the teaching of the mathematical content of space and shape:

For sure. When I started teaching in 1983, space and shape was not part of the curriculum, even now, that Gr R is a more recognised school year, there still seems to be grey areas of what should be done when teaching (PB, SSI).

Only two factors were briefly mentioned by PB. However, these factors did not really influence her teaching, she just mentioned it as part of the conversation we had.

Factor 1 ***Outdoors (Learning environment):***

> *It is important to teach space and shape concepts outside because children should be aware that even the jungle gyms they play on and the trees they climb consist of space and shape.* PB played a game called "the shape walk" when teaching space and shape concepts outdoors (PB, SSI)*.*

She also said:

> T*hese games are played outdoors, where children need to identify different shapes on their "walk" and children then need to describe what shapes they have seen and what that "shape (object) is called, for example, a brick is a rectangle* (PB, SSI).

Factor 2 ***Parental support (demands for teaching space and shape concepts)***

In the interview, the factor of parental support was not spoken about negatively, but PB remarked sometimes:

> *Children often get introduced to mathematical concepts at home or by their parents, but it remains the teachers' responsibility to ensure that the concepts get taught correctly* (PB, SSI).

4.3.3 Case of Participant C

PC taught at a township school (S2.). She was a 24-year-old female teacher. Her home language was Setswana. She was an enthusiastic and spontaneous teacher who enjoyed teaching. She had a Reception Year (Gr R) diploma obtained at the University of South Africa (UNISA). PC had four years of teaching experience and had been teaching Gr R since 2013. She had only taught at this school and she felt that she only ever wanted to teach Gr R (PC, SSI).

4.3.3.1 Observation lesson presented by Participant C

In the case of PC, I observed that she had not experienced much exposure to the subjects of Mathematics. Therefore, her understanding of the MCK seemed vague. Her experiences as a Gr R teacher, and her lack of understanding of the mathematical concepts of space and shape were observed in the general understanding on the concepts thereof and how she perceives teaching the content to the children in her classroom. In PC's observation lesson, she mostly taught using the direct teaching method (face-to-face) (PC, Obs.).

Figure 4.3: Classroom environment and materials used to teach the properties of two-dimensional shapes (2-D)

The photographs in Figure 4.3 reflect the objects PC used in her lesson, as well as what her indoor classroom environment looked like. The first two photographs illustrate flat 2-D plastic shapes, the third photo is a view of her indoor classroom environment and the last photograph is a poster of 2-D and 3-D shapes that PC uses to teach the mathematical concepts of space and shape.

Introduction to the lesson

In her introduction, PC started by welcoming the children, followed by a morning prayer and counting. Children then sang a "counting song". The teacher took the two-dimensional plastic shapes and placed them in the middle of the circle of seated children. Each child got the opportunity to step on the different shapes, and as they stepped on the shape, the children had to tell the teacher what the name and colour of the shape was. For example, if they stepped on a circle, the children had to say "red circle", and so she continued until they had all had a turn. She then moved on to the body of the lesson (PC, Obs.).

Body of the lesson

PC took the "soft shapes", and explained them individually according to their properties. The children counted how many corners each shape had, for example, a square has four sides and four corners. The children repeated after the teacher, as she counted. The shapes were sent around for each child to explore (discovery learning). PC integrated her lesson with counting and grouping bottle tops (PC, Obs.).

Conclusion of the lesson

In conclusion, PC asked the children "get up and go look for rectangles". When the children had done this, she said "good job, now let us identify things in the classrooms that make a square". The children had to identify and name the objects, such as a window in the shape of a square, then did the same, this time looking for a circle (PC, Obs.). The teacher used a case-based learning approach because the children had to apply what they had learnt about space and shape to their own life situations.

4.3.3.2 Interview with Participant C

PC explained that geometry was a subject that she knew little about. She described the term "geometry" as follows:

> *Geometry is a subject, which I know little about, as I did not learn much about it in high school* [she further elaborated that] *it is a subject and that teachers should teach it practically using a hands-on approach* (PC, SSI).

PC had a limited understanding of the MCK of space and shape:

> *What comes to my mind is that it refers to different types of things, such as differences and similarities, using various objects/materials when teaching and having the children interact during the lesson, so that they can understand the content you as a teacher are teaching.*
>
> Additionally, this indicated that her general understanding of space and shape was limited to her own prior exposure to and experiences of learning about space and shape (PC, SSI).

Although she valued geometry as an important content area, she emphasised:

> *I feel it is a very important area of Mathematics, but not a lot of focuses is given to teaching it. I only teach the "basics", I am not familiar with the other things that I can teach (PC, SSI).*

PC also felt that it was important for Gr R teachers to have a good understanding of the MCK of space and shape:

> *it is very important for Gr R teachers to have a good understanding of space and shape; however, it is difficult because little emphasis is placed on the importance thereof* (PC, SSI).

PC answered all questions to the best of her ability, although she did not understand the term pedagogical content knowledge:

> *I don't know hey! I forgot it* (PC, SSI).

However, PC did note that it was crucial that children should be taught more about space and shape from Gr R, because according to her:

> *It will benefit children starting Grade 1* (PC, SSI).

PC's uncertainty about geometrical concepts was further expressed in her attempt to explain the concepts of "geometrical reasoning" and "spatial reasoning":

> *I really don't know, but it has something to do with shapes and space and understanding it, I think* (PC, SSI).

PC mentioned that teaching space and shape was difficult, and that she scaffolded children's understanding by asking questions and repeating the content:

> *I teach what I know, and then I use a lot of questions when teaching. It is difficult, because I have to repeat things a lot, and children don't understand, coz, it is not their language* (PC, SSI).

The concept of instructional approaches was known to her as teaching styles.

*"*Is that like my teaching styles?" I said yes*.* She answered:

> *Now I understand. My teaching style is like me teaching the kids, all of them, sometimes they work in groups. It all depends what they are learning* (PC, SSI).

Due to her overcrowded classroom, she did not follow a play-based approach when teaching. She mostly employed direct teaching:

> *It is mostly me just explaining because it is easier with so many children. I explain the concepts to the children and then I show the children examples* (PC, SSI).

She added:

> *I teach according to CAPS, but I add my own content* (PC, SSI).

PC stated that her instructional approaches to teaching space and shape according to CAPS as:

> *Good. I try my best* (PC, SSI).

She was a passionate teacher and believed that her understanding and implementation of space and shape had an impact on her instructional approaches and practices:

> *It has a very big impact because you need to love what you teach. If you like it, the children will like it too* (PC, SSI).

She added:

> *It is difficult to like something or teach something if you do not know how. Teachers in South Africa are never taken into consideration when policies are written, they just expect we would know how to do it* (PC, SSI).

Her negative perception about guidance for her teaching was mainly focused on CAPS and how to use the document effectively:

> *I have a negative perception about CAPS, I feel that the CAPS document is sometimes beneficial, but I struggle to use it correctly because we have been promised for a long time now that we will go on courses and workshop, but it never happens* (PC, SSI).

CAPS provided no prescribed lesson plans, and she regarded the document as follows:

> *I use CAPS, it helps me, but there are no lesson plans in CAPS, we need that. The Department should put lessons in. I always have to read up, and it takes a lot of time. Not a lot of ideas, I have to Google a lot* (PC, SSI).

PC explained that the guidelines by CAPS were insufficient:

> *It's not enough, hey!* (PC, SSI).

The time spent on teaching the MCK of space and shape was a concern to her. She frankly said:

> *No, it doesn't add up. We mostly learn numbers and counting, not space and shape* (PC, SSI).

PC's explanations highlighted the negative aspects and rarely focused on the positive aspects. When asked whether she felt there was a big gap between policy and practice concerning teaching the mathematical content of space and shape, her answer was brief:

> *No. I don't think there is a gap, there is just not enough activities* (PC, SSI).

However, she contended that many factors influenced her teaching practices with reference to the mathematical content area of space and shape:

> *There are many factors that influence my teaching. Definitely, not having resources. We have minimum resources/materials, and we have to make do with what we have in the class. That's all. I make use of the school building or classroom windows and door or mostly recycled materials, such as bottle tops and boxes for box construction, but when I teach the concepts of space and shape, I use my 2-D plastic cut out shapes* (PC, SSI).

This led me to inquire if she taught 3-D shapes in her classroom. She responded briefly:

Yes. But only if it happens incidentally, and we do not discuss it (PC, SSI).

Factor 1: ***Indoors and outdoors (learning environment):***

PC lacked resources and had limited space in her classroom. She explained:

> *We have a lack of space in our classrooms to teach – too many children to teach and not enough materials to give to each child – children have to share or work in groups. This is very frustrating and makes teaching concepts right, a problem. We have to stack our chairs and tables on top of one another for the children to play, and we cannot have a play corner because there is no space* (PC, SSI).

PC correctly perceives outdoors learning as:

> *It is important, and it should happen incidentally, and children should learn through discovery outdoors, rather than the teacher telling them stuff* (PC, SSI).

She continued:

> *I do not directly teach children about space and shape concept outdoors, but if the children question me on something, for example, the stem of a tree, I would answer their questions and also tell the shape of it, by telling them that the shape is 3-dimensional and that is round and has no sides and no corners"* (PC, SSI).

Factor 2: ***Competent teachers***

I asked PC what she would recommend to other teachers or policymakers to improve the content provided in the CAPS document and to elaborate her answer.

PC, recommended:

> *We need workshops. We need to have workshops on CAPS. The department does not follow up with us, to see if we are OK. They should do something about our employment benefits, Gr R teacher salaries is not good. We don't get the benefits of medical aid or housing. It is not right* (PC, SSI).

Factor 3: ***Working conditions***

Her working conditions were very important but not valued as equally important as those of teachers who taught higher grades (older children) in the FP. Her opinion was that Grade R teachers should receive the same benefits as other FP teachers and should not be

> *excluded or "looked-down on*", *just because Gr R is still part of the preschool phase. Gr R teachers are underpaid and under-valued for the hard work we do* (PC, SSI).

> *We do not get money for new things (materials), I have been teaching here since the school opened the Gr R classes, but ever since then, we haven't received new things. When we ask for things, they tell us there is no money. We need to use our imaginations and improvise every day, but ja, what can we do!* (PC, SSI).

Factor 4: ***Parental support (demands for teaching space and shape concepts)***

PC felt frustrated about the support she received from the parents of the children she taught. She believed:

> *A lot of "problems" could be solved within the education system if parents were more involved in their children's schooling (PC, SSI).*

She made a statement that I found quite interesting and true in my own experience:

> *Parents think, because it this not Grade 1, it is less important* (PC, SSI).

It seemed that the lack of parental support was also linked to poverty:

> *Most parents at our school do not work, and cannot afford the school fees, so they feel ashamed, therefore we never see them* or *"the young children" are left with older children and then it becomes our problem* (PC, SSI).

Factor 5: ***Insufficient teaching of language***

The LoLT on the mathematical content of space and shape was a problematic area, PC explained:

> *It is very difficult for me as a teacher, as most textbooks and learning material are prescribed in English. I am a Setswana speaker and teach in my mother tongue, but some children in my class speak isiZulu or Xhosa as the mother tongue, so it causes a lot of confusion* (PC, SSI).

PC added:

> *Most language has their own dialects, and I have to try and accommodate all children and all languages when teaching. Most shapes we try and teach in just isiZulu and English, but it is a struggle* (PC, SSI).

Improving the language situation in her class was a challenge:

> *I do not know what to do, or how I can go about to improve the language situation in my classroom, it worries me, because some years there's a lot of children who struggle to understand me, and when they go to Grade 1, the Grade 1 teachers are cross, because they say, it was our job to teach them these things before Grade 1* (PC, SSI).

4.3.4 Case of Participant D

PD taught at an urban private school (S3.). She was a 30-year-old female teacher. Her home language was English. She was a passionate and free-spirited teacher, who took each learning opportunity in her stride. She had only taught Gr R since she started teaching 9 years ago. PD was a qualified teacher, with a B.Ed. (FP). Her classroom was well designed and decorated and had a variety of distinct learning corners.

4.3.4.1 Observation lesson presented by Participant D

PD used concrete objects from the environment to guide the children through discovery learning and regarded herself as the facilitator on learning the MCK of space and shape. PD's classroom was warm and inviting (PD, Obs.). She had all the different learning areas in her classroom and the learning of space and shape content was evident through her art on the wall and in her Mathematics display area (PD, Obs.). From the observation, journal notes and interview with PD, it was evident that she believed the MCK of space and shape should be taught to children creatively, to teach them problem-solving skills (PD, SSI).

In the observation lesson, she utilised a lot of different materials where she asked the children to design and build a zoo. Materials included management mats, pictures of a zoo, clipboards, paper, pencils, recyclable materials, wooden blocks, plastic animals, paper and coloured markers. Her classroom was well resourced. She nevertheless did not only use the materials she had at her disposal, but also utilised recycled materials, such as boxes (PD, SSI, and DA.). Figure 4.4 presents PD's materials. The photographs are discussed in chronological order below.

Figure 4.4: Building a zoo with 3-D materials

The first photograph illustrates how PD used the management mats as part of her introduction to her lesson. The next photograph shows the children discussing and planning their "zoo" and in the third photograph the children building their zoos. The last photograph is PD's lesson plan that she provided to me.

Introduction to the lesson

In the introduction of PD's observation lesson, she welcomed me and introduced me to the children. She immediately started with her lesson, as she had already done her morning ring before I arrived. She asked: "Who has been to a zoo before?" All the children raised their hands and were immediately intrigued; they all wanted to share their experiences. PD gave a few children the opportunity to share their stories with their peers before she continued. She then asked the children, "What animals do we find at a zoo?" The children answered lions and zebras; some even explained that the zoo also had aquariums with fish. After their discussion on the topic of the zoo, PD said: "Today we are going to work in groups." She divided the children into groups and placed a picture of a zoo in the middle of each group. She asked the children to work with their "face-partners" (meaning the child sitting opposite them). As the children were sitting in their groups, she posed questions such as "I think, I wonder, I see. What do you think about the zoo picture you have? What do you see in the picture? What makes you wonder in this picture about the zoo?" The children had to discuss the answers with their "face-partners" (working in pairs). Leading to the body of her lesson, she told each group to choose and collect materials they were going to need to build their own zoo.

Body of the lesson

The children regrouped after they chose the materials they were going to use to build their zoos. The teacher then briefly discussed the factors that children should remember when building their zoo:

> It *must be safe for the animals, there must be enough space, their enclosure should reflect their natural habitat, and you should make sure the animals cannot get out*

of the enclosures, because it could be dangerous for the visitors visiting the zoo (PD, DA.).

She asked the children to *"*choose one member of your group to draw the zoo, but all of you should give your ideas". Thereafter, the children started designing and building their zoos (problem-based learning).

Conclusion of the lesson

In the conclusion of her lesson, she asked each group to explain their structures (discovery and inquiry-based learning). She asked them: "How did you build it? What is special about your zoo? Do you think your animals are safe in your zoos?"

4.3.4.2 Interview with Participant D

The term geometry did not only include space and shape aspects to PD; she defined the term as:

> *Geometry in Gr R is how to manipulate things around us, that includes formal concepts that teachers should teach, such as area, volume and length* (PD, SSI).

PD explained her personal experiences and her understanding of space and shape by referring to her direct environment:

> *I enjoy teaching space and shape concepts, it is something different, and it is all around us, I actually don't experience it as bad, I like it* (PD, SSI).

She added:

> *How to manipulate things around us. I think also, think it is everything in our direct environment, it is concrete and abstract objects* (PD, SSI).

She valued the mathematical content area of space and shape as important:

> *It is definitely an important area of mathematics. It is concepts we use daily and it is all around us. Space and shape is definitely under-taught and could be why children struggle with mathematics when they are older.* (PD, SSI).

PD had good teaching approaches to the topic under study, but did not know the meaning of pedagogical content knowledge:

> *Mmmm … I have definitely heard about this before, but no I actually don't know. So, I hope I answer this correctly. It is teaching theories put into practice* (PD, SSI).

This led me to ask if she knew any theories of learning mathematics, such as the theories of Piaget, Vygotsky and Van Hiele. She replied:

> *I have heard about Piaget, I vaguely remember Vygotsky, but Van Hiele definitely not* (PD, SSI).

She described her understanding of the terms "geometrical reasoning" and "spatial reason" as follows:

> *Geometrical reasoning is I would think has to do with the relation to space and shape, but I have never heard of that term before…oh, goodness! And spatial reasoning is the same as geometrical reasoning, I understand it as the space around you, and how you would relate to a space in your environment* (PD, SSI).

PD, effectively scaffolded children's understanding of space and shape during her observation lesson, and in turn, she was able to put her practice into theory as follows:

> *I start by letting children explore with wooden blocks, building things, also making shapes with their bodies. Then I move on to teaching prepositions, using chairs for example, where children have to stand in front of the chair, next to the chair, on top of the chair etc. I teach a lot using waste materials and letting children manipulate different sized objects, for small objects I use tweezers for fine motor development* (PD, SSI).

Additionally, she employed various instructional approaches:

> *Oh goodness! There are so many, I guess the ones I use most includes whole-class teaching, paired learning, working in small groups and individual learning* (PD, SSI).

I asked her what impact teachers' understanding and implementation has had on teachers' instructional approaches and practices (PD, SSI). PD's opinion was that teachers' instructional approaches and practices could have a negative impact on teaching and learning if teachers did not understand the content they had to present to the children:

> *Yes, it does have an impact, because if you don't understand it, you cannot relay it. Teachers need knowledge to teach concepts, but I don't think all teachers have all the knowledge they need* (PD, SSI).

Her perception of the content of space and shape described in CAPS was:

> *I think my perception and understanding of space and shape is adequate. I think CAPS is age-appropriate for Gr R. I am able to implement it in my classroom* (PD, SSI).

PD believed that her perception was not influenced by teachers' perceptions nationally:

> *I don't know about South Africa, but at our school it is positive* (PD, SSI).

PD did not allow the CAPS document influence her views or ideas. She explained that it was important to understand the required outcomes:

> *To me, it is just another document. I do not follow it religiously, but I do look at the outcomes, and then extend it* (PD, SSI).

To her the guidelines were vague, and teaching practices were not optimally promoted, not just for the content of Mathematics, but all content areas in Gr R. PD's response was similar to that of the other participants:

> *Honestly, I don't think the guidelines are very useful. I feel the content provided is adequate and age-appropriate for Gr R, but there should be elaborated on the content of all areas of Mathematics, not just space and shape but also to assist teachers in their teaching* (PD, SSI).

She mentioned that the time spent on teaching the MCK of space and shape was integrated into other content areas as well:

> *Yes, it is mostly integrated into physical education activities* (PD, SSI).

For PD, there was a big gap between policy and practice regarding teaching the mathematical content of space and shape. Her response was brief, yet descriptive:

> *Yes. The document should be elaborated and more ideas, examples and activities should be included, I think that will bridge the gap* (PD, SSI).

According to her, there were limiting factors which influenced her teaching practices:

There are not many factors that influence my teaching practices (PD, SSI).

Factor 1: ***Indoors and outdoors (Learning environment):***

Outdoor learning is not a priority to PD, and it is clear in her reply:

> *Outdoor learning does not often happen,* and *if it happens, it happens mostly through Physical Education or integration with other learning areas* (PD, SSI).

Factor 2: ***Competent teachers***

I asked her what she would recommend to other teachers or policymakers in improving the content provided in the CAPS document. She responded:

> *Teachers should be prepared, before teaching. Policymakers should maybe reflect on the shortfalls experienced by teachers in their classrooms, especially Gr R* (PD, SSI).

Factor 3: ***Insufficient teaching of language***

PD noted the importance of understanding and implementing the correct language when teaching the mathematical concepts of space and shape:

> *I would say that I am more conscious when teaching space and shape, to make sure I use the correct terminology. If I'm not sure, I read up on it, before teaching it* (PD, SSI).

4.3.5 Case of Participant E

PE taught at an urban private school. She was a 51-year-old female teacher. Her home language was English. She was a kind-hearted and loving teacher. PE had been teaching Gr R for 9 years. She had been teaching for 30 years in various grades from Grade 000 (age 3) to Grade 5, but Gr R was her favourite age group. She had a Diploma in Pre-primary Education. She believed that it was important that more emphasis be placed on the subject of Mathematics in general (PE, SSI).

4.3.5.1 Observation lesson presented by Participant E

PE's general understanding of space and shape seemed satisfactory. Her classroom had a warm and inviting atmosphere. The classroom layout was good and children could move freely within the space. During the lesson that was observed, she utilised different instructional approaches to keep the children interested in what they were learning and also encouraged them to collaborate with each other. The materials PE used in her lesson included paper butterflies, Geostacks, Planx, chalk, paper shapes and a symmetry activity worksheet with which she concluded her lesson.

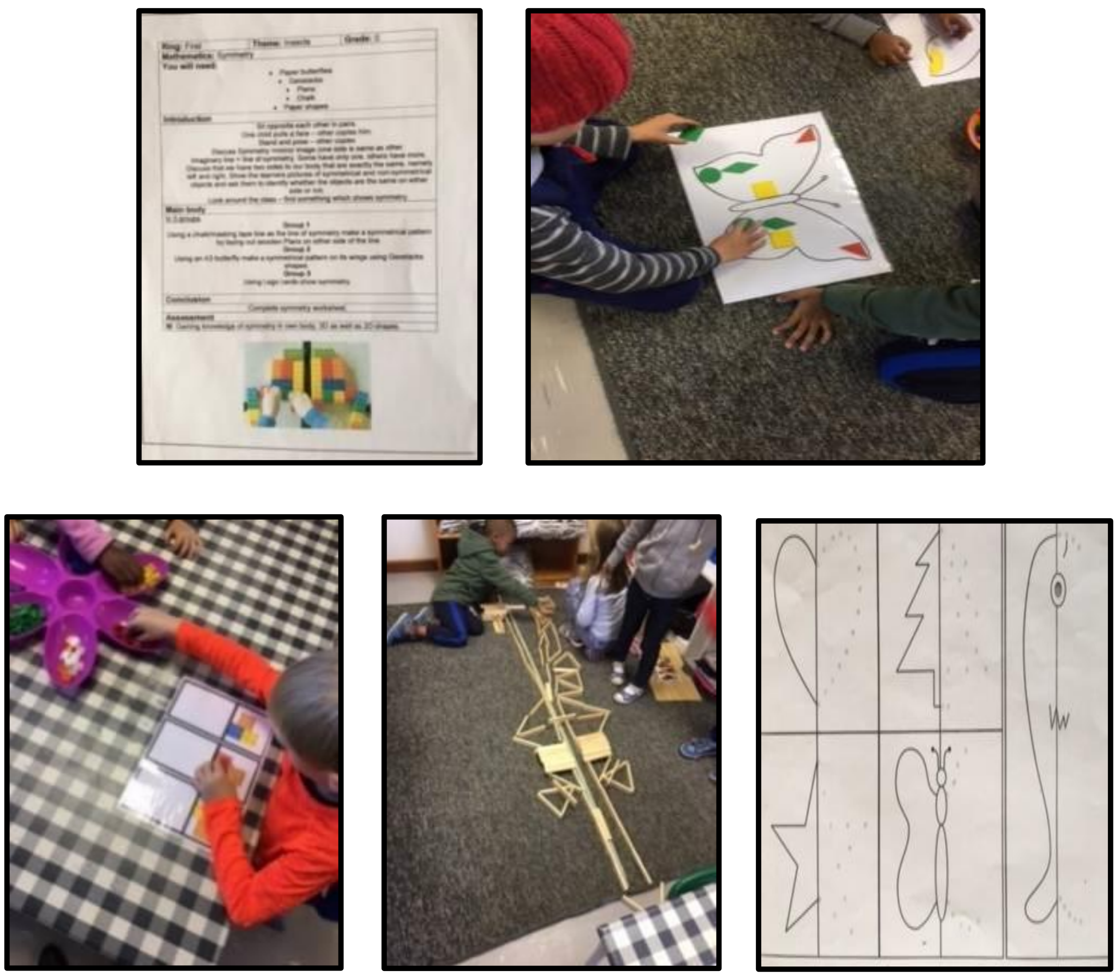

Figure 4.5: Photographs of symmetry lesson's activities

The photographs in Figure 4.5 start with PE's lesson plan for the observation lesson (first photo). The three centre photographs illustrate the chronological order in which PE presented her lesson. The second photograph shows the paper butterflies. The third photograph illustrates the Geostacks. The fourth photo illustrates the Planx, and the last photograph is of the worksheet she used.

Introduction to the lesson

In PE's introduction of her lesson, she welcomed me and told the children to tidy up, as they had been enjoying free play before my arrival. She immediately started with her lesson, as it was just before the break for the children. She introduced the concept of symmetry. PE asked the children to sit opposite each other in pairs. "Right," she said, "now one of you pulls a face, and then your friend should copy you. Everyone should get a turn, OK?" When each child had had a turn, she told the children: "Now stand opposite your friend and make a pose, then let your friend copy your pose, and you copy theirs." PE explained the concept of symmetry, and that it is a mirror image. She went on by discussing what mirror image means, using a small mirror. She said: "A mirror image is when the one side is when one side is the same as the other side." Also, she drew an imaginary line and said: "This line is the line of symmetry." She continued, explaining that "we have two sides to our body, that are exactly the same, for example, your left-hand side and your right-hand side". She had picture cards that she showed the children and then asked them to identify whether the objects on the picture cards were symmetrical or non-symmetrical. The children had the opportunity to answer her questions. Lastly, she told the children to look around the class and find something which is symmetrical. The children seemed to love engaging in this activity (PE, Obs.).

Body of the lesson

In the body of her lesson, PE divided the children into three groups. Each group was assigned to one of three activities that she set out before the start of her lesson.

Group 1 – the children were told to take chalk and to draw a symmetrical line (imaginary line, as the teacher explained), then to use the Planx blocks to create a pattern through laying them out on either side of the "line".

Group 2 – the children were asked to make a symmetrical pattern on butterflies' wings, using Geostacks shapes.

Group 3 – the children were asked to build symmetrical patterns, using paper shapes.

Conclusion of the lesson

As a conclusion, the teacher had a worksheet, where only one side of a shape was given and the children had to complete the other half of the shape to create the full shape (PE, Obs. and DA.).

4.3.5.2 Interview with Participant E

PE calmly defined the term "geometry" in her own words:

> *Geometry refers to working with different shapes and lines. Lines put together form different shapes* (PE, SSI).

For her, children's learning processes were reflected in her experiences when teaching, and linked to her understanding of the MCK of space and shape:

> *I enjoy teaching space and shape concepts to children, I think children are very inquisitive in Gr R, and teaching space and shapes build on that. I think that I understand it better through my years of teaching experience, but you learn new things all the time* (PE, SSI).

Exploration is an important aspect when teaching space and shape. PE explained how she used exploration:

> *What comes to my mind when thinking about space and shape is teaching the different properties and prepositions* that children can learn and explore (PE, SSI).

She believed that teachers' understanding of the mathematical concepts was important, especially for the way it was taught:

I definitely feel it is very important for teachers to have a good understanding of space and shape, because teachers need to be able to explain to children where they are in relation with their environment, in my years of teaching I found it helps children to understand other concepts (not necessarily mathematically related) much better, such as their laterality skills (PE, SSI).

Although PE hesitated when asked whether she understood the term pedagogical content knowledge, she was able to portray her understanding correctly:

I know it has something to do with methods teachers use, and how teachers should teach mathematical concepts … I think! (PE, SSI).

According to her, the terms "geometrical reasoning" and "spatial reasoning" meant:

Geometrical reasoning is understanding shapes and lines and their relation to one another, and spatial reasoning is understanding positions and shape and where objects made up out of different shapes fit in (PE, SSI).

PE scaffolded children's understanding of space and shape according to the expectations of CAPS, even though she did not directly refer to CAPS. Her detailed description was documented as follows:

I like teaching through exploration. Children should learn from their own "mistakes" to see when things work and when things don't. So, I would say that I scaffold children's understanding of space and shape through questioning and using different activities. Activities include sorting and classifying different shapes, building with blocks or other shapes, creating patterns with different shapes and playing games, children like learning when it doesn't feel like work, you know (PE, SSI).

PE believed that her years of teaching experience had moulded her as a teacher and the instructional approaches she used in her classroom reflected this:

I am an oldie … I like teaching through formal work, using assessments, groupwork, individual work and paired working and of course, a lot of repetition (PE, SSI).

She described her view on the effect she believed teachers' understanding and implementation had on their instructional approaches and practices:

> *You know, teachers need knowledge to teach any subject, but with the little ones, teachers need to remember to teach concepts at their level, otherwise it will go into the one ear and out by the other* (PE, SSI).

CAPS provided the basic content teachers needed, according to PE:

> *I think it is well explained and thorough, but I do think Gr R teachers should extend on it; the basic concepts are there* (PE, SSI).

When questioned about how she believed South African teachers perceived CAPS, she answered:

> *Positive impact, because the CAPS document serves it purpose, doing what it should do* (PE, SSI).

PE believed that each teacher had individual needs and that the CAPS document should be amended by each teacher to suit their teaching needs:

> *To me, it is just guidelines that should be extended and adapted according to what every individual needs and desired outcomes of his /her lessons* (PE, SSI).

Time spent on space and shape in Gr R classrooms are not substantial, and time should be integrated into other lessons, which is described in her reply:

> *Nope, we don't teach it formally, maybe we should. We "touch" on it, when it comes up in other lessons* (PE, SSI).

PE reflected on the time when she initially started teaching and strongly believed that the "gap" between policy and practices would continue, due to minor changes that took place over the years. Her answer was not portrayed as either positive or negative:

> *Maybe, I don't know, it has been like that for years, don't think it will change anytime soon* (PE, SSI).

Factors were not something she had thought of, but felt that there was room for improvement in certain areas, such as teaching outdoors:

> *Oh, golly, I don't know of any, let me think… probably teaching outdoors, but in general I am very happy* (PE, SSI).

4.4 Summary of data

Table 4.4: Data analysis according to categories derived from data collected

Broad categories			**Participant responses**		
	PA	**PB**	**PC**	**PD**	**PE**
Defining and understanding geometry	"Everything around us – different objects taking space in an environment".	"Geometrical shapes -how we introduce it to children - children, need to name, identify and explore shapes properties." Understood it as making children aware of shape in their space.	Knew little about geometry. Gr R teachers should teach it practically through a hands-on approach.	"How you manipulate things around you, includes formal concepts such as volume and length."	Defined geometry as "lines and shapes". Felt it was very important for Gr R teachers to understand the content of geometry to implement its concepts.
Teachers' MCK of space and shape	Felt it was important for teachers to have good knowledge. Teacher confident in her teaching abilities. Able to sufficiently explain the term PCK.	"It is crucial – it is the foundation of mathematics." Very passionate about the subject of mathematics. Had a good understanding of terms such as pedagogical	Very important area of mathematics, but only taught what she knew. Not familiar with what she could teach, did not understand the term PCK. Difficult to teach, received little emphasis.	Felt it was an important area of mathematics. Enjoyed teaching it, if she did not know something, she read up on it. believed it was under-taught. "If teachers don't teach it, children	Enjoyed teaching it, felt it made children inquisitive. Teacher felt her teaching experience counted in her favour. Also felt it was very important for teachers to have a good

Broad categories	Participant responses				
	PA	**PB**	**PC**	**PD**	**PE**
		content knowledge.		could struggle in mathematics for later grades."	understanding – needed to explain to children.
Activities for scaffolding children's understanding of space and shape in Gr R	Taught space and shape mostly through movement and kinaesthetic awareness. Used different materials to teach space and shape. Well resourced.	Started with the "basics". First 2-D, then 3-D. Symmetry also very important. Establish what children know and build from that.	Not well resourced. Taught using recyclable materials. Used environment and kinaesthetics, children using their bodies.	Let children explore with wooden blocks first, building with them, and making shapes with their bodies. Also scaffolded by teaching prepositions, felt it is important for spatial awareness.	Taught space and shape concepts through exploration. Activities included sorting, classifying and identifying shapes. Children used their bodies.
Teachers' instructional methods (Ramagoshi, 2015).	Play-based learning and exploration through movement.	Various teaching approaches – more a facilitator than a teacher. Believed in teaching with music and through play.	Depended on what she was teaching, mostly taught directly – too many children. Also used groupwork. Explained concepts and then visually showed them to the children.	Felt it had an impact on teaching practices. Taught space and shape through paired teaching, groupwork and whole-class teaching. Used different approaches.	Formal assessments, paired work, groupwork and whole-class teaching.

Broad categories	Participant responses				
	PA	**PB**	**PC**	**PD**	**PE**
Perceptions about teaching space and shape	Positive perception – enjoyed teaching space and shape concepts, a lot one can do with it.	Felt teachers should be passionate – if teachers did not love teaching it, children would not enjoy learning it. Thought teachers in SA had a negative perception.	Negative perception. Received a lot of empty promises with overcrowded classes and lack of resources.	Did not know, about the perception in SA, but had a positive perception at her school.	Positive perception. Did not affect her, and felt things would not change quickly. Just accepted it, and worked with it.
Understanding of CAPS	Used it mostly as a guideline and extended its content. Felt it lacked creativity.	CAPS workshops provided insufficient knowledge. Only provided an overview. Needed to focus on specific content areas in one workshop, not all content areas.	Content needed to be added. Department did not think of teachers. Activities needed to be added.	Only a guideline, teachers should add to its content.	Served its purpose. Felt it should be extended according to each individual teacher's needs.

Broad categories	Participant responses				
	PA	**PB**	**PC**	**PD**	**PE**
Factors influencing teaching	Insufficient outdoor teaching – should teach outside more often. Parental support	Insufficient outdoor teaching – should teach more often outside. Parental support.	Overcrowded classroom Lack of resources Language Learning environment and working conditions Teacher competency	Insufficient outdoor teaching – does not happen frequently. Integrated with physical education.	Insufficient outdoor teaching.

4.5 Conclusion

Five case studies of Gr R teachers were discussed and presented in relation to their understanding and implementation of the MCK of space and shape. The aim of Chapter 4 was to present research findings according to a case study design and to identify broad categories. The data collection strategies employed provided sufficient data to present the participants' experiences, views, opinions, knowledge and instructional approaches as well as the factors influencing the implementation of the content knowledge of space and shape.

The chapter gave me a clear understanding of the importance of geometry, its complexity and the fact that it was a challenge to many teachers in South Africa. I was convinced that the participants were appropriate for finding answers to my research questions, because purposefully selected Gr teachers who were confronted with the teaching of geometry were the best people to utilise. I was pleasantly surprised with my research findings as they provided me with rich data and lived up to my expectations. Chapter 5 provides a comprehensive, comparative analysis of the existing research literature and the findings.

CHAPTER 5:

COMPARISON OF THE RESEARCH FINDINGSWITH THE LITERATURE

5.1 Introduction

Chapter 4 described the findings of the participants' shared experiences, knowledge and perceptions on teaching Gr R children the content knowledge of space and shape in South Africa. The teachers also explained their understanding of the CAPS and how they implemented geometry using various instructional approaches.

Chapter 5 starts with a glimpse of the research process, followed by a graphical representation (Figure 5.1). The chapter draws comparisons between the research results of the study and the relevant concepts and theories from the literature review as discussed in Chapter 2. I compare the results with the existing literature about teachers' understanding and implementing of the MCK of space and shape. The supportive evidence, gaps, silences and insights into the topic of the content of space and shape are highlighted.

5.2 A glimpse of the research process

The focus of this study was Gr R teachers' understanding and implementing of the mathematical concepts of space and shape in their classrooms in the South African context. The study explored teachers' views, ideas and perceptions and opinions of the subject under study. Its foundation was Chapter 1, with a background description and orientation on which all the other chapters of the study have been based. A comprehensive literature review was undertaken in Chapter 2. The review has been compared with the empirical findings in Chapter 5. Figure 5.1 depicts the findings that were derived from the literature review, participant observations, semi-structured interviews, document analysis and journal-keeping in phases 1, 2 and 3 of the study. Phase 4 in Figure 5.1 represents the findings and recommendations discussed in Chapter 6. All four phases were utilised in the investigation of teachers' understanding and implementation of the MCK of space and shape. The broad categories of the findings outlined in Chapter 4 assisted in identifying the smaller and more manageable themes and subthemes in Chapter 5. The three themes and four subthemes listed in Figure 5.1 are discussed and compared with the literature in Chapter 5.

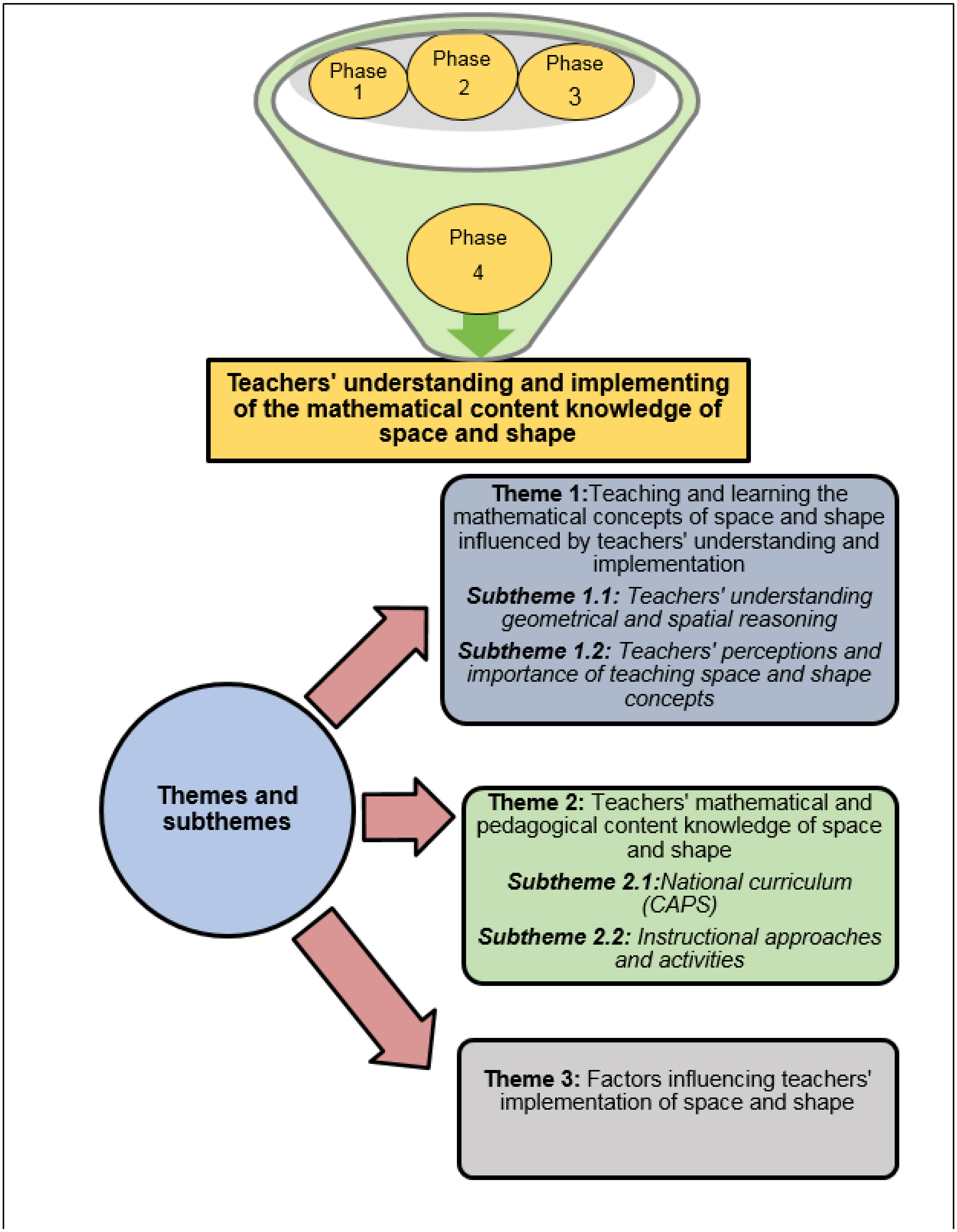

Figure 5.1: Graphical representation of the research process (adapted from Steyn 2014)

The research data revealed that teachers used various instructional approaches that gave children opportunities to learn in a playful way about the mathematical concepts of space and shape.

The study examined the influences of the mathematical and pedagogical content knowledge of space and shape on teachers' teaching practices participating in this study and how the influential factors emerged from their experiences. Teachers' knowledge of the content area of geometry influenced their ability to scaffold children's development by using various activities. The findings in Chapter 4 established that teachers' understanding of mathematical concepts and real-life teaching experiences influence children's learning processes. In Chapter 4, the factors that affect the effective implementation of Mathematics were found to be the school environment, availability of materials and resources, the LoLT and the competencies of teachers. The findings discussed in Chapter 6 reveal that quality teacher training, teachers' experience, well-structured workshops and cooperation among colleagues at schools are significant contributing factors for the effective implementation and understanding of the relation between policy and practice. In this chapter, I answer the research questions, interpret the research findings and provide recommendations and a conclusion on the research project.

5.3 Comparing research results with relevant literature

From an exhaustive examination of the data, seven broad categories emerged, which were described in Table 4.1. The categories have subsequently been refined into smaller and more manageable themes and subthemes that were informed by the research questions and the literature review (Creswell 2012; 2013:180). As can be seen in Figure 5.1, the three main themes are: (a) teaching and learning the mathematical concepts of space and shape influenced by teachers' understanding and implementation; (b) teachers' mathematical and pedagogical content knowledge of space and shape; and (c) factors influencing teachers' implementation of space and shape. Theme 1 has two subthemes, namely teachers' understanding of geometrical and spatial reasoning, and teachers' perceptions and the importance of teaching space and shape. Theme 2's subthemes pertain to the national curriculum (CAPS) and instructional approaches. Theme 3 has no subthemes.

After comparing the literature review in Chapter 2 and the research findings in Chapter 4, it became apparent that there are numerous facets relating to teachers' teaching of the MCK of space and shape in Gr R. These facets can be divided into four categories: supporting evidence (Table 5.1), contradictory evidence (Table 5.2), silences in the literature (Table 5.3) and new insights (Table 5.4). The comparisons were aligned with the themes and subthemes that emerged from the data analysis.

5.3.1 Comparing results to existing knowledge (literature): Supportive evidence

Table 5.1 describes the relationship between the literature and research findings. The existing literature (Chapter 2) and research findings (Chapter 4) are summarised and compared. Each similarity is supported by an interpretive discussion. *Existing knowledge* outlines the literature reviewed in Chapter 2 about the teaching and learning of the MCK of space and shape. *Findings* refers to the findings from the participant observations, semi-structured interviews and document analysis. The *interpretive discussion* deals with the differences and similarities between the literature and teachers' understanding and implementation of space and shape.

Table 5.1: Comparing results to existing knowledge: Supportive evidence (adapted from Ebersöhn 2009)

Themes and subthemes	Existing knowledge (literature)	Findings	Interpretive discussion
Theme 1 Teaching and learning the mathematical concepts of space and shape influenced by teachers' understanding of geometry	Geometry denotes the "study of shapes, their relationships, and their properties" (Bassarear 2012:463). Space and shape (geometry) comprises one of the first mathematical content areas of mathematics that young children spontaneously review and explore and teaching should focus on this facet (Frobisher *et al*. 2007:6).	Participants expressed different views on their understanding of and definitions of space and shape, and their responses supported the notion that teaching through exploration is crucial (S1PA, S1PB, S2PC, S3PD, S3PE).	The literature and research findings support the notion that the mathematical concepts of space and shape should be taught through exploration.
Subtheme 1.1 Teachers' understanding of geometrical and spatial reasoning	With well-reasoned and well-executed instruction, children can use geometric reasoning – defined as "the invention and use of formal conceptual systems to investigate shapes and space" (Battista 2007:843) – to solve geometric problems as they develop their understanding of geometry. Spatial sense is informed by spatial reasoning, which, according to Bahr *et al.* (2010:390), is at the heart of all	Participants were able to explain some aspects of the importance of geometrical and spatial reasoning, referring to a play-based approach when teaching space and shape concepts in their classrooms and stating that children should be a part of the learning process to understand what they are learning (S1, PA, PB, S3, PD, PE.).	The literature and research findings confirm that teachers have different views of the concepts and the curriculum to teach according to the curriculum and that there are aspects concerned with mathematical knowledge that teachers could improve on.

Themes and subthemes	Existing knowledge (literature)	Findings	Interpretive discussion
	mathematical strands and comprises “the ability to think and reason by comparing, manipulating and transforming a mental picture”.		
Subtheme 1.2 Teachers’ perceptions and the importance of teaching space and shape	CDE has stated that teaching and learning of mathematics in South Africa is “amongst the worst in the world as teachers themselves struggle to respond to questions that they are teaching from the curriculum, and expecting the children to answer”. Moreover, teachers lack mathematical knowledge (Green 2011).	The majority of participants had a negative perception but nevertheless felt that space and shape was a very important content area of Mathematics that did not receive enough attention. Participants mentioned that they believed that the majority of teachers (other schools) had a negative perception. Teachers in this study implemented the mathematical content area of space and shape in a positive way during the observation lessons, even though they had their reservations about certain aspects of the concepts of space and shape when they were interviewed (S1, PA, Obs., and SSI. PB, Obs., SSI.	

Themes and subthemes	Existing knowledge (literature)	Findings	Interpretive discussion
		S2, PC, Obs., SSI, S3, PD, Obs. SSI., PE, Obs. SSI).	
Theme 2 Teachers' mathematical and pedagogical content knowledge of space and shape Subtheme 2.1 National curriculum (CAPS)	In the CAPS content area of space and shape, Gr R teachers are required to focus on teaching the properties, relationships, orientations, position and transformations of 2-D shapes and 3-D objects as stipulated in the national curriculum (DoE 2011).	The teachers focused on teaching the properties, relationships, orientations and transformations of 2-D and 3-D shapes/objects in line with CAPS. During the observation lessons, they covered either one or all of these areas in their lessons. The visual representations included in this study serve as confirmation of how teachers achieved the listed outcomes in their classrooms. (S1, PA, Obs., PB, Obs., S2, PC, Obs., S3, PD, Obs. PE, Obs.).	Participating teachers were of the opinion that the curriculum should give more guidelines, as many Gr R teachers were not trained effectively to understand the curriculum.
Subtheme 2.2 Instructional approaches and activities	Space and shape is an important part of young children's mathematical development and should be spread out over the week, with some focused episodes under the guidance of the teacher, and many opportunities for	Participants utilised various instructional approaches during their observational lessons, including guided instruction (S1, PA, Obs., PB, Obs., S2, PC, Obs., S3, PD, Obs. PE, and Obs.).	The literature and research findings of this study confirm that the teachers implemented age-appropriate materials available to scaffold children's development. Few culturally appropriate materials were used. As stipulated in CAPS,

Themes and subthemes	Existing knowledge (literature)	Findings	Interpretive discussion
	construction, sand and water play by the children (DoE 2011:37).		the teachers taught different concepts on the content of space and shape for Gr R, but felt that many teachers found the content of CAPS insufficient in terms of creativity and approaches to teachers.
Theme 3 Factors influencing teachers' implementation of space and shape concepts	Environments play a vital role in children's learning about space and shape because "the environment we are in affects our moods, ability to form relationships, effectiveness in work and play – even our health" (Bullard, 2010: 3). Thus, Gr R classrooms should be exhilarating to children, inspirational in generating enthusiasm and creating an appetite for learning about the MCK of space and shape (Drake 2009 [2010]:1).	Participants had warm and inviting classrooms, and they had a positive disposition toward teaching the mathematical concepts of space and shape. Furthermore, teachers in this study were enthusiastic about teaching the mathematical concepts of space and shape, which seemed to create an appetite for learning about the content of space and shape (S1, PA, Obs., PB, Obs., S2, PC, Obs., S3, PD, Obs. PE, and Obs.).	Learning environments such as classroom spaces affect teachers' teaching practices. Classrooms were well presented and inviting and generated enthusiasm among children, ensuring that an appetite for learning was created. However, the overcrowded classroom environment and insufficient resources seem to be a limitation to effective teaching in the classroom at the township school.

5.3.2 Comparing results in existing knowledge: Contradictory evidence

Table 5.2 indicates the differences between the existing literature and the findings. In this section, existing knowledge is compared to the research findings. The contradictions or differences are explained in an interpretive discussion counter to the themes and subthemes that emerged from the data analysis in Chapter 4. *Existing literature* is supported by similar findings and refers to the literature reviewed in Chapter 2, exploring Gr R teachers' understanding, views, ideas and perceptions and the factors that influence the implementation of the mathematical concepts of space and shape. In the *Findings* column, the results are discussed which derived from analysing the observations, photographs, semi-structured interviews and document analysis. In the last column, the *interpretive discussion* was constructed by my interpretations of the differences between the literature and the analysed data, explained as it relates to the relevant themes and subthemes.

Table 5.2: Comparing results in existing knowledge: Contradictory evidence (adapted from Ebersöhn, 2009)

Themes and subthemes	Existing knowledge (literature)	Findings	Interpretive discussion
Theme 1 Teaching and learning the mathematical concepts of space and shape influenced by teachers' understanding of geometry	In recent years, questions have been raised about the effectiveness of the teaching and learning of mathematics in a South African context (Kruger 2011; Rademeyer 2014; Van der Merwe 2014).	The teachers raised their concerns about teaching mathematics and confirmed that teaching space and shape concepts could be challenging at times.	Teachers need to be adequately trained and workshops need to be employed to make teachers competent in gaining the substantial knowledge required to effectively teach the concepts of geometrical and spatial reasoning and expand their pedagogical content knowledge to promote different learning styles in their Gr R classrooms.

Themes and subthemes	Existing knowledge (literature)	Findings	Interpretive discussion
Subtheme 1.1 Teachers' understanding of geometrical and spatial reasoning	The pedagogical content knowledge in this study includes the knowledge of content and children. Gr R teachers should know that children are diverse, have different learning styles, are active problem-solvers, are able to construct their own mathematical knowledge and are capable of learning mathematics (Charlesworth & Lind 2013).	Although the literature indicates that teachers should have pedagogical knowledge and know that children are diverse and have different learning styles to actively solve problems to construct their own knowledge, there is very little evidence that the participant teachers applied different learning styles to individual children's needs to actively solve the problem. Problems were mostly solved in doing groupwork or paired work or whole class teaching (S1, PA, PB, S2, PC, S3, PD, PE.).	Teachers should provide children with ample opportunities to actively solve problems which in turn will enhance children's understanding of the mathematical concepts of space and shape.
Subtheme 1.2 Teachers' perceptions and the importance of teaching space and shape	International literature states the teaching and learning of certain mathematical concepts are challenging for mathematics teachers and children (Charlesworth & Lind, 2013; Cockburn, 1999; Dunphy, 2009; Holmes, 1985; Orton & Wain,	A teacher felt that she is not trained well enough to effectively teach the mathematical content knowledge of space and shape and therefore her teaching of the mathematical content knowledge of space and shape is a challenging (S2, PC)	Teachers should receive continuous in-service training on all the mathematical concepts taught.

Themes and subthemes	Existing knowledge (literature)	Findings	Interpretive discussion
	1994; Van de Walle & Lovin, 2006).		
Theme 2 Teachers' mathematical and pedagogical content knowledge of space and shape	One of the aspects that seems relevant and integrated with the teaching and learning of space and shape is creative arts, especially in Gr R.	The lessons presented by teachers during their observation lessons, did not included any creative art activities. All the activities that were presented were structured and teacher-directed activates (S1, PA, PB, S2, PC, S3, PD, PE.).	Teachers should maximize children's learning potential through integrating creative art activities, in order for children to incidentally learn about space and shape, through their own drawings, such as drawing a body image picture of themselves.
Subtheme 2.1 National curriculum (CAPS)	According to (DoE, 2011: 13) creative art activities could also have a mathematical emphasis for example using geometric shapes such as circles and squares to make a college or designing a pattern to frame a picture. It is the teachers' knowledge that could maximize learning potential.	Despite teachers explaining that learning should also happen incidentally, there was no evidence such as free-play activities in the fantasy corner, or sand and water play activities as part of teaching the concepts of space and shape (S1, PA, PB, S2, PC, S3, PD, PE.).	Gr R teachers should let children learn through play by providing for example sand and water play to enhance children's learning of the mathematical content knowledge of space and shape.
Subtheme 2.2	The Gr R teacher should be pro-active, a mediator, rather than a facilitator. A mediator makes the	Effective mathematics teachers reflect on their connected mathematical knowledge bases	Teachers should use appropriate resources, mathematical models (2D and

Themes and subthemes	Existing knowledge (literature)	Findings	Interpretive discussion
Instructional approaches and activities	most of incidental learning opportunities that arise spontaneously during a range of child-centered activities such as free play in the fantasy corner or block construction site, sand and water play activities as well as teacher-guided that focus on different mathematical concepts such as space and shape (Department of Basic Education, 2011).	and fluidly combine them with their experience and understanding of geometry when teaching (Luneta 2013).	3D objects) and technology to support learning. These projects could include reports, physical models, computer models, exhibitions, websites and other concrete products that give opportunities to children to show their understanding.
Theme 3 Factors influencing teachers' implementation of space and shape concepts	"Teachers are fundamental to the development of young children's mathematical abilities" (Greenes, 1999:46).	Unfortunately, like most developing countries, teacher in-service training opportunities are quite rare for many South African teachers (Leu, 2004:1). (S1, PA, SSI, PB, SSI, PC, SSI, PD, SSI, PE, SSI.).	The Department of Basic Education should set more finances aside to create opportunities where teachers can attend in-service training to better their teaching practices
	All new entrants intending to become (FP) teachers (qualified to teach from Gr R -3) should register for a B. Ed (FP) rather than for a Gr R Diploma, provided that they meet the	Some participants in this study, only have a Diploma and not a B. Ed. Degree (FP) (S2, PC, SSI., S3, PE, SSI.).	

Themes and subthemes	Existing knowledge (literature)	Findings	Interpretive discussion
	requirements for entry into the B Ed (Andrich, 2015).		
	Casey (2005: 30) further stipulates that the physical environment can portray the message that this is a *space* for children, for instance by means of soft landscaping, dimensions, appealing equipment and ample things with which to interact, which will be an implicit invitation to children to use fully in learning the mathematical concepts of space and shape.	A participant felt that her environment is not appealing, want that her school is under resourced, with limited materials for teaching the mathematical concepts of space and shape. (S2, PC, Obs., SSI.).	Teachers working conditions and environments should be reviewed to ensure that optimal learning takes place.
	"[T]here has been much discussion regarding the 'ideal' learner-teacher ratio" documented by the Department of Education (2005: 38). However, this is not the case as South Africa's "learner-teacher ratio is an average of between 35 and 40 learners per teacher". This is supported by Excell and Linington (2008) intricate on the necessity of an adequate	A participant stated that her classroom is over-crowded and that she does "not have enough resources to give to each child" and that she has "too many kids to teach" (S2, PC, Obs., SSI.). Children come from various cultural backgrounds and teachers feel more comfortable teaching the content of numbers and operations, rather than	

Themes and subthemes	Existing knowledge (literature)	Findings	Interpretive discussion
	number of teachers and explain that teacher shortages may lead to overcrowded classrooms. Teachers are often faced with working conditions in which they are offered little support to implement the mathematical content knowledge of space and shape (Smith, 2015). The one important influence on arithmetic that varies between cultures and the home and school contexts, is that of mathematical language (Dowker, 2005:207). According to researchers, most mathematics-mediated language appears to centred on numbers and lower level thinking skills.	space and shape, as they feel not enough time is spent on teaching the mathematical content knowledge of space and shape (S1, PA, Obs., SSI., PB, Obs., SSI., S2, PC, Obs., SSI., S3, PD, PE, Obs., SSI.).	

5.3.3 Comparing results in existing knowledge: Silences in literature

Table 5.3 presents the silences in the literature, relating to facets that have been emphasised in the findings (as a result of the data collection and analysis) but were not initially considered in the literature review in Chapter 2. The table only has three columns. The *findings* column refers to the results found from analysing the observations, photographs and documents provided by Gr R teachers. The last column, *interpretive discussion*, deals with the silences in current literature.

Table 5.3: Comparing results in existing knowledge: Silences in literature (adapted from Ebersöhn 2009)

Themes and subthemes	Findings	Interpretive discussion
Theme 1 Teaching and learning the mathematical concepts of space and shape influenced by teachers' understanding and implementation. Subtheme 1.1: Teachers' understanding of geometrical and spatial reasoning Subtheme 1.2: Teachers' perceptions and the importance of teaching space and shape,	Higher education institutions do not yet offer qualifications for Gr R. Teachers in this study also experienced this. In their view, Gr R teachers were not adequately skilled to teach the MCK of space and shape and did not know how to make use of geometrical terminology when teaching the mathematical concepts of space and shape, which influenced their perceptions negatively.	Higher education institutions in South Africa should offer qualifications to effectively train teachers. Teachers' perceptions would change if the factors that influence teachers' teaching practices were to be addressed accordingly. Many Gr R teachers in South Africa are under-qualified and only hold certificates for short courses.
Theme 2: Teachers' mathematical and pedagogical	CAPS lacked effective guidance and creativity (S1, PA.). The literature does not mention that the curriculum should be taught creatively, but does state that creative art activities should be incorporated to enhance children's learning of space and shape.	The national curriculum should be more specific and revised to provide guidelines on creativity.

knowledge of space and shape Subtheme 2.1 National curriculum (CAPS) Subtheme 2.2 Instructional approaches and activities	Participant teachers facilitated learning more than teaching it, believed that the mathematical concepts of space and shape should be taught by movement and exploration (S1, PA, PB.).	According to CAPS teachers are encouraged to be mediators rather than facilitators when teaching the MCK of space and shape.
Theme 3: Factors influencing teachers' implementation of space and shape concepts	Teachers explain teaching outdoors did not occur frequently and was mostly integrated with physical movement activities (S2, PC, SSI., S3, PD, SSI., PE, SSI.).	The literature does not focus much on outdoor learning and how teachers should implement space and shape concepts through a play-based approach.

5.3.4 Comparing research findings to existing knowledge: new insights

Table 5.4 summarises the newly gained insights that emerged from the findings in this study. The new insights are briefly interpreted and discussed. In the first column, the themes and subthemes are listed, which emerged after the data collection and data analysis. The second column provides a description of the newly gained insights, and the last column provides an interpretive discussion. This column discusses the new insight in relation to Gr R teachers' understanding and implementation of the MCK of space and shape.

Table 5.4: Comparing research findings to existing knowledge: new insights (adapted from Ebersöhn 2009)

Themes and subthemes	Description	Interpretive discussion
Theme 1: Teaching and learning the mathematical concepts of space and shape influenced by teachers' understanding and implementation. Subtheme 1.1: Teachers' understanding of geometrical and spatial reasoning Subtheme 1.2: Teachers' perceptions and the importance of teaching space and shape	Some Gr R teachers were not aware that the mathematical knowledge includes various strands, such as common knowledge and specialised knowledge, and not only just the MCK, which caused them to teach knowledge that they did not even know existed. The teachers were also not familiar with certain geometrical terminology; they were therefore accessing content without knowing its value or importance, before scaffolding children's development of space and shape activities. The teachers could easily express their perceptions and highlight the importance of space and shape concepts, but continued to teach without reflecting on their practices to improve their knowledge or enhance the children's experiences.	Pre-service and in-service training should focus on increasing teachers' MCK, because some teachers were not familiar with geometrical terminologies or the various strands and instructional approaches. Teachers should be guided to reflect on the effectiveness of their lessons.
Theme 2: Teachers' mathematical and pedagogical knowledge of space and shape Subtheme 2.1 National curriculum (CAPS) Subtheme 2.2	Teachers should work in groups at schools to understand and implement the curriculum better. Collaboration between teachers to effectively understand and implement the curriculum has proven to be good practice.	Cooperating and collaborating with colleagues at school has proven to be effective. Teachers should be encouraged to work together to have a better understanding and implementation of the curriculum. Teachers should implement play-based activities that are less teacher-directed

Themes and subthemes	Description	Interpretive discussion
Instructional approaches and activities		and more mediated through incidental learning. Policymakers should consider that many Gr R teachers are under-qualified and provide comprehensive guidelines and activities to the teachers. Teachers should ensure that materials are culturally appropriate and age-appropriate.
Theme 3: Factors influencing teachers' implementation of space and shape concepts	Factors that significantly influence Gr R teachers' teaching practices: Diverse languages of children Teachers' incompetence Lack of parental environment Overcrowded classrooms'	Teacher training and qualifications should prepare teachers to effectively impart understanding in the context of the diverse needs of the children.

CHAPTER 6:

SUMMARY, RECOMMENDATIONS AND CONCLUSION

6.1 Introduction

In Chapter 5, the research findings were compared with the literature in a sequence of four tables. The interpretive discussion in the first table focused on the similarities between the findings and literature; the second table highlighted the contradictory evidence between the findings and the literature. The third table revealed the silences that exist in the literature but not in the findings. The last table provided new insights linked to the findings and literature. Chapter 6 presents the data analysis and research findings, grouped into three themes and four subthemes, together with a synopsis of the chapters.

The synopsis is followed by the answers to the primary and secondary research questions. The recommendations from the findings are outlined and a conclusion and final thoughts end the study.

6.2 Synopsis of chapters

Chapter 1

Chapter 1 served as the orientation and background of this study. The chapter explained why this study was undertaken. I described the rationale, formulated the research questions, clarified the key concepts and gave a brief explanation of the methodology I employed.

Chapter 2

In Chapter 2, relevant existing research on the topic was sourced and the literature review formed an important part of the study. The chapter started with a discussion of theories that derive from a constructivist approach, including the views of Piaget, Vygotsky and Van Hiele, followed by other important literature relating to teachers' understanding and implementation of space and shape. The teaching and learning components of the mathematical concepts of space and shape in Gr R, CAPS, teachers' instructional approaches and factors that influence teachers' teaching practices were examined. In conclusion, a conceptual framework was derived from the literature and theories.

Chapter 3

Chapter 3 discussed the research methodology that was employed. It consisted of a qualitative approach in an interpretive paradigm and a multiple case study design. Five Gr R teachers in three schools participated in the study to investigate and present their understanding and implementation of the MCK of space and shape.

Chapter 4

Chapter 4 discussed the findings of Gr R teachers' understanding and implementation of space and shape. The findings were presented in a narrative writing style, which helped to identify the broad categories that emerged from the findings. The case of each of the five Gr R teachers was discussed in detail.

Chapter 5

Chapter 5 described the research process, illustrated by a diagram. A comparative analysis of the research findings of the study with the relevant concepts and theories from the literature were discussed in this chapter.

Chapter 6

Chapter 6 is the final chapter of this study. The research question is answered and the recommendations and limitations of the study addressed. A conclusion and final thoughts round off the study.

6.3 Answering the research questions

6.3.1 Primary research question

How do Gr R teachers understand and implement the mathematical content knowledge of space and shape?

The participating teachers stated that the mathematical content area of space and shape in Gr R was a crucial content area, as it was the foundation of Mathematics and led to learning about other mathematical concepts. The participating teachers had different views about teaching the mathematical concepts of space and shape. They were in the main positive about teaching the mathematical concepts of space and shape, although two of the participants believed that the majority of South African teachers had a negative perception of this content area. They felt that many Gr R teachers had not undergone the professional development required in this content area of Mathematics to effectively teach it to children. The teachers explained that many influential factors, such as parental support, the LoLT in mathematics, overcrowded classrooms and a lack of learning materials had a negative impact on their teaching practices.

The research results revealed that the participating Gr R teachers enjoyed teaching the mathematical concepts of space and shape and implemented them with a positive outlook. They conceded that extensive mathematical content and pedagogical content knowledge were important for effective teaching. During the observations, it was evident that the teachers were more facilitators than mediators, as prescribed by CAPS. Nevertheless, the teachers believed that the instructional approaches they used affected the way in which children learnt about the mathematical concepts of space and shape. Their practical teaching experience enabled the Gr R teachers to grasp the importance of teaching the MCK of space and shape.

In the observed lessons, these teachers started with children's prior knowledge and gradually introduced them to the new knowledge of space and shape. Research suggests that mathematical knowledge is constructed relationally (Arzarello *et al.* 2005; Bransford *et al.* 2000; Rudd *et al.* 2008; Van de Walle 2007) and that new knowledge is learnt more effectively when it draws on real and relevant contexts – reinforcing the idea of building on children's prior knowledge (Barnes 2004; Freudenthal 1971). In the body of the lesson, different resources were used to accomplish the outcomes of the lesson. The teachers used wooden blocks, chalk, Planx blocks and recyclable materials, supplemented by various approaches to teaching with the materials. Wolfaardt (2016) states that the use of physical and visual representations to facilitate conceptual understanding assists children in mastering and maintaining mathematical competence on the mathematical content of space and shape in Gr R (see section 2.3.2.2). Some teachers taught the mathematical concepts of space and shape using the direct teaching method, while others preferred working in small groups.

The teachers were aware that a variety of practical approaches should be followed. All the participating Gr R teachers valued a play-based approach and allowing children to use their bodies (kinaesthetics) and senses as tools. Effective instructional approaches should promote increasing insight into the mathematical concepts of space and shape (Kwon 2004; Orton 2004). Thus, according to Steyn (2014), the knowledge of mathematical instructional approaches combines knowledge of how to promote, plan and assess learning and knowledge about the mathematical concepts of space and shape. However, the teachers expressed their concerns about the South African CAPS curriculum and the lack of content that this document contained. The teachers' training and their understanding of and personal experiences with teaching the mathematical content area of space and shape had a significant influence on the effectiveness of their teaching.

The teachers held various views but seemed to have a basic understanding of the mathematical content of space and shape. They regarded the use of relevant materials and the learning environment inside and outside the classroom as important for teaching the mathematical content of space and shape. During the lesson observations and interviews, it was evident that lessons should start with children's' prior knowledge and to scaffold their knowledge by using various resource materials and approaches as well as children's physical bodies (kinaesthetic) and senses. Mathematical learning appears to correlate with 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). 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). This implies that Gr R teachers should incorporate movement when teaching the mathematical concepts of space and shape. The activities were structured with few cultural materials and opportunities for exploration, investigation and play. The observation lessons and semi-structured interviews revealed that the teachers' cultural backgrounds and the experiential knowledge and skills that they acquired through classroom experience influenced their understanding and implementation of mathematics (Lee & Luft 2008). In South Africa, teachers generally seem to regard teaching as a private matter and in general do not share their knowledge, skills and understanding of the curriculum with their colleagues. On the contrary, this research revealed that the teachers who attended regular workshops with peers at their schools seemed to have a better understanding of teaching mathematics and enjoyed it more. Four of the five Gr R teachers seemed to have a satisfactory understanding of the mathematical concepts of space and shape, while one teacher's understanding thereof was rather vague because she said that she lacked a mathematical background. However, the participants mentioned that most teachers lacked sufficient knowledge and skills because the majority of higher institutions did not yet offer qualifications for Gr R teachers and the workshops offered by the DoE were unsatisfactory.

The teachers stated that the mathematical content area of space and shape in Gr R was a crucial content area because it was the foundation of Mathematics and for learning other mathematical concepts. However, all the participants reiterated that not enough time was spent on teaching space and shape and that this content area was mostly integrated into other areas, such as physical movement and art activities.

While all the teachers valued teacher training and education programmes, some of the teachers believed that their teacher education and training lacked value and content. According to the participants, Gr R teachers longed for ongoing support and guidance from the DoE to assist them to implement and understand the MCK of space and shape more effectively. They were aware of the importance of the correct understanding and implementation of the mathematical concepts of space and shape.

The teachers found the guidelines of CAPS insufficient and maintained that CAPS should be more comprehensive and provide them with creative activities and materials. They were more like facilitators instead of mediators as prescribed by CAPS. A mediator makes the most of incidental learning opportunities that arise spontaneously during a range of child-centred activities, such as free-play block construction and sand and water play activities (DoE 2011). Activities were structured with opportunities for exploration, investigation, and play, but there were few cultural materials.

Table 6.1 outlines the principles of effective teaching of space and shape in the Gr R classroom. These principles provide a framework of how teachers understand and implement the MCK of space and shape.

Table 6.1: Principles for effective teaching of space and shape (adapted from Anthony & Walshaw 2009)

Principles for effective teaching of space and shape in the Gr R classroom	Strategies to enhance learning	Findings
Understanding the national curriculum (CAPS)	CAPS offers guidelines for mathematics content knowledge, resources, and the instructional strategies that teachers should teach and use to enhance learning.	Teachers require more from CAPS in terms of guidelines, creative activities, lesson plans etc. Effective workshops (DoE) and sharing ideas with colleagues promote a better understanding and implementation of the curriculum.
Arranging children into groups	Teachers should create opportunities for children to work as individuals or in small groups	The teachers created learning opportunities for children to work as individuals and in small groups. All the teachers made use of individual and small-group approaches to learning.
Building on children's thinking	Activities developed for space and shape should be play-based and built on children's experiences and interests.	The teachers were aware that activities should be taught using a play-based approach. They used various age-appropriate resources and materials to build constructively on children's prior knowledge.
Worthwhile mathematical tasks	Children should be able to make sense of space and shape concepts and become broad-minded. They must be able to justify their solutions.	The teachers used various materials and posed questions to the children that helped them to make sense of space and shape content. Children got the opportunity to discuss a task using their knowledge, prior experiences and various perspectives to solve the problem.

Principles for effective teaching of space and shape in the Gr R classroom	Strategies to enhance learning	Findings
Making connections	Children should be able to apply what they had learnt to their own life situations.	Children were exposed to real-life challenges (by means of resources), which they tried to solve while at the same time building new knowledge.
Assessment for learning	Informal assessment on space and shape should aim at diagnosing learning issues and informing teaching and learning decisions.	The teachers performed informal assessments throughout the observation lesson. Lessons were concluded with assessment tasks to determine the effectiveness of the lesson.
Mathematical communication	Children should be engaged in using various ways of finding the answers rather than just finding the correct answer.	Children were continuously engaged in the learning process and given opportunities to find the correct answers.
Mathematical language	The use of correct language is encouraged, which includes the use of the correct mathematical terminology of space and shape. The teacher is expected to explain the terminology to the children for a better understanding of concepts.	The teachers used the correct age-appropriate language (e.g. circle, square, triangles, sides, corners). During the observation lessons, they explained the terminology of the concepts in the introduction and body of the lesson (Chapter 4).
Tools and representation	Teachers should use appropriate resources, mathematical models (2-D and 3-D) and technology to support learning.	All the teachers used age-appropriate resources in their lessons for teaching the mathematical models (2-D and 3-D) which supported children's learning.

Principles for effective teaching of space and shape in the Gr R classroom	Strategies to enhance learning	Findings
Gr R teachers' knowledge	Substantial content knowledge and pedagogical content knowledge of teachers should assist children to develop a grounded understanding of space and shape concepts. Teachers should be able to respond to children's mathematical needs using their knowledge.	The teachers applied their knowledge and skills acquired through classroom experience to respond to the children's mathematical needs. Effective in-service training is necessary to strengthen teachers' content knowledge and pedagogical content knowledge (Table 2.3).

6.4 Secondary research questions

6.4.1 Secondary research question one

How do Gr R teachers perceive the importance of space and shape?

The participating teachers perceive the content area of space and shape as important for the foundation of Mathematics. Gr R teachers did not only discuss their own comprehension and understanding of the topic under study, but also their perceptions of other teachers nationwide. The teachers felt that many teachers in South Africa have negative perceptions about the teaching of space and shape because they do not have the knowledge and skills to teach it effectively. The results summarized in Table 4.1 show that the participants believe that Gr R teachers should be trained to gain knowledge and skills, but currently do not receive enough training opportunities as most universities do not yet offer Gr R qualifications. The workshops provided by the Department of Education are not effective with no follow-ups. To address this concern the following sub-headings are provided:

Teacher training and practical experiences impacting their perceptions for understanding the importance of space and shape concepts

In table 4.1 the Gr R teachers' personal information and backgrounds are presented. The teachers' training programmes as well as practical experience of teaching Gr R children differ greatly. One Gr R teacher has a Reception Year (Gr R) Diploma from UNISA (University of South Africa) and four years of practical teaching experience, another teacher has a Diploma in Early Childhood Education with 30 years of practical teaching experience. The other three teachers have degrees in Early Childhood Development with fifteen, twenty-one, and nine years of teaching experience respectively. The teacher with the least teaching experience admitted that her understanding of the mathematical concepts of space and shape was vague, due to the lack of teacher training and her own practical experience of teaching these mathematical concepts to Gr R children. Another teacher also stated that she felt that teacher training programmes were lacking and inefficient and that the content area of space and shape in Mathematics did not receive the attention it required. One teacher noted that their school arranged the required in-service training and that it was beneficial to their teaching practices. The school arranged workshops for teachers to share ideas and approaches for implementing mathematics. The teachers who had more teaching experience believed that their years of practical teaching experience were an advantage, giving them a better understanding of the mathematical concepts of geometry (space and shape).

All the teachers believed that children had to explore and be actively engaged in learning the MCK of space and shape. The teachers pointed out that the mathematical content prescribed for the concepts of space and shape in the national curriculum (CAPS) had to be taught in a fun and playful way to children, which would encourage children to favour the subject of Mathematics in later grades of schooling.

The research results established that the Gr R teachers had mixed perceptions on whether teachers in South Africa had a positive or negative perception of teaching the MCK of space and shape. Two teachers felt that South African teachers had negative perceptions. One teacher believed that teachers should have a passion for what they were teaching, otherwise children would not enjoy learning about the concept of space and shape. Another teacher indicated that South African teachers had a negative perception about teaching Mathematics because teachers had not received the training support and materials they had been promised from the school and the DoE. On the other hand, two of the teachers remarked that although they were not sure how teachers perceived it nationally, they had a positive perception at their schools, as their schools were well resourced and they received the necessary support that enhanced the effectiveness of their teaching.

6.4.2 Secondary research question two

How do Gr R teachers explain the mathematical content knowledge of space and shape?

The teachers had a basic understanding of the mathematical content of space and shape. It was evident during the observation lessons and semi-structured interviews that the teachers' training and teaching experience of learning and teaching the MCK of space and shape influenced their understanding and implementation differently. The teachers who explained that they enjoyed teaching mathematics and that they were passionate about the subject received additional support and workshops at their schools to improve their teaching practices. The teacher who indicated that she received no support or additional training to improve her teaching practices was rather vague in explaining the concepts and admitted that it was difficult to understand the curriculum without support.

The Gr R teachers' understanding of the MCK of space and shape varied. All the teachers involved in this study felt that it was crucial for teachers to have a good understanding of the MCK of space and shape. Nevertheless, the four teachers who understood the meaning of content knowledge of space and shape explained that they enjoy teaching the content area. One teacher explained that she was unfamiliar with the content of space and shape and that she only taught the knowledge she has on this topic from previous experience, which was not sufficient as she did not have Mathematics as a subject in high school. She mentioned that it was difficult to teach and that this content area received little emphasis and less than the time prescribed in the curriculum. Another teacher supported her statement, and said that she felt that this content area of mathematics is under-taught, and it was the teachers' responsibility to teach it, because for them the content knowledge of space and shape formed the foundation of Mathematics in Gr R. The teachers with more teaching experience in this study explained the MCK of space and shape in greater depth than the teacher who had less teaching experience. Accordingly, the teachers with more teaching experience, had a more positive disposition, than the teachers with less experience.

The teachers from School 1 who collaborated and shared their ideas and understanding of teaching mathematics had a better explanation than the other schools. They implemented their understanding with more confidence and in more detail than the participants from the other schools. However, the Gr R teachers of School 3 also explained their understanding of the mathematical concepts of space and shape well, but they do not collaborate as much, as School 1. The Gr R teacher from School 2 planned her own lessons and does not collaborate at all with her colleagues. It seems that teachers are more confident in their teaching practices and have a better understanding of the MCK if they cooperate and share their experiences, views and ideas about a specific topic and lessons.

6.4.3 Secondary research question three

How do Gr R teachers scaffold children's development of the MCK of space and shape?

Scaffolding refers to the way in which teachers use content and learning material to foster and enhance the teaching and learning of the mathematical concepts of space and shape. The teachers had varied responses to the question of how they scaffolded children's development of the mathematical content knowledge of space and shape. They explained that they started their teaching by first establishing what prior knowledge the children had. These teachers also believed that children learnt space and shape concepts best through movement activities and when they added music while teaching. All the participants stated that children should learn space and shape concepts kinaesthetically (using their bodies) and by exploring the properties of shapes. It was evident during the observation lessons that the teachers scaffolded children's knowledge by building on their prior knowledge using various teaching materials and approaches, especially exploration and learners' physical bodies.

The teachers maintained that it was important to obtain content and build learners' knowledge from their learning environments inside and outside the classroom. They explained that learning about space and shape occasionally took place outdoors. This type of learning mostly occurred incidentally during play-times.

Resources are necessary to enhance children's knowledge of space and shape. One teacher felt that her learning environment lacked basic resources and that her overcrowded classroom has a negative effect on the scaffolding of the children's development of mathematics, as she had to improvise when teaching. Due to her school's financial constraints, she did not have enough resources for the children in the class and therefore mostly used recyclable materials when teaching. The teachers who believed they were well resourced were able to confidently explain how they went about scaffolding children's mathematical development by using various materials. For example, they used wooden blocks and 2-D and 3-D objects, which the children had to sort and classify, to teach the properties of shapes. Some of the teachers were aware of their role as facilitators. Some of the others scaffolded the children's development through direct teaching (one-on-one), as it was more convenient and less time-consuming.

Because the teachers believed that the content area of space lacked content, their practices were negatively influenced and it could lead to a lack of motivation and inspiration in teaching these concepts to children.

All the teachers in this study mentioned how they scaffolded children's development indoors. However, one teacher did provide examples of how she taught space and shape concepts outdoors. She explained a game called the "shape walk". Children had to go for a walk outdoors, looking for objects that were different shapes.

Although the Gr R teachers perceived their role in the scaffolding of children's geometrical learning as important, there were few references to the importance of free play for learning. They were more concerned with teaching the content of space and shape through exploration, and children learning with their bodies.

It was found that Gr R teachers in general did not teach the mathematical content of space and shape as separate lessons but mostly integrated this content area into other learning areas in their classrooms. It may therefore be assumed that there is a gap between policy and practice in South Africa, given the divergence between what is stipulated in policy documents and the Gr R teachers' descriptions of their teaching of the mathematical content knowledge of space and shape.

6.4.4 Secondary research question four

Is there a gap between policy and practice in the teaching of the mathematical content knowledge of space and shape in Gr R?

All the Gr R teachers felt that there were gaps between policy and practice in the teaching of the mathematical content knowledge of space and shape. Three of the teachers regarded the CAPS document as a guideline only and not as a working document. The teachers felt that content and activities should be added to the curriculum and that the content should be extended. One teacher added that she felt that the curriculum lacked creativity. Another remarked that the DoE should consider teachers when drafting policy documents. In her opinion, teachers and their schools and contexts were not taken into consideration when the curriculum was being drafted. One of the teachers said that the CAPS workshops did not impart sufficient knowledge, only an overview with no practical examples and no follow-ups by officials of the DBE. The teachers felt that there was a lack of understanding of the policy and its practical implementation. Three of them regarded the CAPS document as a guideline only and not as a working document. They wanted more comprehensive content and activities added to the curriculum. One teacher added that she felt that the curriculum lack creativity, while another expressed that she feels that the DoE should consider teachers' knowledge and skills when drafting policy documents, as she felt that teachers are not taken into consideration in this regard. Furthermore, a participant felt that CAPS workshops provide insufficient knowledge, and skills that it only provides an overview of the curriculum and not practical guidelines for implementation The participants maintained that the content area of space lacked explanatory content, which could lead to misunderstanding, confusion and a lack in motivation and inspiration in teaching these concepts to children. However, it was found that teachers who collaborated with their colleagues by attending workshops and lesson discussions had a better understanding of the curriculum and how to implement it in practice.

It was found that most Gr R teachers do not teach the mathematical content of space and shape, as individual lessons, but that this content area is mostly integrated into other learning areas in Gr R teachers' classrooms. Teachers could focus more on the content of space and shape, rather than integrating it with other learning areas.

6.5 Findings and recommendations

It was found significant that teaching experience, together with regular workshops and discussions on curriculum content and teaching practices with counterparts at other schools had a positive impact on the participants' teaching of the mathematical content of shape and space. However, they believed that Gr R teachers in South Africa did not have substantial mathematical knowledge and that the CAPS curriculum provided insufficient guidance to Gr R teachers. In the next section, the findings followed by the recommendations are discussed.

Finding 1: The Curriculum and Assessment Policy Statement needs to be more comprehensive

Currently, CAPS contains limited and insufficient content and guidelines, especially about creative ideas and activities that teachers can use when teaching the mathematical content area of space and shape.

Recommendation 1

The DBE should elaborate on the current content and add activities and creativity to help teachers to teach the concepts and content of space and shape.

Finding 2: Quality teacher education programmes

In this study, the Gr R teachers felt that teachers in South Africa were not adequately trained and qualified and that their own training had not been sufficient to understand and effectively implement the mathematical content knowledge of space and shape. The workshops provided by the DoE are insufficient and need follow-ups.

Recommendation 2

Teachers need to be supported by the DBE through valuable and information-rich workshops to improve their competency in teaching Mathematics in Gr R, especially on the content of space and shape. Regular follow-ups at schools to guide teachers are necessary. Higher education institutions in South Africa should offer programmes that are linked to a qualification for Gr R teachers.

Finding 3: Township schools should be adequately resourced

Township schools do not seem to be well resourced and the schools do not have the financial means to equip classrooms with the basic resources to teach the mathematical concepts of space and shape. The teacher concerned felt that she had to cope with the resources she had and use recyclable materials.

Recommendation 3

Teachers teaching in underprivileged communities, such as some township schools, should be supported by the DBE, receiving resources together with training so that teachers can use them for scaffolding children's development of the mathematical concepts of space and shape.

Finding 4: Teachers should be made aware of the benefits of teaching outdoors for children's understanding of space and shape

Teachers regard the outdoor learning environment as important but they do not use it frequently. The participants explained that the concepts of space and shape were only taught outdoors when integrated with other content areas, such as physical movement activities.

Recommendation 4

Since the curriculum for Gr R is play-based, the DoE should incorporate a section in the curriculum that can guide teachers on how to incorporate and utilise their outdoor learning environment when teaching the mathematical content knowledge of space and shape.

6.6 Further research suggestions

Suggestion 1

A study on a play-based approach to the teaching of the mathematical content knowledge of space and shape.

Suggestion 2

A study on the effective use of outdoor learning environments for teaching the mathematical content of space and shape.

Suggestion 3

A study on how the DoE can ensure that teachers in public schools receive the necessary support and guidance (effective workshops) to teach Mathematics.

Suggestion 4

A study on how universities could ensure that pre-service teachers are properly trained in the content and teaching practice of Mathematics.

6.7 Limitations of the study

- This study consisted of only five participants and I was not able to make generalisations to the wider population.
- The data collection process only included one semi-structured interview, as I had limited time available for collecting data. A second semi-structured interview, could have aided in having more saturated data on the topic.
- It was a challenge to get schools that were willing to accommodate me, as many schools felt it would interfere with their academic programs.

6.7.1 Addressing the limitations

- This study being a qualitative study, was limited to only a small sample of Gr R teachers (five Gr R teachers) from three different primary schools. Additionally, I was able to address the reliability of this study, which allowed me to discover new frontiers on this topic and field of studying how Gr R teachers understand and implement the mathematical content knowledge of space and shape a South African context.
- Time management and planning proved to be a challenge. The study was conducted over a short period of time, and the gathering of data had to be collected in a limited time frame, to accommodate all the participants in a time best suited to them. However, by means of document analysis and field notes (journal keeping), these set backs were effectively addressed in ensuring the study was completed on time and that I was able to collect information-rich data.

- In this study, public and two private schools are included. This resulted two schools being three term schools and another a four-term school, which meant that they have different school calendars. Setting up meetings with principals and the contacting of schools to ask permission to conduct research at their schools was more complicated, than initially planned. Various schools said that they could not be of assistance, as it would interfere with their academic program or that they will be on holiday by that time. I addressed this imitation by setting up personal meetings with the principals to explain the reason for conducting this study, and reassuring the schools that they if it proved too much constraints and challenges on their academic programs and teachers, that they may withdraw themselves during any stage of the research process, and that no questions will be asked for their decision in doing so.

6.8 Conclusion

Teachers have different views of geometrical concepts such as geometrical and spatial reasoning. Some have a clear understanding, whilst others have a vague understanding. They might implement it correctly, but might not know the exact meaning of the geometrical concepts. It seems that some Gr R teachers are not adequately skilled in teaching the mathematical content knowledge of space and shape, and need to be informed and trained to understand and implement various teaching approaches and how to involve children in playful learning while scaffolding their development.

The teaching of the mathematical content knowledge of space and shape, should be taught through incidental learning and less structured activities. Teachers should implement free-play activities such as playing games, playing in the fantasy corner and sand and water play should be encouraged, to enhance learning opportunities for children. Teachers should be trained to effectively implement the curriculum and shown how to adapt it to the school context and creatively use the available and culturally relevant material. In-service training in South Africa seems to be ineffective with no follow-ups. Teachers are negative about the way workshops are being conducted because they do not enhance their understanding and implementation of the mathematical content knowledge of space and shape. The DBE should address this issue if better results are to be obtained and compared to national and international standardised tests such as the ANA TMISS tests in later grades in schools. The study revealed that an effective approach to understanding and implementing mathematics is to have teachers working in clusters and organising their own workshops on developing material and implementing lessons at their schools. Working conditions, teacher incompetencies and insufficient resources must be addressed so that this mathematical content area can receive the attention it requires to establish a good mathematical foundation in children.

6.9 Final thoughts

This study has been a journey of learning, reflecting and discovering. I have gained a new perspective and knowledge through reviewing the literature. Understanding Gr R teachers' views, opinions, perceptions and practices has enabled me to critically reflect on my personal views, opinions and perceptions when teaching the mathematical concepts of geometry in my own classroom. In addition, the answers to my research questions as well as my research findings have made me much more aware of the importance of teaching the mathematical content of space and shape, and to continuously and critically focus on how I teach Mathematics to the children in my class. This study included photographs of the materials and activities the five participants used during their observation lesson, giving the readers of this study an in-depth and visual understanding of how teachers can use such materials to scaffold children's development and help them to gain a better understanding of the mathematical content of space and shape. I believe that this study affords the readers the opportunity to create a holistic picture of how Gr R teachers understand and implement the mathematical content knowledge of space and shape.

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APPENDICES

APPENDIX A:
PRINCIPAL LETTER OF CONSENT

Dear Principal

I am a student, busy with my Master's degree in Early Childhood Education at the University of Pretoria. I am doing a study on Gr R teachers' understanding and implementation of the mathematical content knowledge of space and shape. With your permission, I would like to include Gr R teachers from your primary school in this study. If you wish to grant me permission to do research at your school, I would please like to have a copy of teachers' lesson plans or other relevant documentation where you admit that Gr R teachers teach the mathematical content knowledge of space and shape.

The purpose of this study is purely for research. I will not mention the name of your school or teachers participating in this study. In regard to protecting the anonymity of your school and its teachers I will use pseudonyms. Two Gr R teachers will be selected based on pre-determined criteria.

The data will be collected as follow:

- Upon our first meeting, I will ask teachers to give me copies of 3 different lesson plans, which, reflect teaching the mathematical content knowledge of space and shape in Gr R.
- In March 2017, I will come and observe teachers' presenting a lesson based on the mathematical content knowledge of space and shape.
- After I have had the opportunity to observe the teachers presenting their lessons, I will conduct a 30-45-minute semi-structured interview with teachers in April 2017, focussing on research questions applicable to my study.
- In May 2017, I will return again to do another semi-structured interview with them to discuss lesson plans as well as other research questions.

- I will make field notes in the form of a personal journey of my personal observations throughout the research process.

I would greatly appreciate your co-operation. Please sign your consent with full knowledge of the nature, purpose and procedures that will be followed during the research. A copy of this consent form will be given to you.

- I consent to allow Gr R teachers from my primary school to participate in the above-mentioned research study, I consent that samples may be collected for the following: structured observations and semi-structured interviews.

I authorise the researcher to do research and collect data at my school, including field notes, lesson plans and interviews for data analysis.

If your school chooses to participate in the study, please complete the accompanying consent form. If you have any queries about the research, I can be contacted telephonically at 083 391 9916 or via email at mclachlan.justine@gmail.com. Alternatively, you can contact my supervisor. Professor C. Hartell at 012 420 5990 or email his at cycil.hartell@up.ac.za. Feedback will be made available to the participants and the school in the form of a summary of the study and its results approximately six to nine months after the interviews.

Your permission to conduct this study in the school would be greatly appreciated.

Kind regards

____________________________	____________________________
Name of student: J. Mclachlan	Name of supervisor: Prof C. Hartell

Consent form

I,________________________________, consent to Justine Mclachlan's interviewing Gr R teachers from my school for her study on teachers' understanding of and implementing the mathematical content area of space and shape. I understand that:

- The participation of the teachers will be voluntary.
- There will be no risks or benefits from choosing to participate in this study.
- The teachers may refrain from answering questions they prefer not to.
- The teachers may withdraw from the study at any time.
- No information that may identify the school or the teachers will be included in the research report, and all the teachers' responses will remain confidential.
- I will be informed as fully as possible as to the aims of the research and possible implications of the research.

Signature____________________ Date________________________

APPENDIX B:

PARTICIPANT'S LETTER OF CONSENT

Research study: Gr R teachers' understanding of and implementing the mathematical content area of space and shape.

Name of participant:

Name of investigator: Miss J. Mclachlan

Dear Gr R Teacher

I am a student doing my Master's degree in Early Childhood Education at the University of Pretoria. The purpose of my research study is to gain insight into Gr R teachers' understanding and implementation of the mathematical content knowledge of space and shape. With this letter I would like to invite you to take part in this study. If at any point during the research study you want to withdraw it is your right to do so and I will respect your decision.

The data will be collected as follows:

- Upon our first meeting I will ask you to provide me with copies of 3 different lesson plans which reflect teaching the mathematical content knowledge of space and shape. I will collect these copies from you within a week after our first meeting.
- During March 2017 I will observe a lesson taught by you on the mathematical content knowledge of space and shape at a time and date best suited to you.
- After the observation, I will conduct a 30-45 minute, semi-structured interview with you in April 2017, focussing on research questions applicable to my study.
- In May 2017 I will return again to do another 30-45 minute, semi-structured interview with you and to discuss lesson plans as well as other research questions.

You are welcome to ask questions before or during the time of participation. If you have any concerns regarding the data collection procedure you are welcome to notify me. You will be given the opportunity to verify my expressed views and the transcriptions made of interviews. You need not to fear for the safety or exposure of any children in your school as I will not use any data where children's faces can be identified.

I can assure you that you can trust me with the data I collect from you. I will safeguard the information you provide me with and the data collected from you will be kept confidential. I will not mention your name and will respect your privacy and anonymity by making use of a pseudonym or code name when referring to data collected from you.

Please sign to indicate full comprehension of the nature, purpose and procedures of the research and to give your consent to participate. You will be provided with a copy of this consent form.

- I consent to participate in the above mentioned research study and I consent that samples may be collected from the following: structured observation and the semi-structured interviews.
- I authorise the use of documents and interviews for data analysis.

If you choose to participate in the study, please complete the accompanying consent form. If you have any queries about the research, I can be contacted telephonically at 083 391 9916 or via email at mclachlan.justine@gmail.com. Alternatively, you can contact my supervisor, Prof C. Hartell, at 012 420 5525 or email her atcycil.hartell@up.ac.za. Feedback will be made available to the participants and the school in the form of a summary of the study and its results approximately six to nine months after the interviews.

Your participation in this study would be greatly appreciated.

Kind regards

____________________________ ____________________________

Name of student: J. Mclachlan

Name of supervisor: Prof C.Hartell

Consent form

I,____, consent to being interviewed by Justine Mclachlan for her study on Gr R teachers' understanding of and implementing the mathematical content area of space and shape.

- My participation in this interview is voluntary.
- There are no foreseeable risks or benefits in choosing to participate in this study.
- I may refuse to answer any questions I prefer not to.
- I may withdraw from this study at any time.
- No information that may identify me will be included in the research report, and my responses will remain strictly confidential.

Signature__________________________ Date__________________________

Contact number___________________

APPENDIX C:

CONSENT FORM (RECORDING)

I,____, consent to being interviewed by Justine Mclachlan for her study on Gr R teachers' understanding and implementation of the mathematical content area of space and shape.

- Only the researcher and her supervisor will have access to the tapes and transcripts.
- All tape recordings will be destroyed after two years if the research is not published and after six years if the research is published.
- No identifying information will be used in the transcripts or the research report. I will be referred to by a pseudonym throughout the research process.
- The researcher may use direct quotations in the research report if there is no identifying information.

Signed_____________________________

APPENDIX D:

INDIVIDUAL SEMI-STRUCTURED INTERVIEW SCHEDULE 1

Interview questions/prompts (the questions are only guidelines and the researcher will be guided by the lesson plans and structured observations

This individual semi-structured interview was used in April 2017 after I have observed Gr R teachers teaching the mathematical content knowledge of space and shape.

Open-ended questions:

- How long have you been teaching Grade R?
- Have you only taught any other grade? Which Grade?
- What are your qualifications? B.Ed. degree/diploma, please elaborate your answer.
- How would you define the term "geometry"?
- What comes to mind when you think about the mathematical content knowledge of space and shape?
- Do you feel it is important for Gr R teachers to have a good understanding of the mathematical content area of space and shape? (If your answer is yes, please elaborate)
- How do you perceive/feel about the mathematical content provided in the CAPS document for Grade R?
- How does the mathematical content knowledge of space and shape influence a Gr R classroom?
- What can Gr R teachers do to enrich their vocabulary of the mathematical content knowledge of space and shape?

- Do you feel the guidelines provided in the CAPS document are useful for your daily teaching methods?
- What teaching methods do you employ in your classroom to teach the mathematical content area of space and shape?
- What kind of impact, if any, do you think teachers' understanding and implementation of the mathematical content area of space and shape have on teachers' teaching practises?
- How do you understand the term "geometrical reasoning"?
- How do you understand the term "spatial reasoning"?
- What activities do you use to implement the mathematical content knowledge of space and shape and to enhance learning in your classroom?
- Are you aware of the term Pedagogical Content Knowledge? What do you understand under the term PCK?
- Do you think Gr R teachers in South Africa have a positive or negative perception about understanding and implementing the mathematical content knowledge of space and shape? Please elaborate your answer.

APPENDIX E:

CONSENT LETTER FOR PARENTAL PERMISSION

Research study: Gr R teachers' understanding of and implementing the mathematical content area of space and shape.

Name of learner:

Name of investigator: Miss J. Mclachlan

Dear Gr 0 Parent

I am a student doing my Master's degree in Early Childhood Education at the University of Pretoria. The purpose of my research study is to gain insight into Gr R teachers' understanding and implementation of the mathematical content knowledge of space and shape.

With this letter I would like to ask your permission to have your child present, during the time I intend to observe your child's teachers presenting a lesson on space and shape in their classroom. The duration of the lesson would be +/- 30 minutes.

Please note that, I will not interview any children or ask them any questions, nor will they be mentioned in any form during or after the research process. The sole purpose of this research study is on the teachers only.

I would like to thank you in advance for your kindness and cooperation to conduct research with your child present during my observation at their classroom.

Please complete the accompanying consent form to indicate full comprehension of the nature, purpose and procedures of the research and to give your consent for your child to be present during my observation.

If you have any queries about the research, I can be contacted telephonically at 083 391 9916 or via email at mclachlan.justine@gmail.com. Alternatively, you can contact my supervisor, Prof C. Hartell, at 012 420 5525 or email him at cycil.hartell@up.ac.za.

Feedback will be made available to the teachers and the school in the form of a summary of the study and its results approximately six to nine months after the interviews.

Your consent for your child being present while his /her teacher is being observed would be greatly appreciated.

Kind regards

____

Name of student: J. Mclachlan

____

Name of supervisor: Prof C.Hartell

Consent form

I,____,give consent for my child to be present during the lesson presented by Justine Mclachlan for her study on Gr R teachers' understanding of and implementing the mathematical content area of space and shape.

Parent's Signature______________________ Date______________________