

The emergence of semiotic reflection through a multimodal approach to teaching and learning in a grade 1 Mathematics classroom

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DECLARATION

I the undersigned hereby declare that the work contained in this thesis is my own original work and that I have not previously in its entirety or in part submitted it at any university for a degree.

A handwritten signature in dark ink, appearing to read 'M. Pieters', is centered on the page. The signature is written in a cursive style with a large initial 'M'.

Signature

10 October 2017

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PREFACE

The journey of educational design research was an exciting process to address education problems in classroom practice. I started the process in 2014 with the learners in my Grade 1 class, but I had the privilege to teach the same learners again in Grade 3 (2016). I saw the benefits of the research in their mathematics results. The spatial thoughts of these learners (who were exposed to multimodal activities) are better developed than the other two classes in the same grade. Their verbal reasoning developed faster than that of the other learners in the same grade.

I would like to thank my mentor, HM van Niekerk, for her support and guidance through the research. My husband, Johann, and my son, Neil, supported me throughout the research process. Although the dissertation is done, the research process will go on in my classroom practice.

To God be all the glory.

ABSTRACT

We are currently living in an era in which most learners are exposed to aspects of technology that affect their lives outside of school on a daily basis. The current generation is growing up in an era characterised by a multimodal approach to information dissemination, leaning more towards the utilisation of images and the screen as the source and expression of information. Because of this shift from the book or text to the image or screen metaphor, the educational fraternity needs to take cognisance of the fundamentally new understanding of communication, knowledge and information processing brought about by these various technologies and the consequential impact thereof on teaching and learning.

This research has the overall focus to investigate the emergent relationships between the multitude of semiotic modes of production that can be presented to and utilised by learners to become mathematically literate via a multimodal approach to teaching and learning, while being vigilant about the possibilities of transferring this knowledge to other domains of literacy, such as language or scientific literacy. The ability to engage with content in a reflective way, while utilising the overall semiotic challenges of the content with the ensuing agency that is required to achieve success, is of fundamental importance in education.

The complexity of the average South African primary school classroom, which reflects a diversity of socio-economic and cultural differences, poses an enormous challenge to both teacher and learners, when dealing with the teaching of a content domain that relies on the capacity of learners to make sense of a multitude of signs and symbols in the context of mathematics.

Some of the major findings emphasise the importance of the early development of semiotic reflection as coupled to visualisation in the process of sensemaking, not only of mathematics, but also of verbal reasoning and reading skills.

Key terms: Grade 1, mathematics, multimodal, semiotics, semiotic reflection, visualisation

OPSOMMING

Ons leef tans in 'n era waarin die meeste leerders blootgestel word aan tegnologie. Leerders se lewens binne en buite die skoolkonteks word daagliks deur tegnologie beïnvloed. Die huidige generasie word groot in 'n era van 'n multimodale benadering tot inligtingverspreiding en rekenaarskermbeelde as bron van inligting. As gevolg van die skuif vanaf gedrukte boeke na die rekenaarskerm is dit nodig dat onderrig en leer dienoreenkomstig moet verander. 'n Nuwe begrip van kommunikasie, inligting en kennis is nodig in die moderne onderwys.

Hierdie navorsing fokus oor die algemeen op die ondersoek van opkomende verwantskappe tussen verskeie semiotiese modusse van produkte wat aan leerders aangebied en deur hulle gebruik word. Die doel is om leerders wiskundig geletterd te maak deur 'n multimodale benadering tot onderrig en leer, asook om geletterdheid in ander kennisdomeine, soos tale en wetenskaplike geletterdheid, te bevorder. Die vaardigheid om op 'n reflektiewe wyse betrokke te raak by inhoud, is van kritieke belang in die onderwys.

Die kompleksiteit van 'n algemene Suid-Afrikaanse laerskoolklas met diverse sosio-ekonomiese en kultuurverskille is 'n groot uitdaging vir onderwysers en leerders, veral as die domein afhang van leerders se kapasiteit om sin te maak van die verskeidenheid tekens en simbole in 'n wiskunde-konteks.

Van die hoofbevindinge van die studie beklemtoon die belangrikheid van vroeë ontwikkeling van semiotiese refleksie, tesame met die vermoë van leerders om prosesse te visualiseer om sin te maak van nie net wiskunde nie, maar ook verbale redenering en leesvermoë.

Sleuteltermes: graad 1, multimodale, semiotiek, semiotiese refleksie, visualisering, wiskunde

TABLE OF CONTENTS

DECLARATION	III
PREFACE	IV
ABSTRACT	V
OPSOMMING.....	VI
LIST OF TABLES	X
LIST OF FIGURES.....	XI
LIST OF ACRONYMS.....	XII
CHAPTER 1 INTRODUCTION.....	1
1.1 Introduction.....	1
1.2 Research questions	2
1.3 Theories used to address the research questions.....	2
1.4 Wooden blocks used for the research	3
1.5 Layout of chapters	3
CHAPTER 2 LITERATURE REVIEW.....	4
2.1 Introduction.....	5
2.2 Theories of young learners perception and knowledge of space and shape	5
2.2.1 Piaget.....	6
2.2.2 Vygotsky.....	7
2.2.2.1 Piaget versus Vygotskian approaches	8
2.2.3 Van Hiele.....	9
2.2.3.1 Level 0: Visualisation	10
2.2.3.2 Level 1: Analysis.....	10
2.2.3.3 Level 2: Informal deduction.....	11
2.2.3.4 Instructional phases	11
2.2.3.5 Lack of progress according to Van Hiele.....	12

2.3	Multimodality	13
2.3.1	The role of multimodality in learners`reading abilities.....	15
2.4	Domain-specific theories used to analyse data	15
2.4.1	Spatial structuring abilities	16
2.4.1.1	Spatial visualisation	16
2.4.1.2	Spatial orientation	17
2.4.1.3	Insight into shape.....	17
2.4.2	Components of semiotic systems	17
2.4.2.1	A set of signs	18
2.4.2.2	A set of rules.....	18
2.4.2.3	An underlying meaning structure	19
2.4.2.4	Agency	19
2.4.2.5	Emergence	21
2.4.3	Spatial operational capacity model	22
2.4.3.1	Perception	22
2.4.3.2	Dimensionality	23
2.4.3.3	Transformations.....	23
2.4.3.4	Mobility	23
2.5	Summery and conclusion	24
CHAPTER 3 METHODOLOGY		25
3.1	Introduction.....	25
3.2	Intrinsic case study	26
3.3	Explanatory case study	26
3.4	Multiple case study	26
3.5	Case study research in practice.....	28
3.5	Data gathering in educational design research	28
3.7	Using audio-video material to gather data.....	31
3.8	Theoretical perspectives.....	32

3.9	Ethical implication of visual data	33
3.9	Shortcomings of this research.....	33

CHAPTER 4 DATA REPRESENTATION AND ANALYSIS 34

4.1	Introduction.....	35
4.2	The process of data gathering	35
4.3	Data representation	36
4.3.1	Representing dynamic visual data through TRAR protocol	37
4.4	Data analysis	50
4.4.1	Data from learners` products of responses to tasks	50
4.4.2	Spatial structuring abilities	50
4.4.3	Components of semiotic systems	54
4.4.4	The spatial operation capacity model (SOC).....	56
4.4.5	Conclusion of data gathered through products of tasks done.....	58
4.5	Data analysis of processes of meaning making	60
4.5.1	Data analysis through the process of the tasks done	60
4.5.2	Discussion of processes of meaning-making through agency	63
4.5.3	Conclusions of data gathered through the processes of tasks done	64
4.5.4	Conclusion on data gathered through reading activities.....	64

CHAPTER 5 CONCLUSION AND RECOMMENDATIONS..... 65

5.1	Summary of research finding	65
5.2	Three-dimensional stimuli to three-dimensional responses.....	66
5.3	Three-dimensional to two dimensional.....	66
5.4	Two-dimensional to three-dimensional.....	66
5.5	Two-dimensional to two-dimensional	68
5.6	Two-dimensional to verbal	68
5.7	Two-dimensional to abstract coding.....	68
5.8	Verbal to three-dimensional	68

5.9	Conclusion about multimodality	69
5.10	Answering the research questions	70
5.11	Recommendations.....	72
5.11.1	Teaching and learning in Grade 1	73
5.11.2	Implications for teacher training	73
BIBLIOGRAPHY		74
ANNEXURES.....		81
ADDENDUM A: A SAMPLE OF PARENTS` CONSENT FORM.....		81
ADDENDUM B: ETHICS CLEARANCE FROM NWU		85
ADDENDUM C: CONSENT FROM THE SCHOOL GOVERNING BODY		86
ADDENDUM D: CONSENT FROM NORTH WEST DEPARTMENT OF EDUCATION		89

LIST OF TABLES

Table 3-1:	Data-gathering methods	29
Table 4-1:	Data representation of task	37
Table 4-2:	SOC model	46
Table 4-3:	Analysis of tasks 1 to 6	47
Table 4-4:	Analysis of tasks 7 to 10	48
Table 4-5:	Analysis of task 11 to 15	49
Table 4-6:	Detail about meaning-making processes	60
Table 5-1:	Summary of task sequence and results	65

LIST OF FIGURES

Figure 1-1:	Numbering of soma blocks	3
Figure 2-1:	Layout of literature review	4
Figure 2-2:	The Van Hiele levels	10
Figure 2-3:	Soma blocks	11
Figure 2-4:	Components of spatial structuring abilities	16
Figure 2-5:	Components of semiotic systems	18
Figure 2-6:	Modal of sign appropriation	19
Figure 2-7:	SOC theoretical framework	22
Figure 3-1:	Layout of qualitative case study methodology	25
Figure 3-2:	Continuum of inference level	27
Figure 3.3:	Briefcase for learners` work	29
Figure 4-1:	Layout of data of research	34
Figure 4-2:	TRAR Protocol.....	37
Figure 4-3:	Fixed soma blocks	51
Figure 4-4:	Loose blocks.....	52
Figure 4-5:	Learners` drawing of fixed blocks	52
Figure 4-6:	Learners` drawing of loose blocks	52
Figure 4-7:	Stimulus to task 15A	56
Figure 5-1:	Dimensions of stimulus and responses.....	66
Figure 5-2:	Visual stimulus pyramid	70

LIST OF ACRONYMS

CAPS	Curriculum and Assessment Policy Statement
CHAT	Cultural –Historical Activity theory
DBE	Department of Basic Education
ECDE	Early Childhood Development and Education
EDR	Educational Design Research
FP	Foundation Phase
SOC	Spatial Operational Capacity Model
TRAR	Task Response Analyses Regulation

CHAPTER 1 INTRODUCTION

1.1 Introduction

We are currently living in an era in which most learners are exposed to aspects of technology that affect their lives outside of school on a daily basis. Grade 1 learners know how to use a cell phone, MP3 player, DVD player and interactive computer games such as Playstation (Yelland, Lee, O'Rourke & Harrison, 2008). Many learners gather information from information media that are more or less technologically based. Most Grade 1 learners cannot read when they start attending school at the beginning of the year, but most of them know how to use a computer and a cell phone. The previous generation grew up in an environment that can be called "the typographical era", where print and books were the key sources of knowledge (Giesecke, 2007). The current generation is growing up in an era characterised by a multimodal approach to information dissemination, leaning more towards the utilisation of images and the screen as source and expression of information. Because of this shift from the book or text to the image or screen metaphor, the educational fraternity needs to take cognisance of the fundamentally new understanding of communication, knowledge and information processing brought about by these various technologies (Giesecke, 2007), and its consequential impact on teaching and learning.

According to Yelland et al. (2008), multimodality refers to a concept of communication that merges different modes (the written, the visual and the gestural) of sensemaking into one entity. Multimodal text often incorporates sounds, written and spoken words, pictures and animations, and is most often associated with the use of digital devices, such as computers or tablets.

When Grade 1 learners in South Africa enter formal schooling, they are often confronted with a largely mono-modal literacy culture being the major access point to learning about their world. These learners are required to make a major shift from the rich world of meaning made in countless ways outside of formal schooling to a much more uni-dimensional world of textual communication, through the limited use of either formal letters or mathematical symbols. This complicates the situation because they are required to access information through media and modes they have not yet mastered, while simultaneously ignoring their own wealth of ready-made knowledge of other modes of sensemaking and communication that they bring with them (Switzer, 2009).

This research has as its overall focus to investigate the emergent relationships between the multitude of semiotic modes of production that can be presented to and utilised by learners to become mathematically literate via a multimodal approach to teaching and learning.

While being vigilant about the possibilities of transferring this knowledge to other domains of literacy, such as language or scientific literacy. The researcher of this study will use educational design research to address this complex problem.

Educational design research has two motives (McKenney & Reeves, 2015). The first motive is driven by practical problems, for example in this study, the emergence of semiotic reflection in a Grade 1 mathematics classroom. The second motive is to find adequate methods to yield the kinds of empirical insight as well as theoretical advancement that can address problems of the first motive (McKenney & Reeves, 2015). Educational design research is recommended for practical problems without how-to-do guidelines for addressing these research questions (Kelly, 2013).

1.2 Research questions

The problem of mathematics education in South Africa is complex enough that it cannot be addressed with a single question and answer. The main research question is as follows:

What is the nature of the emergence of semiotic representational reflection in a Grade 1 mathematics classroom?

The following sub-questions emerge from the main research question:

Sub-question 1: What is the nature of the emergence of semiotic sensemaking in a Grade 1 mathematics classroom?

Sub-question 2: What is the nature of the signs used in semiotic reflection?

Sub-question 3: What is the role of the mobility of multimodal representations on the emergence of semiotic representations?

Sub-question 4: What is the nature of the agency that learners adopt during the process of semiotic reflection?

Sub-question 5: What contribution could knowledge about the emergence of semiotic reflection make to assist learners in the domains of reading and writing?

1.3 Theories used to address the research questions

The researcher of this study stood on the shoulders of the giants to address these research questions. Grand and trustworthy theories in educational research, namely those of Piaget, Vygotsky and Van Hiele, are used as a lens to view mathematics education in this research.

To zoom in on the domain of spatial thoughts of learners, specific lenses are used, namely the spatial structuring abilities of Van Nes and Van Eerde (2010), the components of semiotic systems (Ernest, 2008a) and the spatial operational model (Sack & Van Niekerk, 2009).

Research questions regarding the nature of agency are addressed through Ernest's (2005) domain-specific theory. Learners' agency is manifested through four consecutive phases, demarcated as appropriation, transformation, publication and conventionalisation.

1.4 Wooden blocks used for the research

The main medium to gather data for this research were wooden blocks. Loose wooden blocks were packed in plastic (zip-lock) bags and the fixed soma block sets were stored in margarine tubs. The soma blocks were numbered (see Figure 1.1) for communication purposes. These seven blocks form a cube when packed together in a certain way.

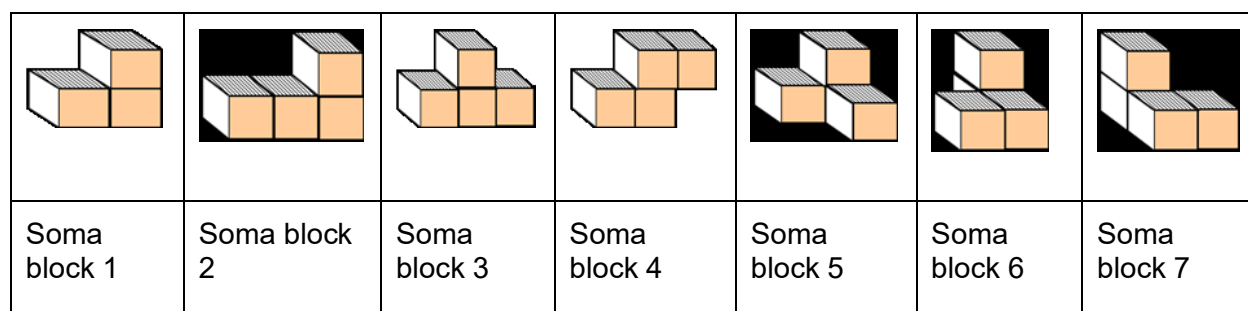


Figure 1-1: Numbering the soma blocks.

1.5 Layout of chapters

This research consists of five chapters. The first chapter is an introduction to the research. Chapter 2 explains how grand theories, such as those of Piaget, Vygotsky and Van Hiele, are still applicable in current education, and domain-specific theories are discussed in the literature review. Chapter 3 shows the methods and benefits for educational design research. Data-gathering processes, data representations and analysis form part of Chapter 4. Chapter 5 consists of conclusions and recommendations from the research.

CHAPTER 2 LITERATURE REVIEW

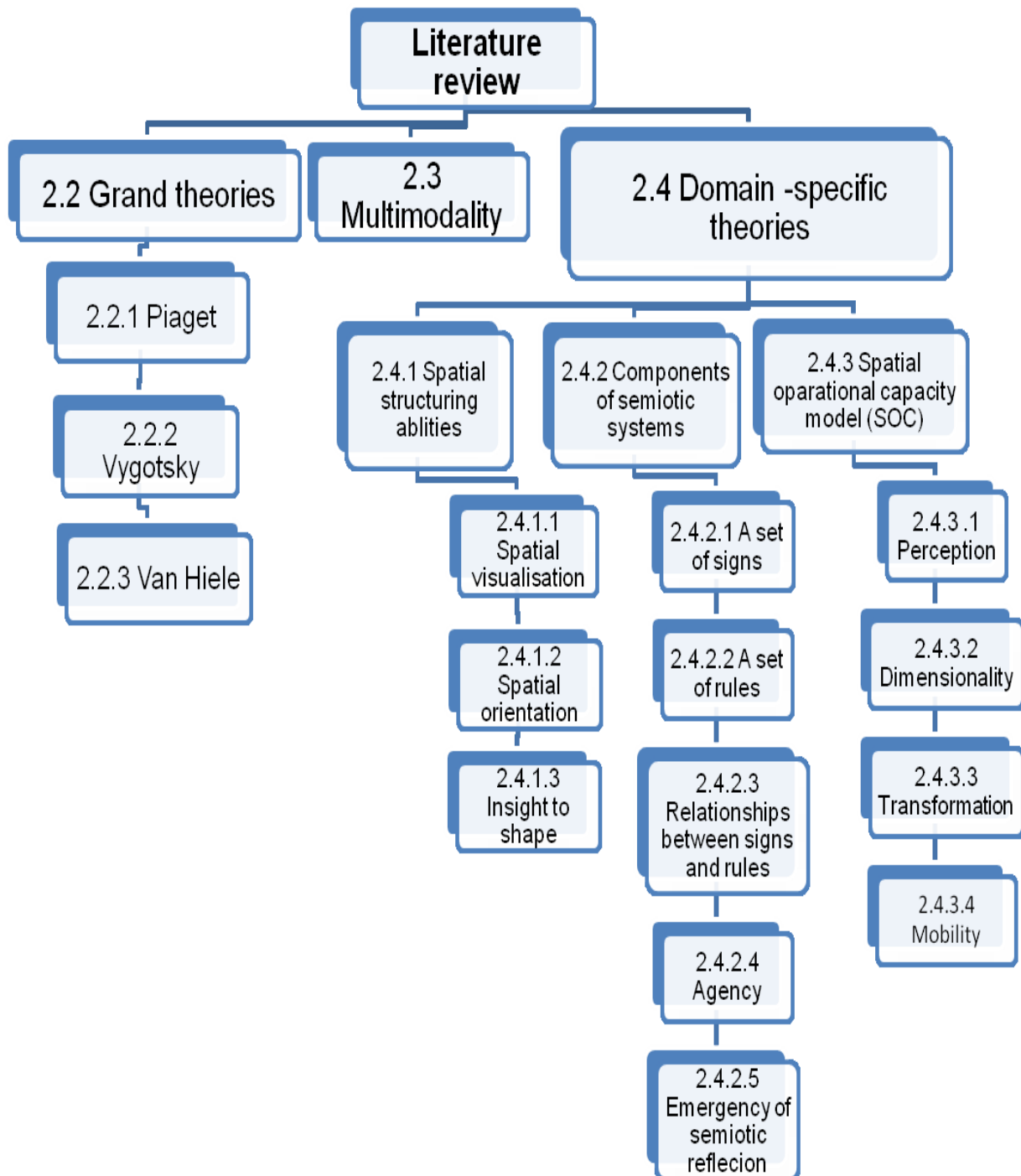


Figure 2-1: Layout of literature review chapter.

2.1 Introduction

In this research, the theories of Piaget (1967), Vygotsky (1978) and Van Hiele (1959) were utilised as grand theories in these analyses, while Van Nes's spatial structuring abilities (2010), Ernest's components of semiotic systems (2008) and the spatial operational capacity (SOC) model (Sack & Van Niekerk, 2009) formed the subject-specific lenses. The overarching focus of this research is semiotic reflections in the Grade 1 mathematics classroom. Sriraman and English (2010, p. 213) state that "as soon as we consider how to approach the problems of teaching and learning, more precisely, of mathematical cognition within the social and cultural environments provided by educational institutions, we become aware of the ***semiotic dimension*** of mathematics". This *semiotic dimension* introduces a deep problem for mathematics cognition and epistemology. As Otte (2006, p. 17) has written, "A mathematical object, such as a number or a function does not exist independently of the totality of its possible representations, but it must not be confused with any particular representation, either."

The triadic utilisation of three theories, namely the spatial structuring abilities, the components of semiotic systems and the SOC model that were used to interpret and analyse the data, imports the idea of a **multimodal approach**.

One should keep in mind that learners do not enter the formal schooling environment as a clean slate. Every learner's experience of his or her total history forms part of the toolkit with which he or she faces the formal learning situation at school.

2.2 Theories of young learners' perception and knowledge of space and shape

Three theories form the foundational background of the study, namely those of Piaget (1967), Vygotsky (1978) and Van Hiele (1959). These researchers did their research decades ago, before technology played a big role in education, but the theories are still applicable to current education.

Piaget's theory guided the researcher to study learners' representations based on the origin of three kinds of knowledge. Vygotsky guided the researcher to understand cultural-historical diversity and Vygotsky's views on social interaction, language development and visual perceptions are applicable to this research. Van Hiele contributed to the understanding of geometry and spatial development of young learners.

Investigating the spatial thoughts of learners from various perspectives, including those of Piaget, Vygotsky and Van Hiele, adds the benefit of deepening our understanding of the role of language in semiotics. In other words, when the teacher understands the role of language in

semiotics, he or she is able to guide the learners to better language development, and better language development leads to better mathematics education.

2.2.1 Piaget`s perspective on human knowledge

Piaget studied the nature of the origin of human knowledge and distinguished between three kinds of knowledge – physical knowledge, social knowledge and logical knowledge. The distinction between the three kinds of knowledge is based on their ultimate sources and modes of structuring (Kamii, 1996).

Physical knowledge is the knowledge of objects in an external reality (Kamii, 1996). These are facts about the features of something in the learners' world, for example, when the learners know that the window is transparent, the crayon is red or the air is warm and dry today. Physical knowledge resides within the objects themselves and can be discovered by exploring objects and noticing their qualities. Piaget claimed that young learners initially discriminate objects on their basic topological features, such as being closed or otherwise topologically equivalent, especially when given only tactile, rather than visual perception of shape (Piaget & Inhelder, 1967). Piaget's research showed that it became clear that only older children could discriminate rectilinear from curvilinear forms. Piaget uses the term "nearbyness", which does not describe topology, but rather distance as external reality. Other researchers (for example, Newcombe & Huttenlocher, 2000) tested Piaget's theory by showing learners a shape and after the shape has been removed, asking the learners to identify the "most like" shape (Sarama & Clements, 2009). The development of physical knowledge is a focus in this research.

Physical knowledge was developed in this research by representing a stimulus (a graphic image of a wooden block structure) to the learners to investigate their building skills. To test Piaget's term "nearbyness" (Sarama & Clements, 2009), the same stimulus is represented a further distance away from the learners to compare their building skills when the stimulus is not in their reach.

Social knowledge is written and spoken languages made by people (Kamii, 1996). Social knowledge is arbitrary and knowable only by being told or demonstrated by other people. The participants of this research are mostly speakers of Setswana (an indigenous South African language) and English is their second language. Therefore, it is more complicated to investigate the learners' social knowledge, because language is part of social knowledge.

Logico-mathematical knowledge consists of logical relationships created by each individual and is the hardest to develop (Kamii, 1996). The brain builds neural connections that connect pieces of knowledge to one another to form new knowledge. Knowledge is complicated to understand because the relationships do not exist in the external world. Logico-mathematical

knowledge is constructed by each individual, inside his or her own mind. It does not come from the outside. It cannot be seen, heard, felt or told. The ultimate source of logico-mathematical knowledge is thus in the mind of each learner (Kamii, 1996).

The researcher used different representations, such as pictures of blocks, real wooden blocks and graphic and numeric representations, to attempt to influence learners' logico-mathematical knowledge. To develop logico-mathematical knowledge, the researcher should use multiple modes of representations. A single mode of representation does not clarify relationships of spatial thoughts.

Another view of Piaget is that learners' representation of space is not a perceptual appreciation of what they see around them (spatial environment), but rather constructed from previous experience of activities regarding the object represented (Sarama & Clements, 2009). To represent a straight line, the hand or eye follows the direction without changing direction, and the idea of an angle is seen as two intersecting movements (Piaget et al., 1967).

In this research, Piaget's abovementioned three kinds of knowledge guided the researcher to develop learners' spatial thoughts.

2.2.2 Vygotsky's views on teaching and learning

Vygotsky was of the opinion that to track the mental development of a learner, the researcher should establish the development of symbolic processes, for example speech, during the general activity of the learner (Rieber, 1987). Symbolic activity begins to play an organising role, penetrating into the process of using tools and ensuring the appearance of new forms of behaviour.

The participants of this study reflected this new symbolic process when they started to draw the wooden structures. The learners developed the need to represent the stimuli in a three-dimensional fashion that led to new forms of behaviour. The moment that speech and the use of symbolic signs are included to master situations, having preliminarily mastered their own behaviour, a radically new organisation of behaviour arises, as well as new relations to the environment (Rieber, 1987).

Vygotsky studied **social interaction** through verbal thoughts, logical memory, voluntary actions and higher mental functions, and came to the conclusion that socio-historical conditions of a person's life have the greatest influence on spatial development (Zaporozhets, 2002a). Vygotsky also included a culture aspect in his research. South African learners have a diverse culture that influence teaching and learning.

The participants in this study come from a variety of different socio-historical backgrounds. They speak different languages – Setswana, English and Afrikaans – but the language of instruction is English. **Language** influences the verbal thoughts of learners, which are one of the features that Vygotsky studied. Vygotsky showed that meaningful perceptions can only be developed through the participation of speech, by combining the process of perception with the process of verbal thought (Zaporozhets, 2002a).

This implicates that the Grade 1 learners in the mathematics classroom need to speak about their thoughts regarding the stimuli. Learners do not only need to speak to the teacher, but should be allowed to speak to their peers. The teacher arranged the learners' desks in a way that they can learn socially.

In this study, the young learners worked with concrete apparatus, they touched the wooden blocks and they spoke about their experience. The more learners played with the blocks and communicated, the more experience they gained and the faster they reacted (responded) to the tasks.

Zaporozhets (2002a) stated that after enough experiences had been gained, the verbal thought developed, and intellectualisation of perceptual processes took place. According to Vygotsky, perceptual structures are a product of development, under the influence of verbal communication with other people and individual assimilation of social experience (Zaporozhets, 2002a).

In the process of learner development, primary connections of sensory processes with affect break down and, in their place, new inter-functional relations are formed between memory and perceptions. Stimuli reproduction then takes place from the memory and connections are made from past experience. This results in the development of perceptions as its constancy. At higher stages of development, perceptions begin to approximate in verbal thought.

In the early years of spatial development, visual perceptions are directly associated with emotional processes and movement, in relation to the learners' surrounding reality. As a learner develops, sensory processes and movement form new relations between perceptions and memory. Connections are made by the learners, based on previous experience. In other words, learners remember visual perceptions, and experience is needed for spatial development.

2.2.2.1 Piagetian versus Vygotskian approaches

Vianna and Stetsenko (2006) describe the notions of teaching and learning in two versions of constructivism, namely the socio-interactional version (where insights of both Piaget and

Vygotsky are often merged) and the cultural-historical version, founded by Vygotsky and expanded to activity theory.

The Piagetian and Vygotskian approaches do have aspects in common. For example, both the Piagetian and Vygotskian approaches (as psychological constructivist theories) represent and embody the transactional, contextualised and relational modes of thinking about human development (Vianna & Stetsenko, 2006).

The differences between Piaget and Vygotsky rest in their views on the nature of human life. Piaget rooted his mode of thinking in Darwin's insights on evolution; Vygotsky built on the Marxist tradition (Vianna & Stetsenko, 2006). Piaget described cognitive development in age categories, but without experience, a learner can outgrow his or her age group without cognitive development.

Vygotsky studied social interaction, language development and visual perceptions of learners, and stated that learners develop and learn as they actively change the world they live in. Learners simultaneously change themselves and gain knowledge of themselves and of the world, through changing the world (Vianna & Stetsenko, 2006). This view of Vygotsky supports the situation that is reflected in many South African classrooms. Learners change a great deal from the beginning of Grade 1 to the end of Grade 1. When learners learn to read, write and do mathematics in Grade 1, their thoughts change so that they are empowered to change their own worlds

2.2.3 Van Hiele's levels of geometrical development

Dutch educators and researchers, Pierre and Dina van Hiele, firstly developed a five-level hierarchical model that explains learners' progress and sequence of geometrical development, which is still applicable to mathematics education today (Fuys, Geddes & Tischler, 1988). The five hierarchical thinking levels build upon each other. Learners can only progress from one level to the next with guided activities. The instructional phases (between two thinking levels) are necessary to progress from one level to the next.

The Van Hieles secondly developed a teaching trajectory that guides the researcher in teaching geometry to adolescents. The Van Hieles used two-dimensional shapes for their research. In this research, three-dimensional objects (wooden blocks) were used. To identify sets of properties is still applicable to this research, although it is in a three-dimensional domain. The thinking levels are stipulated in Figure 2-2 below.

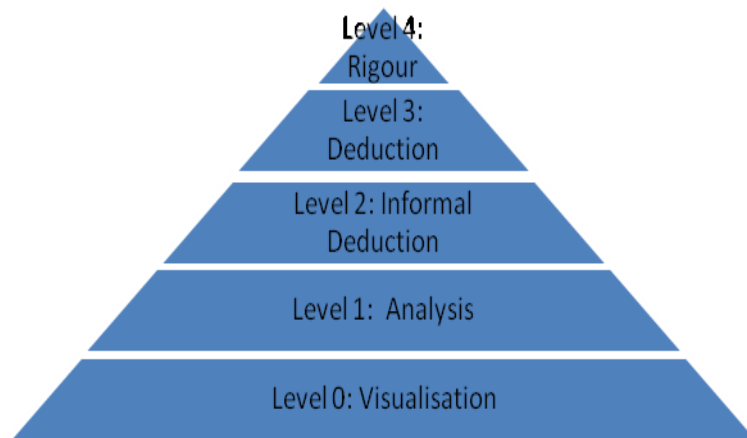


Figure 2-2: The Van Hiele's levels of geometric development. (Adapted from Van Hiele, 1959, p. 14)

2.2.3.1 Level 0: Visualisation

Learners on level 0 rely on a “gestalt-like approach” to recognise and name figures. At this level (pre-recognition level) learners are not yet able to reliably distinguish circles, triangles and squares from non-examples of those classes (Sarama & Clements, 2009). This visualisation level is applicable in a Grade 1 mathematics class because learners in Grade 1 are at the starting level. They depend on visual aids to name the parts of an object. At the beginning of Grade 1, the learners do not have the verbal skills yet to analyse a shape. Learners identify names of shapes and compare geometric figures. As learners progress during the year, some learners’ verbal skills develop faster than those of others, and then it is possible for them to progress to level 1 (Fuys et al., 1988).

2.2.3.2 Level 1: Analysis

At the analysis level, learners are able to discuss shape according to a class of shape. Learners analyse geometric figures in terms of their components and the relationships among the components. Learners discover rules or properties of shapes. For learners to be able to discuss rules and properties of shapes, they need to develop the appropriate vocabulary. Educators teaching at this level need to use words to explain concepts, for example opposite sides, corresponding angles are congruent, in front and behind, and diagonals bisect (Fuys et al., 1988).

Van Hiele noted that some learners appear to be “geometry deprived” in terms of their vocabulary. Some learners use non-standard language and others use standard language, although sometimes imprecisely (Fuys et al., 1988). Participants of this research created their

own non-standard language and they called the three-dimensional stimuli “z for zebra house” (Figure 2.3.1), “l for lion house” (Figure 2.3.2) and “t for train house” (Figure 2.3.3).

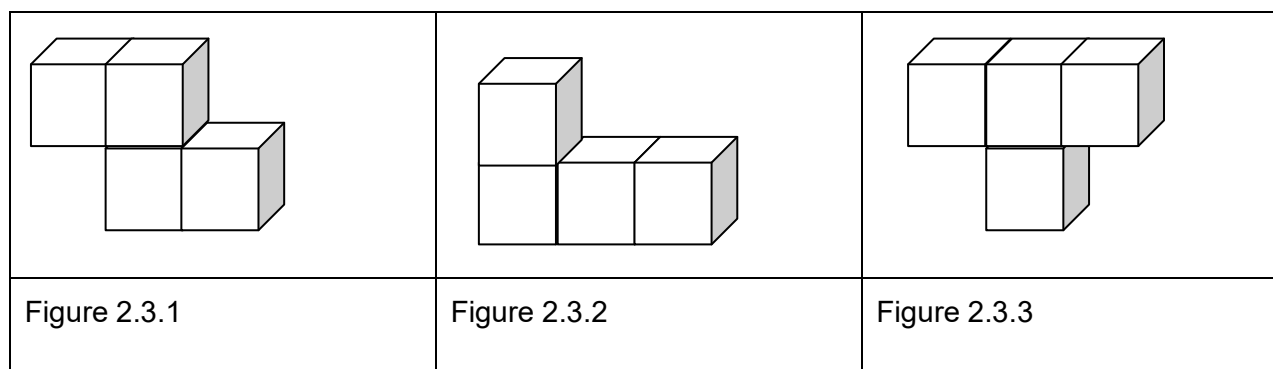


Figure 2-3: Images of soma blocks.

It is clear that language and experience play an important role in the development of learners’ thinking levels. Language is a critical factor in the movement through the Van Hiele levels. Van Hiele notes that many failures in teaching geometry result from a language barrier between learners and their teacher (Fuys et al., 1988). In other words, the teacher uses a higher level of terms and vocabulary than the learners’ thinking level.

2.2.3.3 Level 2: Informal deduction

At the informal deduction level, learners start to think about the relationships between the properties of shapes. Minimum characteristics of shapes are used for reasoning conversations. Learners logically interrelate previously discovered properties and rules by following informal arguments (Fuys et al., 1988). Learners on level 2 are able to identify sets of properties that characterise a class of figures and tests that are sufficient. The researcher assumes that learners of this study will not get to this level of thinking in their Grade 1 year. Most learners will still be on level 1 or even 0 at the end of Grade 1.

2.2.3.4 Instructional phases

According to Van Hiele (1959), the progress from one level to the next involves five phases: the information phase, guided orientation, explication, free orientation and, lastly, integration. In other words, the way in which the learners are taught, is also very important.

1. During the **information** phase, the learner gets information while exploring the shapes. This phase may include exercises such as examining examples and non-examples of shapes. In the Grade 1 class, the information phase could be free play with shapes to gain information about the shapes. Participants of this research had the opportunity for free play with the wooden blocks. The learners had informal conversations about the

blocks, so they started to create their own language and called the wooden blocks “houses”.

2. **Guided orientation** includes tasks that involve different relations of the network that is to be formed. Grade 1 learners may do activities that includes folding, measuring and looking for symmetry in shapes (Fuys et al., 1988). In this research, learners built the wooden structures according to graphic images provided. In this way, the learners could compare the blocks with the images.
3. During the **explicitation** phase, learners need language to communicate information about the shapes (Fuys et al., 1988). Grade 1 learners will express ideas about figures, but the educator should guide learners to use mathematical terminology. One of the tasks of this research was to create a way to remember the structure that had been represented previously. Learners could draw, write a note or code the blocks to remember how to represent it in the future. This task was to guide learners to communicate (verbally and in writing) about the wooden structures.
4. The **free orientation** phase provides the opportunity for learners to do more complex tasks on his or her own. In the Grade 1 mathematics class, learners could explore more complex shapes, for example a kite (Fuys et al., 1988). The researcher of this study used the same activity as for the information phase, but the size of the stimuli (graphic images) and the size of the response (wooden blocks) were different. The stimuli were represented a distance away from where the learners sat.
5. The **integration** phase takes place when learners can summarise all that they have learned and can reflect the information in their actions. The integration phase of this study took place in the computer lab, where the learners got the opportunity to build the structures on the computer.

Without these phases, learners would not make progress through the thinking levels (Fuys et al., 1988). Learners need to go through all these instructional phases on level 0 to progress to level 1. The skills and language learned from these activities (during the instructional phases) form the base for the next level of thinking.

2.2.3.5 Lack of progress according to Van Hiele

The Van Hiele levels of geometric development describe thinking processes regarding two-dimensional shapes. In this study, three-dimensional objects and two-dimensional shapes were used for investigation, but the Van Hiele model was still applicable to this study, because the theory is not only about the shapes and objects, but also about the spatial thoughts of learners

(Fuys et al., 1988). Van Hiele noticed that some learners made remarkable progress from one level to another, and other learners made little or no progress. According to Van Hiele, the following factors may explain the lack of progress of some learners: lack of prerequisite knowledge; language barriers – the lack of terms and precision language; unresponsiveness to directives (instructions, signs or symbols); lack of realisation of what is expected of the learners; lack of experience in reasoning or expressing themselves verbally; insufficient or inappropriate activities to promote progress in thinking levels; insufficient time to assimilate new concepts and experiences; rote attitude towards learning; and not being reflective about their own knowledge (Fuys et al., 1988).

According to Van Hiele (1959), progress from one level of thoughts to the next level of thoughts relies on instruction, and not on the age or biological maturation of the learners.

The average age of Grade 1 learners in a South African classroom is six to eight years, but these learners do not have much experience with formal spatial activities, as only part of the class time for the mathematics curriculum focuses on number concepts and operations (65% of the Grade 1 curriculum). Space and shape constitute only 11% of the Grade 1 South African curriculum. In other words, one of the reasons for a lack of progress is that learners do not get enough opportunity to develop spatial thoughts during class time.

The researcher used the perspectives of the abovementioned theories (of Piaget, Vygotsky and Van Hiele) to utilise data regarding spatial development of young learners. Piaget, Vygotsky and Van Hiele did their research in times when technology did not have a great influence on teaching and learning. In this study, the researcher makes use of different modes (including computer software) of representing stimuli to learners. These different modes lead us to the topic of multimodality.

2.3 Multimodality

In contemporary times, the world of business, commerce and industry has changed as a result of the tremendous range of scientific and technological innovation. It is becoming increasingly evident that schools have changed very little during the past 200 years (Yelland et al., 2008). There is a contradiction between our school systems and the life and reality of learners. In order for our learners to live a meaningful life in the 21st century, we need an education system that stimulates learners to acquire new skills, so that they are able to build new knowledge (Yelland et al., 2008). An educational system that does not change with time will be burdened with dysfunctional knowledge. When environmental conditions and societal structures change, clinging to the proven stock of knowledge reduces the chances of survival of subsequent generations (Giesecke, 2007). In the majority of current educational systems, there is only a

homogeneous model of communication that mainly utilises printed text for teaching and learning. This is a too simple model of acquisition of knowledge and information for the 21st century, which is driven by technology, exposing learners to a multimodal environment outside of formal schooling (Yelland et al., 2008).

Bezemer and Kress (2008) suggested key concepts that delineate the domain of a multimodal representational world, which include entities such as modes, medium, site of display, frame and design. These key concepts are discussed below.

- **Modes** are the socially and culturally shaped resources for meaning-making. Writing, speech, image and layout are examples of different modes. In this research, learners responded through different modes (pictures, built constructions and text) that were observed. Meanings are made when more than one mode is used (Bezemer & Kress, 2008). For this research, the learners were encouraged to utilise as many modes as required to make sense of their learning. As seen in Table 4-1, row H, learners drew wooden blocks in various ways. They spoke about the task and created their own terms for the soma blocks (for example, “z for zebra house”).
- **Medium** is the substance through which meaning becomes available, such as oil on canvas (Bezemer & Kress 2008). The media that were used in this research, were loose wooden blocks and fixed wooden blocks (soma blocks), images of the wooden blocks, computer software with which learners built blocks, playing cards with images of blocks, and pictures that learners draw of blocks.
- **Site of display** is the space where the medium is used. In this study, the classroom was the macro space, while the nature of the problems they would encounter would appropriate a micro space. In the case of working with wooden blocks, one of the micro spaces would be the utilisation of a so-called “floorplan”. Learners were provided with a “mini-floorplan” on their desks to build the construction upon. A mini-floorplan is an A4 paper with a grid on. The wooden blocks are the same size as the grid.

- **Frames** define texts in terms of activities (Bezemer & Kress, 2008). Spatial operations on space and shape (as in the current curriculum) were the frame of this research. In this research, the context was mainly building with wooden blocks.
- **Design** is the practice where modes, media, frames and sites of display are on the one side of the coin, and the characteristics of the learners as well as the rhetorical purpose are on the other side of the coin (Bezemer & Kress, 2008). For Grade 1 learners (who

are not able to read yet) major attention is given to own constructions and productions as tools of reflection.

2.3.1 The role of multimodality in learners' reading abilities

The main aim for Grade 1 learners in the South African curriculum is to learn how to read and write. The medium mostly used in a South African Grade 1 class is books. Learners associate letters and words with images because the South African curriculum requires teachers to provide pictures so that learners can learn through association. Learners depend on images to read, and when no images are available, the learners cannot read.

The learners associate graphic images (cards) with the three-dimensional structures. In other words, when learners see a card, they can identify the full-scale object represented on the card. To be able to make meaning of a letter or word, the same working memory in the brain as that of making meaning of graphic images is used (Krajewski, 2009). Jewitt (2008) calls meaning-making processes of literacy (reading and writing) and mathematics "multi-literacies". In other words, multi-literacies are the ability to make meaning of a variety of semiotic representations. Reading abilities and spatial thoughts are both included in multi-literacies. This implicates that learners who can read, can make meaning of spatial thoughts, and vice versa.

In order to assist with the domain-specific analysis in this research, this multimodality lens will be subdivided into three domain-specific theories.

2.4 Domain-specific theories used to analyse data

One of the foci of the study is semiotic reflection in a Grade 1 mathematics classroom. In other words, the researcher investigated what semiotics was utilised when the learners worked with the wooden blocks and spoke about the graphic cards. Beyond the basic definition for semiotics (the study of sign), there is a considerable variation as to what semiotics involves. Semiotics involves the study not only of what sign is in everyday speech, but of anything standing for something else. In a semiotic sense, sign comprises the form of words, gestures, pictures, images and sounds (Chandler, 2007). These signs are not in isolation, but form part of sets of signs. Semioticians study how meaning is made and how reality is represented (Chandler, 2007).

In this research, the researcher used three domain-specific theories to analyse the data. The first theory used, is spatial structuring abilities of Van Nes and Van Eerde (2010). The second domain-specific theory is components of semiotic systems (Ernest, 2008a). This theory guided the researcher to determine the process of sign production through agency. The third

domain-specific theory is the SOC model of Sack and Van Niekerk (2009) that guided the researcher in investigating the nature of the stimuli used in this research.

2.4.1 Spatial structuring abilities

Spatial structuring can be defined as:

...the mental operation of constructing an organisation or form for and object of set of objects. Spatially structuring an object determines its nature of shape by identifying its spatial components, combining components into spatial composites, and establishing interrelationships between and among components and composites. (Battista & Clements, 1996, p. 503)

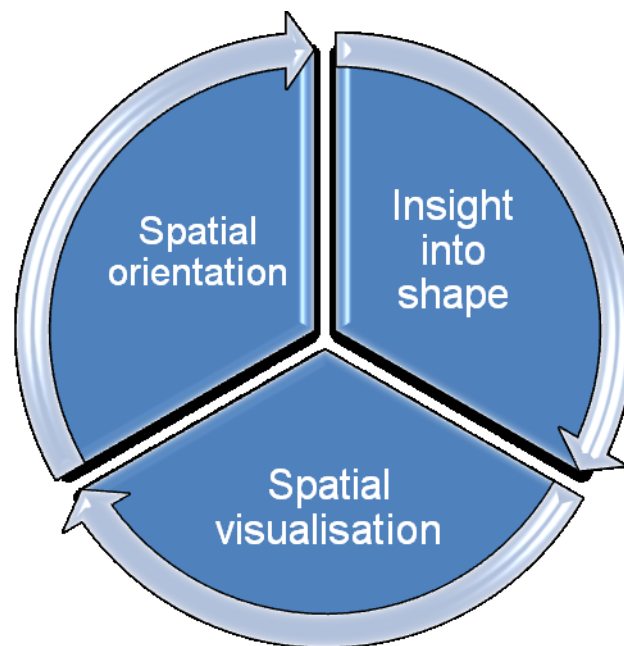


Figure 2-4: Components of spatial structuring abilities.

The data gathered in this study can be sub-categorised into three components of spatial structuring abilities of learners, namely spatial visualisation, spatial orientation, and insight into shape to perceive parts of wholes (Van Nes & Van Eerde, 2010).

2.4.1.1 Spatial visualisation

Spatial visualisation is the ability of learners to manipulate mental images and rearrange objects to investigate and explore the composition of a structure. This includes the ability to mentally picture the movement of two- and three-dimensional spatial objects. When learners are busy with a spatial visualisation task, all parts of a representation may be mentally moved or altered (Van Nes & Van Eerde, 2010). Grade 1 learners already apply spatial visualisation skills, for example when they imagine where the classroom, tuck shop or bathroom is on the school terrain.

2.4.1.2 Spatial orientation

Spatial orientation refers to describing how learners “make their way” in space. The spatial structuring factor in spatial orientation involves integrating previously abstracted items to build new structures. Grade 1 learners’ spatial orientation still depends on the distance of the stimulus. When the stimulus is close to the learner’s body, he or she can easier “make his or her way in space” than when the stimulus is represented over a distance.

2.4.1.3 Insight into shape

Insight into shapes helps learners to perceive parts of wholes of geometric patterns, transformation of an object, congruency of shapes, and symmetry (Van Nes & Van Eerde, 2010). Similar to the first component (spatial visualisation), the learners need to mentally manipulate spatial forms from a fixed perspective. This ability involves making reference to shapes and figures as well as to familiar structures, such as their own bodies. When learners communicate about such structures, their vocabulary increase and they enrich their imagination. By using the gestalt principles, learners can separate forms that form the figures. Insight into shape and their relations enables children to make references to familiar figures, such as their own bodies, to geometrical figures, such as mosaics, and to geometric patterns, such as dots on configurations on dice or dominoes (Clements & Sarama, 2007).

2.4.2 Components of semiotic systems

Mathematical thinking can be conceptualised as a form of semiotic activity (Dijk, Van Oers & Terwel, 2004), utilising symbols and representations to create meaning. The use of signs, symbols or representations is always part of semiotic activity, and semiotic activity is an activity of working out the meaning of signs referring to external objects (Dijk et al., 2004). A semiotic system is a compound sign, made up of constituent signs, and can be uttered in many ways (spoken, written, drawn or represented electronically, and may include gestures, letters, mathematical symbols, diagrams, tables, et cetera). Signs are always part of social and historical practice, and semiotic systems are always incorporated into all human activities.

The researcher chose to utilise three components of semiotic systems to analyse the data in order to understand the meaning-making processes of Grade 1 learners. The data are categorised into the three components of semiotic systems, namely a set of signs, a set of rules of sign use and productions, and an underlining meaning structure, incorporating a set of relationships between these signs and rules (Ernest, 2008a).

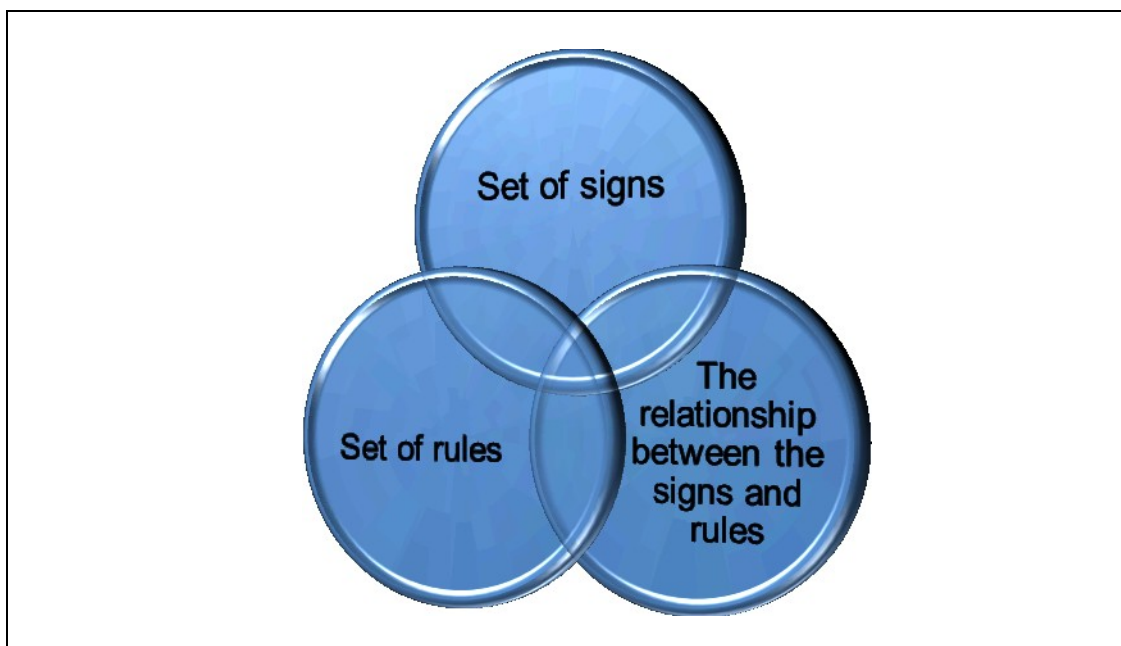


Figure 2-5: Components of semiotic systems.

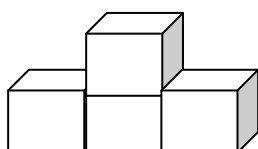
2.4.2.1 A set of signs

Semiotic systems can have multimodal sets of signs, including verbal sounds, spoken words, repetitive body movements, wooden blocks, graphic images, drawings and written text. Sack and Van Niekerk (2009) classified the sets of signs into four categories, namely full-scale objects, virtual real images, conventional graphic images, and iconic images. In this research, the full-scale images are wooden blocks, the virtual real images are computer software in the school's computer class, the conventional graphic images are the cards made by the teacher as a teaching aid, and the iconic images are the pictures that learners draw of the blocks.

2.4.2.2 A set of rules

The set of rules for sign use and productions can be analysed into three types: syntactic, semantic and pragmatic (Ernest, 2008c). Syntactic rules are based on signs, such as rules for producing well-formulated formulas (Ernest, 2008c). Semantic rules are used when the learner assigns an interpretation to and makes meaning of a sign. Pragmatic rules are determined by social convention that includes contingent and rhetorical rules (Ernest, 2008c).

An example that emerged from this research was that after a few months of experience of drawing blocks, some learners developed the need to show dimension in their drawings, so they started to draw a smaller block on top of the other block to show dimension.



Learners will draw this structure like this:



The learners thus created their own “rules” to create dimension in their sign representation.

2.4.2.3 An underlying meaning structure

The third component of semiotic systems is an underlying meaning structure (Ernest, 2008b). In other words, one can describe the meaning structure in three ways: as a set of mathematical content, as an informal mathematical theory and, lastly, as a previously constructed semiotic system (Ernest, 2008b). When learners interact with these signs, one should take a closer look as the model of sign appropriation and sign use that leads to agency.

2.4.2.4 Agency

Knowledge acquisition does not happen in isolation, but is more an act of sharing knowledge among learners and their educator (Naude & Meier, 2015). When learners take new knowledge and make it their own, we call it “agency”. Learners’ agency is manifested in communicative activity that evolves sign reception and sign productions processes (Ernest, 2005). The following is a model that attempts to show how a sign (semiotic system) is adopted by the individual learner through four consecutive phases, demarcated as appropriation, transformation, publication and conventionalisation.

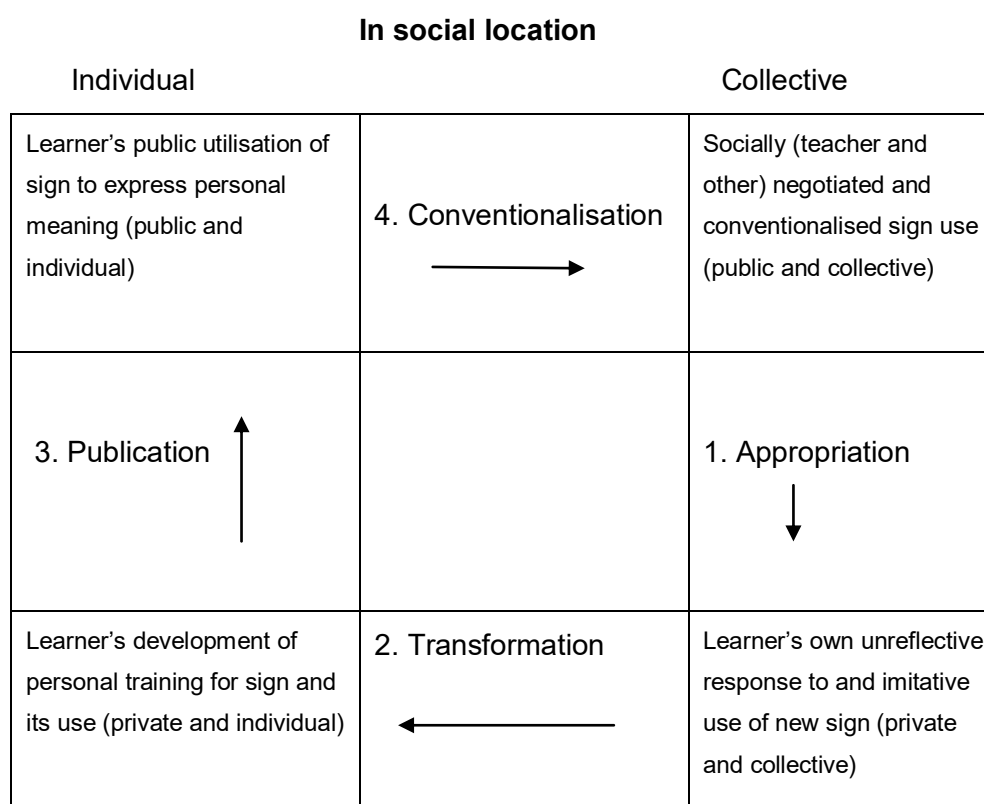


Figure 2-6: Model of sign appropriation and use (Ernest, 2005)

The **appropriation** phase leads to a learner's own unreflective response to and imitative use of a single sign. The learner has thus appropriated a collective sign into something for him- or herself that is private. This is also the route by means of which learners appropriate the rules of sign use. Agency is manifested in several ways in this phase, including attending to the public sign utterance and becoming aware of the immediate context and association of the sign use (Ernest, 2005).

When the appropriation phase for a particular sign is completed, the learner will usually develop personal meaning for the sign and its use. This **transformation phase** transforms it into something that is individual as well as private, because of the personal meaning associated with the sign. Attention, persistence and repeated performance in both sign utterances and explanatory meta-discourse evidently are manifestations of agency.

In the third phase (**publication**), the individual learner engages in a conversational act in publicly performing or making a sign utterance. The overall cycle in which agency manifests, is mostly evident and clear in this phase. Agency is involved in interpreting the context and in choosing the mode, type and particular sign response and in making it. Mathematically, this could vary from a quick, spontaneous response to a question, to constructing an extended text, revised over a period of time (Ernest, 2005).

Finally, the agency is completed when the process of **conventionalisation** takes place. In this phase, learners' sign productions have been fed into the social milieu. The outcome is an agreed or imposed conventionalisation that is both public and collective. Typically the conventionalised sign that is accepted, will need to satisfy the following criteria: relevance, justification and form (Ernest, 2005). In the classroom practice, this cycle of agency is visible in each lesson, but there is another trend visible that is not mentioned in the above cycle, namely learners copying from one another. Farrel and Lawandowsky (2015) call this copying behaviour "social norming". These researchers suggest that people frequently model their behaviour on what others around them are doing. First, the behaviour of each learner has a direct effect on his immediate friend next to him or her (this relationship is reciprocal). Whenever a learner changes his or her behaviour, the consequences of this decision ripple through the class over time (Farrel et al., 2015). We can guess that learners who copy from other learners, use this behaviour to make meaning of the task given to them.

Learners' sensemaking abilities increase when a variety of modes are used, but schools still use only printed material. The researcher of this study believes that learners will learn faster when a full-scale object is shown along with a picture. She also saw that learners can relate to three-dimensional objects easier than to two-dimensional images. Therefore, it is better to show

more real objects in the Grade 1 class. In this study, the researcher provided the Grade 1 learners with wooden blocks, graphic cards and computer software as different modes to use.

2.4.2.5 Emergence of semiotic reflection

Sriraman and English (2010, p. 217) make the connections between the relatedness of symbols and emergence the criteria of studying emergence, by stating as follows:

The reference field lodged within a symbol can be greatly enhanced when that symbol is part of a network of symbols — in fact, it is the only way. Emergent meanings come to light because of the new links among symbols. This phenomenon can be termed the semiotic capacity of a symbol system.

Two important requirements are necessary for the emergence of semiotic activity in the teaching learning situation: firstly, the presence of meaningful problems as part of the activities those young learners are exposed to (Dijk et al., 2004); and secondly, a disposition that can be described as the level of agency that the learner adopts during this process. In this research, the researcher adopted the attitude of “making the road as the road is walked, and walking the road as the road is made”.

This notion of **emergence** has considerable currency in mathematics education (Roth & Maheux, 2014), because it is conceptualised by three intertwined key features that are required for a theory of emergence as category:

- Emergence belongs to two worlds, and in such a way that the newer world cannot be derived from the older one; even though the latter constitutes the condition of emergence, as category, it encompasses the whole transition between the two worlds. The two different worlds of emergence are simultaneous. First it situates emergence as the centre of our investigation and the second world conceptualises this centre in terms of an encounter (Roth & Maheux, 2014). In this study, the researcher called the wooden structures “houses”, for the learners to link the new ideas to something they know.
- Emergence cannot be predicted or reified in some “thing”. How learners respond to the tasks is unpredictable, and for the sake of triangulation, the researcher conducted some tasks more than once, to compare the emergence. In this research, task 10 was the same as tasks 1 and 2, but were conducted a few months later in the study to compare the emergence.
- Emergence is not a homogenous *thing*, but a heterogeneous, non-self-identical flow of transiting in which agential and pathic (passive) dimensions breed in a creative expression of mind or consciousness, understood as social phenomena (Roth & Maheux, 2014).

2.4.3 Spatial operational capacity model

The spatial operational capacity (SOC) theoretical framework of Sack and Van Niekerk (2009) is utilised for analysing and describing semiotic preferential usage. The SOC model, as seen in Figure 2-7, shows how stimuli can be presented to learners (in full-scale virtual images, conventional images or iconic images). The task that follows after the stimulus, involves transformation types, in which fashion the response will be revealed (for example, full scale or images).

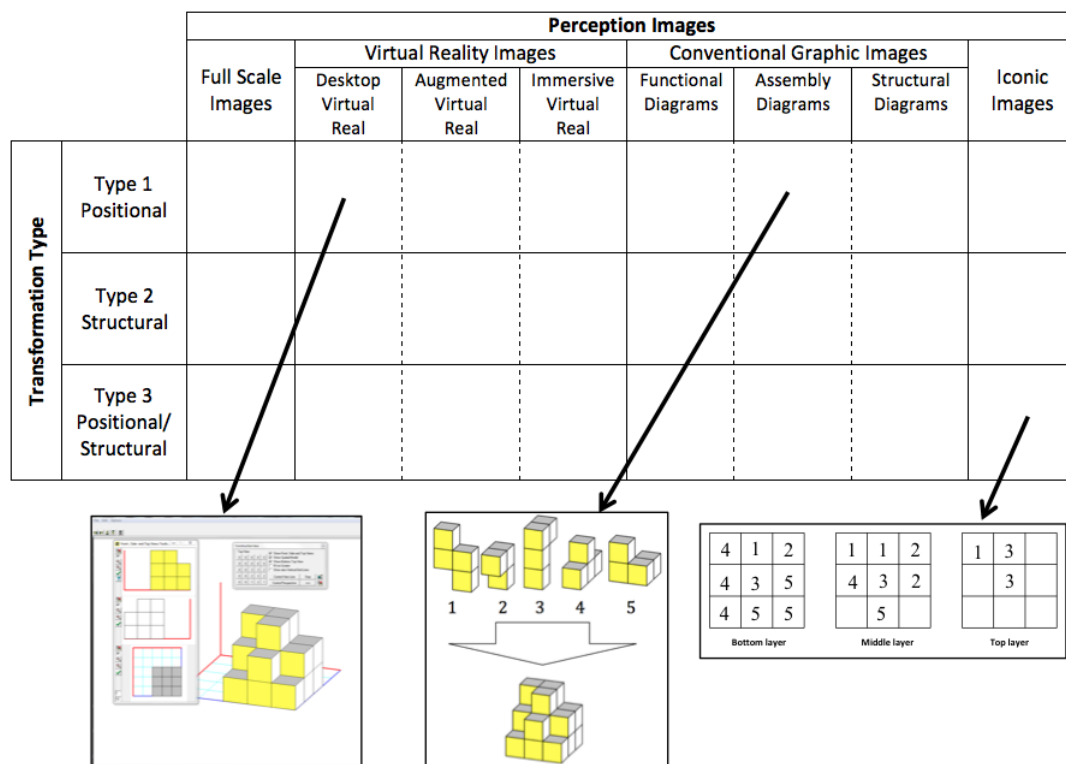


Figure 2-7: Spatial operational capacity (SOC) theoretical framework.

This model consists of four main categories of variables that can contribute to the complexity of a visual or tactile image (sign) as a stimulus in task design (Sack & Van Niekerk, 2009), namely perception, dimensionality, transformation and mobility.

2.4.3.1 Perception

The stimuli with which visual information is presented to the learner are grouped in four different categories, namely full-scale images, virtual real images, conventional graphic images and iconic images. These categories are differentiated by the closeness of the representation to reality in both a visual and a tactile sense. In this research, wooden blocks were used as full-scale models, with graphic cards representing the wooden blocks as conventional images and the computer representing the wooden blocks as virtual real images.

2.4.3.2 Dimensionality

The objects that are presented via the visual information that the learner perceives, processes or acts on, can be either one-dimensional (points and lines), two-dimensional (for example triangles and quadrilaterals) or three-dimensional images (for example prisms and pyramids), and may be a part of or the entire presented stimulus.

In this research, the graphic cards were two-dimensional and the wooden blocks were three-dimensional. The image on the two-dimensional cards represented the full-scale blocks. Different structures could be represented in two- and three-dimensional ways.

2.4.3.3 Transformations

A critically important cognitive process that must be addressed during visual processing, while acting on the object(s) represented by the image, is the ability to comprehend the nature of the changes that objects and situations can undergo during perception. In other words, this is the ability of the learner to keep track of what is fixed and what changes when objects and situations are manipulated. The three different kinds of transformations that objects, which are represented via visual images, can undergo, are positional, structural, or combined positional-structural changes.

In this research, the learners got a three-dimensional stimulus and responded with a two-dimensional image, and vice versa, especially in the context of wooden blocks. For the purpose of task 9 (see Table 4-1, row H), the learners were instructed to draw the soma blocks. In other words, the learners received a three-dimensional stimulus and responded in a two-dimensional fashion.

2.4.3.4 Mobility

The visual images the contemporary learners encountered that were represented with respect to mobility, were determined by the nature of the visual image per se. This variable reflects the importance that the researchers ascribe to the role of the body in visual imaging (Hansen, 2004). This mobility aspect can be represented as a continuum between a static medium (printed or typographic materials) and a potentially dynamic medium (digital and electronic materials) (Rückriem, 2009). These different kinds of mobility are represented in this model as static (print), semi-dynamic (for example PowerPoint slides or photo slides), or dynamic (video, film or television) images.

Participants of this research were able to construct structures on a computer using graphic images or wooden blocks (see task 15A and task 15B). The virtual images that the learners constructed, represented the graphic cards as well as the wooden blocks.

The SOC model formed part of the interpretation model that was used to analyse the data from the different modalities that were gathered during the research. The nature of this model lends itself to the whole idea of multimodality, as defined by Bezemer and Kress (2008) and Yelland et al. (2008).

2.5 Summary and conclusion

In order to unpack semiotic emergence of mathematical sensemaking through a multimodal approach to teaching and learning of mathematics in a Grade 1 classroom, three domain-specific theories were merged to form a hybrid theoretical framework for analysis, namely the spatial structuring abilities of Van Nes and Van Eerde, the components of semiotic systems of Ernest, and the SOC model of Sack and Van Niekerk.

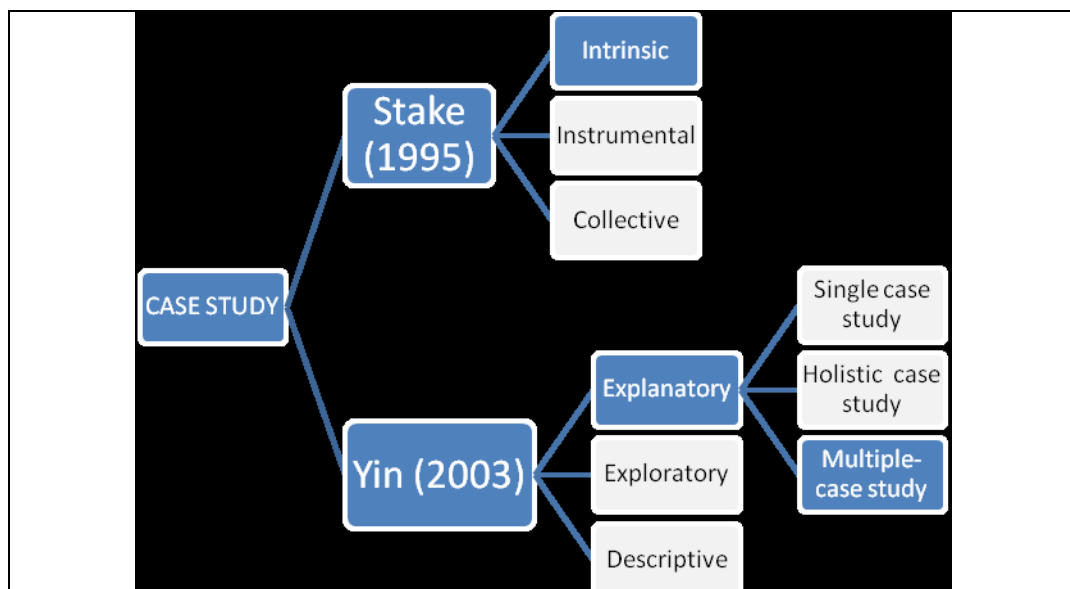
This hybridised theory will serve as a lens to describe the emergence of semiotic reflection of Grade 1 learners in a multilingual classroom in South Africa, with the added purpose of describing the importance of learner agency as learners progress through the year.

CHAPTER 3 RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

The researcher of this study made use of a case study as defined by Baxter and Jack (2008) as a research methodology that provides tools to researchers to study complex phenomena in their context. A case study is an empirical inquiry that investigates a contemporary phenomenon within its real life context, especially when the boundaries between phenomenon and context are not clearly evident (Yin 1994). Using case study as a research methodology assisted the researcher to explore the professional practice of education and make evidence- informed decisions in the classroom (Baxter & Jack, 2008). Yin (2003) stated that a case study is appropriate when a) the research answers how or why questions, b) the behaviour of the participants cannot be controlled by the researcher, c) the researcher studies contextual conditions because she believes they are relevant to the phenomenon under study and d) boundaries are not clear between phenomenon and context.

The philosophical underpinning for educational case study according to Stake (1995) and Yin (2003) is based on a constructivist paradigm. Constructivism claims that the truth is relative, that it is dependent on a person's perspective and it is built on the premise of a social construction of reality. The participants of this research will have the opportunity to tell their stories about mathematical experiences. Through these stories the learners are able to describe their views and this will enable the researcher to understand the learners' actions.



**Figure 3-1: Layout of qualitative case study methodology
(Adapted from Baxter & Jack ,2008)**

Case study research designs may be classified as intrinsic, instrumental or collective (Stake, 1995). Types of case study research designs include exploratory, explanatory and descriptive case studies (Yin, 2003). Case studies may also be differentiated between single, holistic and multiple-case studies (Yin, 2003). As indicated (with darker shading) in figure 3-1 this research is based on a hybrid of an **intrinsic, explanatory multiple case study**.

3.2 Intrinsic case study

Intrinsic designs focus on a particular individual, event, situation, program, activity or class. An instrumental design is used to better understand a theory or problem. A collective design is used to understand a theory or problem by combining information from smaller cases (Hancock & Algozzine, 2016). This research can be classified as an intrinsic case study, because the researcher is focused on 1 class to investigate the semiotic representations. Stake (1995) uses the term intrinsic and suggests that the researcher who has a genuine interest in the case should use this approach when the intent is to better understand the case.

Yin (2003) applies, what he calls, propositions to guide the research process, while Stake (1995) uses issues for case study research. These propositions and issues are necessary to build a conceptual framework that guides the research. The purpose of a conceptual framework is to identify the participants of the case study and describe the relationship build on experience (Baxter & Jack, 2008).

3.3 Explanatory case study

According to Yin (2003) an explanatory case study would be used if the researcher is seeking the answer to a question that seeks to explain the presumed causal links in real –life interventions that are too complex for the survey or experimental strategies. In evaluation language, the explanations would link program implantations with program effects. In this research, the researcher is seeking answers to semiotic representation in the grade 1 class. Presentations and representations are produced in a multimodal approach to investigate language regarding teaching and learning of grade 1 mathematics.

3.4 Multiple case study

A multiple- case study enables the researcher to explore differences within and between cases to find similarities and differences across cases (Baxter & Jack, 2008). In this research the researcher will give the same stimulus to the participants and look at the similarities and

differences the in learners` responses. The goal is to replicate findings across cases and comparisons will be drawn. The researcher chose a multiple case study, because it will allow her to analyze within each setting and across settings, while a holistic case study with embedded units only allows the researcher to understand one case (Baxter & Jack, 2008).

By implication, this translates to the idea that formerly qualitative and quantitative views are now re-positioned on a scale that is simultaneously continuous and discontinuous (Ercikan & Roth, 2006) (see Figure 3-2).

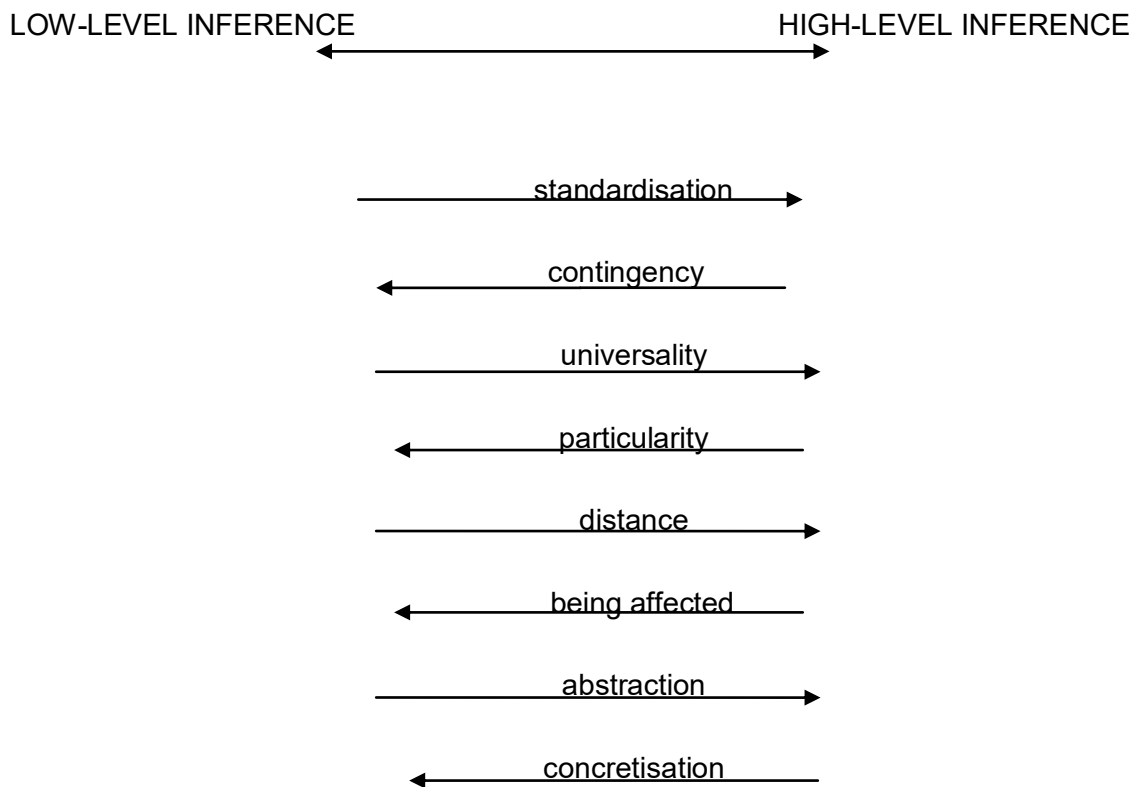


Figure 3-2: Continuum of low-level inference to high-level inference research and associated tendencies for knowledge characteristics along eight dimensions.

(Ercikan & Roth, 2006, p. 20)

By taking this stance, the researcher is first and foremost allowing the nature of the research questions to dictate their positioning on this continuum regarding the choice of data source construction. The researcher used educational case study to address these research questions in practice. According to Ercikan and Roth (2006), research questions can be classified into three main categories, namely:

- Questions that attempt to answer what is happening. With this type of research question, one can use methods such as ethnographic studies, phenomenological studies, case studies, population description or interviews.

- Questions dealing with the idea of establishing a systematic effect. This type of research question explores causal relationships and involves a form of experimental design linked to a causal model.
- Questions that attempt to answer why and how things are happening. This type of research question explores the causal aspect or mechanism. By making use of an interactive approach to design, the validity related to reliability and generalisability is addressed.

3.5 Case study research in practice

In our current educational system, texts are mostly in book form, where the teacher and the book (or authors of the book) have authority in teaching and learning. These authorities tell the learners to read from left to right, and from top to bottom, and how to make meaning of the text (Domingo, Jewitt & Kress, 2014). Knowledge is presented in a fixed manner. Books have chapters, and pages are numbered (Kress, 2005).

In that way, knowledge is unavailable to learners who cannot follow these fixed rules. Technology in the 21st century has changed the role of images. Images are now more often available on a screen than on paper, and are able to move. The viewer no longer needs to view from left to right to make sense of the image. Websites call the readers “visitors” and change the authority (Domingo et al., 2014). The visitors of the website find information (not knowledge) in the new semiotic world to build their own knowledge (Kress, 2005). The learners, who were participants in this study, all had access to television. The images on the television are colourful and moving, while the images that we provide in school, are on paper – quite dull and mono-modal, compared to what the learners are used to. There is no easy solution to this complex problem (mathematical education) and it can only be solved with educational case study research. Educational case study research captures the process of intervention to adapt the task to suit the learners’ levels of thinking.

We cannot change the influence of technology, but we can use technology to improve education through educational research to investigate a problem, develop intervention, create knowledge and make practical contributions.

3.6 Data gathering in this research

The data for this research were gathered as a combination of visual, audio and written methods for the following practical reasons: firstly, the researcher wanted to explore a range of responses of learners, including gestures, words, noises, facial expressions and body movement; secondly, to provide multiple “truths” and reflecting different learners’ perspectives;

thirdly, for triangulation to gauge the validity of emerging finds; and, lastly, to deal with technical challenges, for example learners' soft voices, background noises and actions or absence of actions (Flewitt, 2006). Data gathering focuses on knowledge gained from the research to address the research questions.

In the process of data gathering, it is necessary to record data through a finely grained system. A briefcase was designed to store drawings and other hard copy "work" of the learners in a chronological order.



Figure 3-3: Briefcase for learners' work.

After each session of data gathering, the audio-video footage was viewed and transcribed after each lesson, and filed in the appropriate file on the researcher's computer. The drawings and notes of the sessions were also filed in the briefcase. The researcher transcribed the field notes as soon as possible after the session, so that information would not get lost over time. The various methods of data gathering used in this research, are summarized in Table 3-1 below.

Table 3-1: Data-gathering methods (adapted from Flewitt, 2006).

Method of gathering data	Feature methods used	Purpose methods used
Initial observation	Researcher observe learners	To make diagnostic assessment
Audio-video recordings	Recording learners while they are interacting with wooden blocks and other activities	To understand complexities and dynamics of processes of interactions

Field notes	Written comments as well as video-recorded comments of interaction details	To supplement audio-video data, and to add detail that is not included in the footage
Interviews	Open-ended (informal) interviews with participants	To capture coincidental learning and to observe learners' language use
Drawings	Learners' drawings	These drawings can be classified into levels of thinking
Consultations	The researcher consults her mentor	The mentor's advice validates and helps to develop the data-gathering process

The hardcopy data (for example, learners' drawings and field notes) were filed and stored systematically. Observations, interviews and consultations were video recorded to form part of the data for this research.

The tasks were planned according to the TRAR protocol. Each letter of this acronym represents an action of data gathering, namely T – task, R – response, A – analysis and R – regulation (Van Niekerk, 2017).

Tasks were designed to gather data for the research. The researcher designed 15 tasks for this study with the research question in mind.

The learners' **responses** to these tasks were categorised into three categories, namely correct, partially correct, or incorrect. A **correct** response could be presented in different ways; an example is when the task was to construct any three different constructions with four blocks each, and the learner did so. A **partially correct** response was when one variable of the task was correct, but the second variable was incorrect; an example is when the task was to construct three different constructions with four blocks each, and the learner constructed only two different constructions with four blocks each. An **incorrect response** was when the learner did not understand the task, and did something else, such as counting the blocks on the floorplan instead of constructing blocks.

Analysis deals with an evaluation, using theoretically based knowledge (Van Niekerk, 2017). The products of the responses were analysed according to spatial structuring abilities (Van Nes & Van Eerde, 2010), components of semiotic systems (Ernest, 2008b) and the SOC model (Sack & Van Niekerk, 2009). The aim with the analysis was to diagnose the learners' levels of thinking as individuals and as a Grade 1 group. The researcher noticed trends of sign production when the learners' responses were analysed. Sign production processes were analysed according to agency phases (Ernest, 2005).

After the responses have been analysed, the researcher makes informed decisions about future activities. This process is called "**regulation**" (Van Niekerk, 2017). The TRAR protocol is a handy tool in conducting educational design research. A main advantage of the TRAR protocol is that the researcher can prepare the tasks based on the level of the learners, which is an iterative process of educational design research (Van Niekerk, 2017).

Tasks 1 to 6 were done in one sitting in July. The researcher conducted a design experiment by creating a reading book in July, just before the winter recess. Tasks 7 to 10 were conducted in October. Task 7 was done in a single sitting; task 8 had two parts, the first part before playtime and the second part after playtime; and tasks 9 and 10 were each done in a single sitting. Tasks 11 to 15 were done in November, just before the school assessment was conducted. Tasks 11 to 14 were done in one sitting. The next week, the data-gathering session took place in the school's computer lab, and tasks 15A and B were done.

3.7 Using audio-video material to gather data

The use of video footage to investigate the emergence of semiotic reflection through a **multimodal approach** to teaching and learning in a Grade 1 mathematics classroom forces a re-examination of current methodological and ethical practices, as well as the implication for constructions of knowledge theory (Flewitt, 2006). The audio-video material made it possible to study eye contact, body movement and facial expressions that can, with the manipulation of objects, sometimes supplement or replace speech. The phases of agency (appropriation, transformation, publication and conventionalisation) became clear when the researcher studied the learners' body language in the audio-video footage (see paragraph 2.4.2.4). At first, learners kept their thoughts private until they made meaning of the concept; only then did publication take place and did learners have a more open body language. The use of audio and video footage increases the researcher's awareness of potential learning in different modes and influences the methods of data collecting, representing, interpreting and disseminating (Flewitt, 2006).

3.8 Theoretical perspectives

The participants of this research were from several different contexts of culture. Most of the learners were speakers of Setswana (indigenous African language spoken in the area where the research was done), but there were Afrikaans and English learners as well. The language of instruction in the classroom was English. Ruckriem (2009) cautions against the exclusive use of one theory, for example the cultural historical activity theory (CHAT), as the major guiding theory in current educational research. He advocates for a hybridised view on theory usage, by viewing CHAT as a boundary, crossing between the activity theory, systems theory and media theory.

The researcher preferred to put these theories into action simultaneously, as didactical tools in a joint analysis of the teaching and learning phenomena superimposed on the same empirical data. The purpose for doing this would be to better understand the scope and power of each of these theoretical frameworks, as well as to explore their possible complementarities.

CHAT is a triangular mode of action (Engeström, Miettinen & Punamaki, 1999). In the 1920s and 1930s, L.S. Vygotsky, A.N. Leont'ev and A.R. Luria were the researchers who initiated the cultural-historical take on Russian psychology (Engeström et al., 1999). Human activity is mobile, rich in variations and endlessly multifaceted in content and form. It is necessary for activity theory to reflect on that richness and mobility (Engeström et al., 1999). The four steps in activity theory are (i) to observe contemporary everyday behaviour, (ii) to reconstruct the historical phases of the cultural evolution of the behaviour under investigation, (iii) experimental production to change to form higher forms of behaviour, and (iv) to observe the actual development in naturally occurring behaviour (Engeström et al., 1999). These are all important elements of a learning-teaching situation, which forms part of the investigative framework of this study.

Each epistemology is the epistemology of a period within the development of media (Postman, 1988). The historical, new and basic societal transformation cannot be approached by the Vygotskian concept of mediation only, because these concepts stem from a time when there were no computers and no networks (Ruckriem, 2009). Engeström makes use of both Vygotsky's and Leont'ev's models of mediation, to create a more contemporary media theory (Ruckriem, 2009).

The abovementioned data-gathering process also has ethical implications that need to be addressed.

3.9 Ethical implications of visual data

When the participants of a study are vulnerable members of the society, for example young learners, the researcher has an increased ethical responsibility. Using visual images of Grade 1 learners, makes issues of consent even more sensitive (Flewitt, 2006). In this study, the researcher created an informed consent form for the learners' parents to read and sign. The learners' identities were protected to avoid criticism, anxiety and self-doubt. Even if the learners' parents gave signed consent at the beginning of the study for visual images to be produced, the participants' life circumstances could change and, therefore, the content might change at any time of the research, and parents had the right to withdraw their children from the study at any time.

A parents' evening was held at school for the participants' parents, where the details of the research were discussed. Parents were welcome to ask questions before letters of consent were given to the parents of these young children (see Addendum A). The learners were informed about the research process before they gave verbal consent at the parents' evening. Only after the parents had signed the letter of consent, the research team used video cameras in the classroom. The necessary documentation was submitted to the Department of Education, so that the data-gathering process could start. The Ethics Committee of the North-West University issued an ethical clearance to this research – clearance number NWU-00162-15-A2 (see Addendum B). All ethical aspects were legal and correct before the data were gathered.

3.10 Shortcomings of this research

South Africa is a diverse country with many languages and cultures. This implicates that this research is unique and its findings are applicable to these participants. A shortcoming in this research is the language of learners, especially at the beginning of the year. English is, for most learners in this research, a second language. As the year goes by, the learners practise their English and the language barrier dissolves day by day. The researcher assumes that if this research was done with learners who are educated in their mother tongue, the findings might be different.

CHAPTER 4 DATA PRENTATION AND ANALYSIS

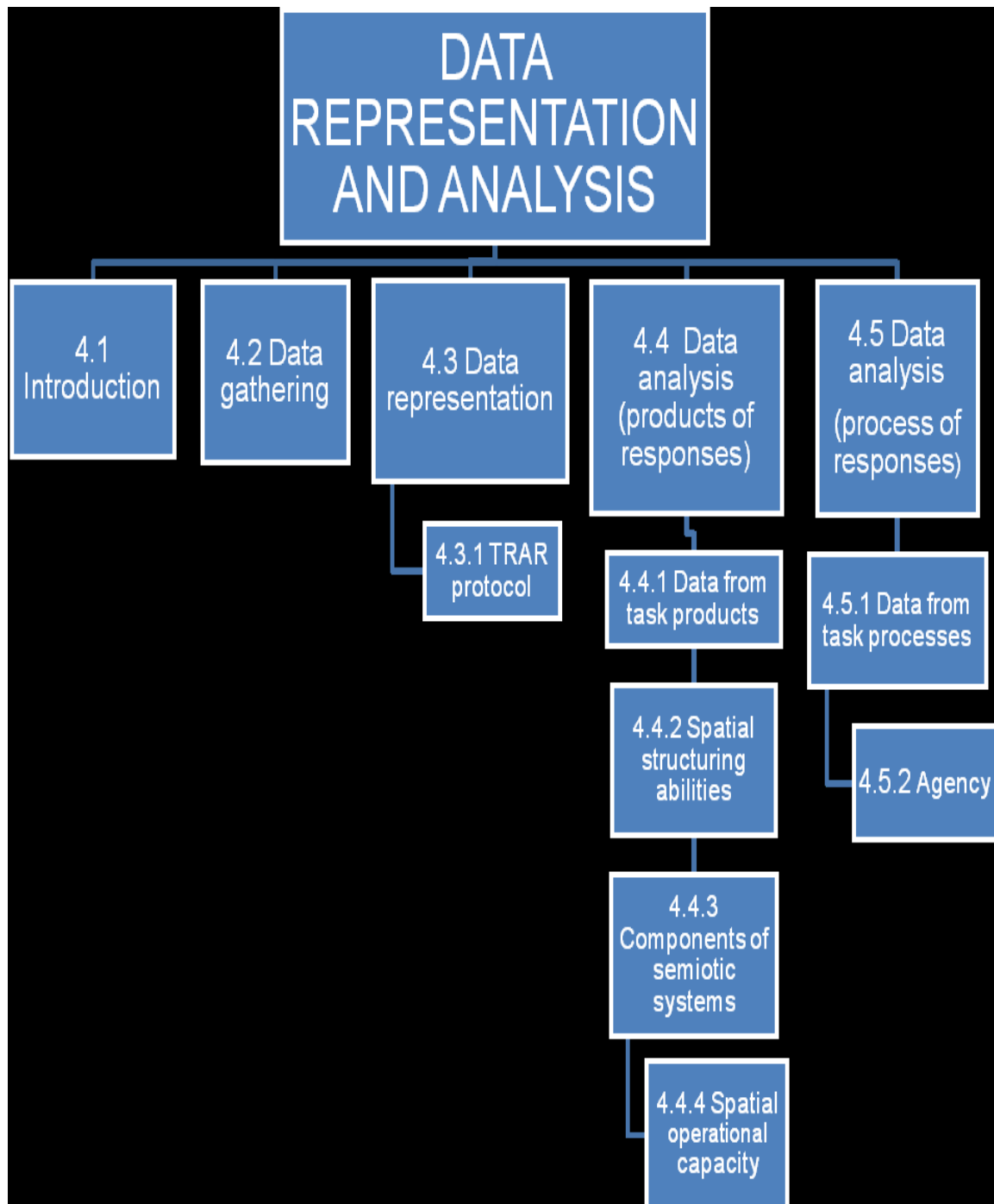


Figure 4-1: Layout of data of research.

4.1 Introduction

Design research requires frequent collection and coordination of a complex array of data sources. Data sources include products of learning (the learners' writing and drawings), classroom discourse, body posture and gestures, task and activity structures, patterns of social interaction, inscriptions, notations and other tools, and responses to interviews, tests or other forms of formal assessment (Cobb et al., 2003). It is important to note that design research follows a holistic approach, which emphasises isolated variables (Plomp, 2013). Data were generated daily through various data sources and were analysed the same day to prepare for the next lesson.

The purpose of design research is to develop intervention; therefore, data are gathered and analysed through systematic educational and instructional design processes.

The abovementioned cycle of data gathering and analysis was done by recording learning activities with a video camera.

The researcher-teacher of this study used her Grade 1 learners as participants for the research. There were 30 learners in her class, from the ages of six to eight years. The research process started at the beginning of the year, when learners got the opportunity for free play with wooden blocks, cards, mirrors and paper to draw on. The learners built constructions with blocks and used images of the blocks that were the same size. Grade 1 learners do not change classes; in other words, they stay with the same teacher the whole school day. That implicates that the researcher could use time for the sessions as needed. Some sessions lasted half an hour, while other session went on for a whole hour. The sessions were video recorded and analysed, in order to plan the next session. The last sessions were in November of the research year.

4.2 The process of data gathering

McKenney and Reeves (2015) argue that educational design research is not a methodology, but rather a qualitative and quantitative mixed method to answer research questions. In this study, the researcher video recorded the lessons and observed the activities. The researcher gathered data by planning and conducting 15 tasks with the learners. The learners had the opportunity to play with and explore the blocks and other representations before the tasks were conducted. The learners were so interested in the wooden blocks that they did not want to listen to instructions. The researcher therefore gave the learners as much opportunities as possible to play with the blocks, so that they could get used to the material before the tasks were performed.

An iteration of systematic design cycle (Plomp, 2013) guided the researcher to analyse the problem identified. Prototypes of representations (stimuli to be used in tasks) were designed and developed. The planned tasks were represented to learners to gather data. Retrospection was done to see if intervention was needed (to identify a problem). The iteration of systematic design cycle started again in the process of data gathering.

Before the data were gathered, the researcher started with a classroom discussion with the purpose of introducing the learners to structure and three-dimensional constructions. The researcher explained that one wooden block represents one “room” and four “rooms” stacked together form a “house” (Van Nes & Van Eerde, 2010). These “houses” are “economical houses” and may only have four “rooms”: a kitchen, bedroom, bathroom and living room. The learners had the opportunity to explore the wooden blocks before the first task was exposed. The researcher video recorded the free-play sessions. The audio-video material recorded in these sessions captured visual communication, and tactile and some verbal interaction among the learners and the class teacher. Learners’ drawings and writing pieces, which they created during data-gathering sessions, were chronological filed for research purposes. The researcher initially observed the learners’ behaviour towards the blocks and made field notes to start the iteration of systematic design cycle. During sessions, the researcher interviewed learners to gather data about the language used by the learners.

After tasks 1 to 6, the researcher noticed the link between the reading abilities and spatial thoughts of the learners. The learners who were able to read, were also able to make meaning of the graphic representations. Learners who struggled with reading, also struggled with the tasks given to them. The researcher wanted to explore the abovementioned observation, and created a “reading book”. The images in the reading book were pictures created with geometric shapes, but the sentences below the images did not match the pictures; for example, the image is a picture of four triangles, but the sentence is “I see three squares”. The words used in the reading book were words from the learners’ vocabulary list. The learners were supposed to be familiar with number names, because it is part of their English language education. The researcher spent one session on the reading of the reading book.

Regular consultations were arranged with the mentor of the study to guide the data-gathering process.

4.3 Data representation

In order to get a more comprehensive picture of what learners did, the researcher took a dualistic approach to representing the data: firstly, by a sequence that mainly focuses on the products of what the learners did in the different tasks (this is a more static approach); and

secondly, by a process analysis to give a more dynamic approach to how the learners' thinking levels evolved.

The task, response, analysis and regulation (TRAR) protocol was used to structure and represent data.

4.3.1 Representing dynamic visual data through TRAR protocol

Flewitt (2006) refers to the term “representing data”, rather than “transcribing data”, because it suits the description of the interactive process involved in transforming visual, multi-method data resources better. The interpretation of the TRAR protocol for this research was used to set a task (present a stimulus), state a response, then analyse the response and regulate the task.

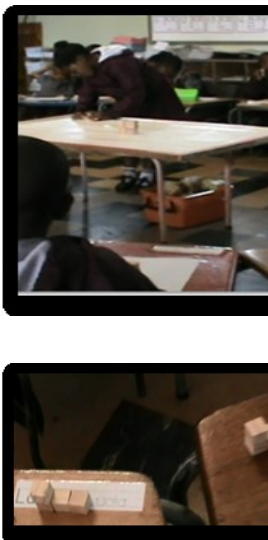
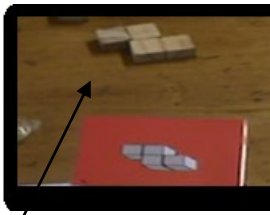
TRAR-Protocol			
Task	Response	Analysis	Regulation
	Correct		
	Partially correct		
	Incorrect		

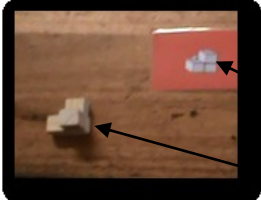
Figure 4-2: The TRAR protocol.

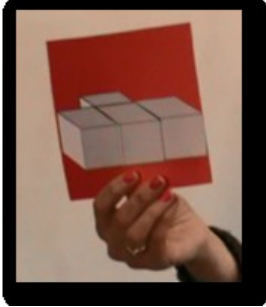
The data gathered in this study is best represented in a TRAR protocol. The 15 tasks that were done to gather data are showcased in Table 4-1 below.

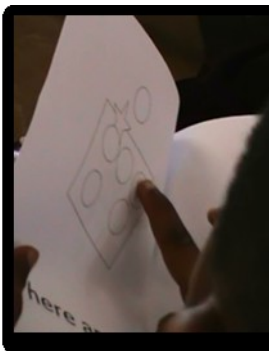
Table 4-1: Data representation of tasks

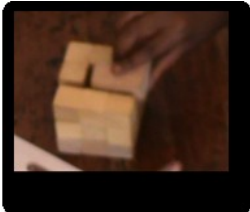
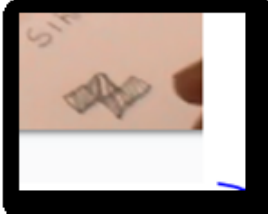
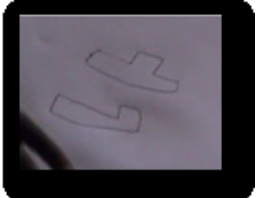
	1	2	3	4
	Date and description of activity	Teacher's instructions to the learners	Learners' responses	Visual supplementary data of correct responses of learners

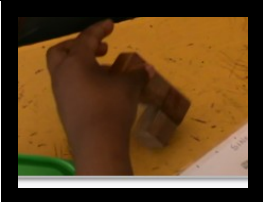
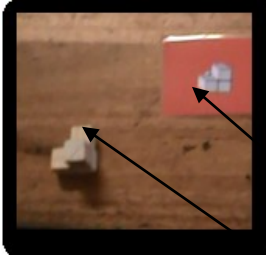
A	January – June: Preparatory activities.	These activities were mostly free play. In some of these tasks, the teacher or a learner built a full-scale object and the learners rebuilt or copied it with their blocks.	All the learners rebuilt the structures 100% correct. A three-dimensional stimulus to a three-dimensional response was on the learners' visual level (level 0 of Van Hiele)	
B	Task 1 (23 July): The purpose of the task was to diagnose if the learners could make sense of two-dimensional representations. Each learner received a graphic image of a wooden structure and a set of loose wooden blocks. The blocks on the graphic images were the same size as the real blocks. According to the SOC model, the stimulus is a conventional graphic image.	<i>“Look at your red card and build the house that you see.”</i> 	Learners took four blocks and built the constructions represented on the cards. According to the SOC model, transformation type 1 (only positional transformation) was expected from the learners.	 This image is an example of the correct response.
C	Task 2 (23 July): The purpose of task 2 was to verify the findings	<i>“Take the next card and build the house that you see</i>	Learners used four blocks to build the constructions	

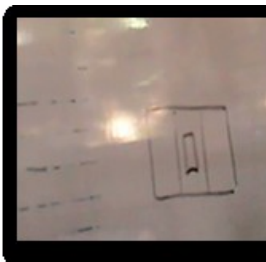
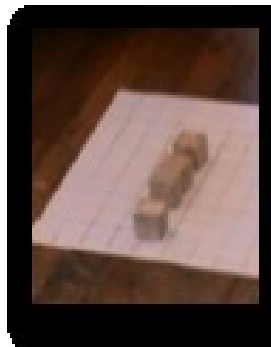
	that were generated in task 1. Each learner received a second graphic image of a wooden structure (different from the first task) and a set of loose wooden blocks. The blocks on the graphic images were the same size as the real blocks.	<i>on the card."</i> 	represented on the cards.	
D	Task 3 (23 July): The purpose of the task was to investigate positional and structural transformation according to the SOC model. In other words, the researcher wanted to see what learners would do with the blocks represented as bigger images. The researcher placed a larger graphic image on each desk. In other words, two learners shared a graphic image on their desk. The blocks on the graphic images were larger than the loose wooden blocks on their desks.	<i>"Build the house that you see on the big card."</i> 	One girl asked: <i>"But we want to build with the bigger blocks."</i> Another girl answered: <i>"You can still do it with your small blocks, you don't need Teacher's blocks".</i>	

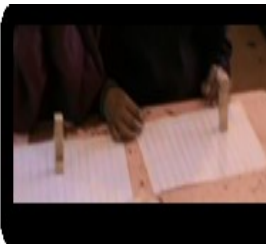
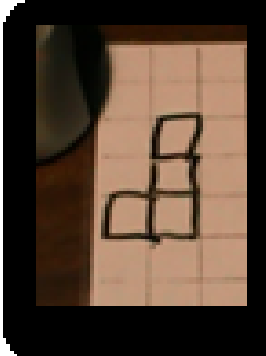
E	Task 4, 5 and 6 (23 July): The purpose of the tasks was to investigate if learners could make sense of the representation if it was not close to their bodies. The stimulus for task 4 was an image of soma block 3; task 5 represented soma block 2; and task 6 was an image of soma block 5 (see Figure 1-1) During these tasks, only one card was used as stimulus, but the card was shown in front of the class at the writing board, therefore learners could not touch the stimulus anymore. All the abovementioned tasks used a two-dimensional stimulus and required a three-dimensional response	<i>“Now we all build the same house. Look at the card on the board and build it.”</i> 	The stimulus was at a distance and learners could not touch the card to count the blocks, so most learners added more blocks than were represented on the stimulus. According to the SOC model, the response will undergo a positional and structural transformation.	
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	30 July: Reading activity The purpose of this activity was to explore the link between reading abilities and spatial thoughts. The stimulus was a reading book created by the researcher with geometric images and simple sentences. The images and sentences differed from each other to observe whether the learners trusted text or image more.	<i>“Read the sentence and if the sentence and the picture differ, tell me which one is true.”</i>	Most learners struggled to read the sentence, because they were confused by the picture that did not represent the same thing as the sentence. One learner pretended to be sick so that the researcher would not give her the opportunity to read out loud. The learners who used phonics to sound the words and counted the shapes with their fingers were more successful. All the learners agreed that the image was right and the text was wrong, and that the text needed to change to match the image.	 
F	Task 7 (15 October): The purpose of the task was to investigate social knowledge and to evaluate if learners understood spatial terms.	<i>“Use your twelve blocks to make three different houses with four rooms each.”</i>	Most learners did it as required, but others got confused with the variables – they built four houses with three rooms each.	

	The stimulus for this task was verbal instructions to build three different wooden constructions, with four blocks in each construction.			
G	Task 8 (20 October): The purpose of the task was to investigate a set of signs and to evaluate if learners were able to “read” their own representations (drawings). This was the first time that learners used their own drawings as a stimulus. The task required of learners to build the structure represented in their own drawings.	<i>“Look at the houses that you have drawn before playtime, now build those exact same houses from your drawings.”</i>	Learners built as was required from them. They were able to produce signs and make meaning from these signs produced by them.	
H	Task 9 (21 October): The purpose of the task was to introduce fixed soma blocks to the learners and to investigate their understanding of parts of a whole.	<i>“Draw the seven all-ready built houses.”</i> 	Some learners drew them correctly, but coloured the inside to show dimension. Others traced the blocks without inside lines.	 

	 The stimuli in this task were seven three-dimensional fixed soma wooden blocks. The task was to draw all seven soma blocks.			
I	Task 10 (27 October): The purpose of task 10 was to examine the progress of the spatial operational capacity of the learners. Task 10 was exactly the same as task 1 and 2. Each learner received a graphic image of a structure and learners needed to construct the structure with loose wooden blocks.	<i>"Build the house that is on the card."</i>  Stimulus Response	This exercise was a repetitive exercise of task 1, and all the learners responded correctly.	
J	Task 11 (5 November): The purpose of the task was to investigate if learners could make sense of the representations that they had created. The second purpose of the task was to lead them to iconic	<i>"I drew this house on the board; try to build it."</i> 	Their reaction was that the task was too easy.	

	images (codes), as represented by the SOC model. The task was to build a wooden construction from a drawing (soma 3) on the board.			
K	Task 12 (5 November): The purpose of the task was the same as task 11. The task was to build a wooden construction from a drawing on the board. The images on the board was the same construction, but in a different orientation.	<i>"I drew this house on the board; try to build it."</i> 	The learners were eager to start building; they had a small competition to see who completed the structure first.	
L	Task 13 (5 November): The purpose of the task was to introduce coding, as represented on the SOC model as iconic images. After the learners showed confidence in using graphic images as stimuli, the researcher decided to explore iconic images as stimuli. The task was to build a wooden construction from a code "1 2 1"	<i>"Try to build the house that looks like this."</i> 	Only one child got it correct. The rest of the class made spaces between the blocks. Intervention was done to help the learners make meaning from codes.	

	written on the board.			
M	Task 14 (5 November): The purpose of the task was to test if learners could make sense of coding. To confirm the data gathered from task 13, the researcher designed another task using a code as stimulus. The code used in task 14 was a number “4” written on the board. The task was to construct the structure represented by the code.	<i>“Can you do this one?”</i> 	After class intervention, most learners got it right.	
N	Task 15A (11 November): The purpose of the task was to test spatial structuring abilities. This task took place in the school’s computer class. A conventional graphic image on a card was represented as the stimulus. The learners could respond by using any drawing, coding or writing method to represent the original given stimulus.	<i>“Draw or code this card on your paper; you may use any kind of note, even words.”</i> 	Some learners coded “1 3” on their paper and others drew the structure.	 

O	Task 15B (11 November) The purpose of the task was to test spatial visualisation. Task 15B required of the learners to use their responses to task 15A and construct the structure as a virtual reality image (on the Geocadabra computer software).	<i>“Use your drawing or code or notes and build the house on the computer.”</i>	Almost all the learners created the image in the opposite orientation as the original stimulus.	
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Table 4-2 below is a representation of the coding of the SOC model.

Table 4-2: SOC model.

Transformation type		Presentation images							
		Full scale	Virtual reality images			Conventional graphic images			Iconic image
			Desktop virtual real	Augmented virtual real	Immersive	Functional diagram	Assembly diagram	Structural diagram	
	Type 1 Positional	1a	1b	1c	1d	1e	1f	1g	1h
	Type 2 Structural	2a	2b	2c	2d	2e	2f	2g	2h
Type 3 Positional and Structural	3a	3b	3c	3d	3e	3f	3g	3h	

The responses of these tasks were qualified in categories of correct (green), partially correct (orange), and incorrect (red) on an Excel spreadsheet (see Table 4-3). When a learner did not take part in the task, the block was shaded grey. Key 1 indicates dimensionality, for

example a two-dimensional stimulus to a three-dimensional response. Key 2 states the transformation type on the SOC model.

Table 4-3: Analysis of tasks 1 to 6.

Key 1: Dimensionality (two-dimensional or three-dimensional)

Key 2: SOC coding (see Table 4-2)

	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	
Key 1:	2D-3D	2D-3D	2D-3D	2D-3D	2D-3D	2D-3D	Learners' % correct
Key 2:	1e-1a	1e-1a	1e-*2a	1e-2a	1e-2e	2e-2b	
Learner 1							50%
Learner 2							0%
Learner 3							0%
Learner 4							83%
Learner 5							50%
Learner 6							50%
Learner 7							50%
Learner 8							100%
Learner 9							50%
Learner 10							50%
Learner 11							50%
Learner 12							50%
Learner 13							83%
Learner 14							50%
Learner 15							50%
Learner 16							50%
Learner 17							50%
Learner 18							50%
Learner 19							50%
Learner 20							83%
Learner 21							50%
Learner 22							33%
Learner 23							50%
Learner 24							50%
Learner 25							50%
Learner 26							40%
Learner 27							50%
Learner 28							50%
Learner 29							33%
correct	90%	90%	90%	17%	10%	3%	
partially correct		3%					
incorrect	10%	7%	10%	83%	90%	97%	

Table 4-4: Analysis of tasks 7 to 10.

Key 1: Dimensionality (two-dimensional or three-dimensional)

Key 2: SOC coding (see Table 4-2)

	Task 7	Task 8	Task 9	Task 10	
Key 1	verbal-3D	2D-3D	3D-2D	2D-3D	Learners'
Key 2		1e-1a	1a-1e	1e-1a	% correct
Learner 1					25%
Learner 2					25%
Learner 3					25%
Learner 4					75%
Learner 5					50%
Learner 6					25%
Learner 7					100%
Learner 8					100%
Learner 9					75%
Learner 10					50%
Learner 11					50%
Learner 12					50%
Learner 13					100%
Learner 14					100%
Learner 15					100%
Learner 16					100%
Learner 17					75%
Learner 18					50%
Learner 19					75%
Learner 20					100%
Learner 21					25%
Learner 22					25%
Learner 23					100%
Learner 24					75%
Learner 25					100%
Learner 26	*				75%
Learner 27					50%
Learner 28					75%
Learner 29					75%
correct	48%	76%	48%	97%	
partially correct	24%	3%	31%		
incorrect	28%	21%	14%		
	100%	100%	93%		

Table 4-5: Analysis of tasks 11 to 15.

Key 1: Dimensionality (two-dimensional or three-dimensional)

Key 2: SOC coding (see Table 4-2)

	Task 11	Task 12	Task 13	Task 14	Task 15A	Task 15B	
Key 1:	2D-3D	2D-3D	2D-3D	2D-3D	2D-2D	2D-2D	Learners' % correct
Key 2:	1a-1a	1e-1a	1h-1a	1h-1a	1e-1g	1g-1h	
Learner 1							64%
Learner 2							33%
Learner 3							0%
Learner 4							64%
Learner 5							50%
Learner 6							33%
Learner 7							64%
Learner 8							64%
Learner 9							64%
Learner 10							50%
Learner 11							64%
Learner 12							64%
Learner 13							64%
Learner 14							64%
Learner 15							64%
Learner 16							64%
Learner 17							50%
Learner 18							64%
Learner 19							64%
Learner 20							64%
Learner 21							64%
Learner 22							50%
Learner 23							64%
Learner 24							64%
Learner 25							50%
Learner 26							64%
Learner 27							50%
Learner 28							64%
Learner 29							0%
correct	93%	90%	3%	83%	69%	0%	
partially correct		3%			21%	90%	
incorrect	7%	7%	97%	17%	10%	10%	

The data were gathered and represented in the order of the 15 tasks. The researcher used the three theories to analyse the data, namely spatial structuring abilities, components of semiotic systems and the SOC model.

4.4 Data analysis

As seen in Figure 4-1, data analysis was done after each video recording. The findings of the data led to the design and development of the following task. Sometimes revision was needed, and then the researcher designed a task to do intervention. Interaction among learners during the learning activities formed part of the data that had to be analysed.

4.4.1 Data from learners' products of responses to tasks

The researcher viewed and reviewed the audio-video material to study the language, images, physical activities and visual communication of the learners. Sign-making activities that are key components in constructing meaning can be observed. According to Flewitt (2006), a sign is the basic unit of meaning, where sign is defined as form, chosen from a range of possible forms, to carry meaning. The approach of using visual material adds a new understanding of learning processes by investigating learners' actions and choices of modes. Attributes of forms of meaning-making, other than language, including drawings, can be observed and investigated through audio-video material. Combinations of modes such as pictures, diagrams, facial expressions, gestures, words and physical actions add richness and complexity to the data (Flewitt, 2006). These modes are interwoven with language meaning-making modes. Although combining visual, audio (language) and written media is a rich method of using data, it creates new practical, ethical and methodology challenges (Flewitt, 2006).

4.4.2 Spatial structuring abilities

Three spatial structuring abilities – spatial orientation, spatial visualisation and perceiving parts of wholes (Van Nes & Van Eerde, 2010) – were used to analyse the data (see paragraph 2.4.1). These frameworks were used to analyse learners' spatial structuring abilities.

In order to complete **tasks 1 and 2** successfully, all three spatial structuring abilities were required. In other words, spatial visualisation, structuring and perceiving parts of wholes were required. **Task 3** (row D in Table 4-1) used graphic cards that represented the structure on a bigger scale than the actual blocks, and learners needed spatial visualisation to manipulate mental images (Van Nes & Van Eerde, 2010) in order to construct the "houses". In tasks 1 to 3, 90% of the learners succeeded.

During **task 4, 5 and 6** (row E in Table 4-1) learners had to represent the structure seen over a distance, using “gestalt” principles (Van Nes & Van Eerde, 2010). The insight into shape to perceive parts of wholes is influenced when the stimulus is at a distance. Learners could not touch the card and count the blocks on the card. Most of the learners constructed the full-scale structure with more blocks than were represented on the card. Only 17% of the learners were successful in task 4; 10% were successful in task 5; but only 3% were able to do task 6. Most learners constructed the image with too many blocks or with gaps.

The stimulus for **task 7** was verbal instructions. According to Van Nes (2010), subsidising may be defined as an automated perceptual process that all people can apply only to a small collection of up to four objects. In other words, learners can make sense of the instructions, if a small collection of objects (three houses) are required. The instructions of this task included a second variable that learners had to keep in mind (four blocks for each house). Some learners kept only the number “three” in mind and some learners kept only the number “four” in mind. This resulted in a 48% success rate. The learners who did not succeed, constructed four “houses” with three “rooms”.

Task 8 (row G in Table 4-1) was the first time that learners used their own drawings as stimuli. Three quarters of the learners (76%) were able to “read” their own images successfully. The other quarter of the learners did not have the ability to integrate abstract items to form new structures (Van Nes & Van Eerde, 2010).

Task 9 (row H in Table 4-1) focused on the third component of spatial structuring abilities – perceiving parts of wholes (Van Nes & Van Eerde, 2010). Learners considered a fixed soma block (Figure 4-3) as one whole.



Figure 4-3: Fixed soma block.



Figure 4-4: Four loose blocks.

Learners considered four loose wooden blocks constructed in the same orientation (Figure 4-4) as four units and not as one unit. The researcher recognised these perceptions of learners, when 48% of the learners traced the fixed soma block without lines (Figure 4-5), but drew lines between the loose blocks (Figure 4-6).

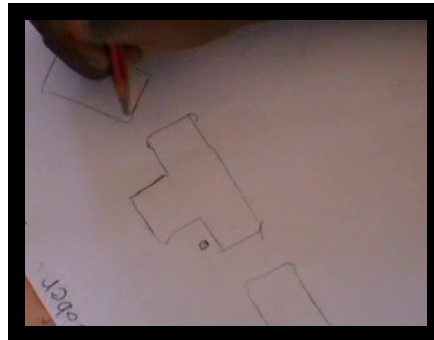


Figure 4-5: A learner's drawing of a fixed block.

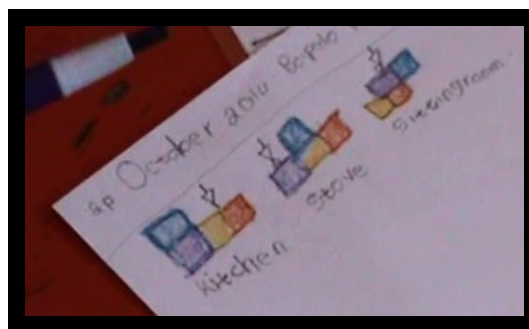


Figure 4-6: A learner's drawing of loose blocks.

Task 10 (row I in Table 4-1) was a repetition of task 1 and 2, but done three months later. All the learners (97%) were successful in this activity. Therefore, it is clear that the spatial structuring abilities of the learners improved over time, as they received many opportunities to gain experience.

Task 11 (row J in Table 4-1): According to Van Nes and Van Eerde (2010), spatial sense has three components that help learners “grasp the world” and develop mathematical thinking. One of these components is spatial visualisation. Spatial visualisation is the ability to manipulate mental images to explore the composition. Most of the learners (93%) had the ability to construct the “house” that was represented in the correct orientation. In other words, the learners’ spatial visualisation was developed enough for them to use the mental image on the board to construct the object that is represented.

Task 12 (row K in Table 4-1) too was an experiment designed to investigate spatial visualisation. The instruction for this task was the same as in task 11, but the image on the board was in another orientation. Most of the learners (90%) had the spatial visualisation ability to make sense of the images on the board and to represent it in a full-scale mode.

Task 13 (row L in Table 4-1) was more of a challenge for the learners, because it was the first time they were introduced to a code. The same structure was represented as in task 11 and 12, but in the form of a code, namely “1 2 1”. Most learners (97%) constructed the structure as three separate wholes and not as one whole. Only learner number 28 constructed the structure as one whole. The researcher asked learner number 28 to tell the class about his thoughts while he was busy with task 13, and intervention was done before task 14 was started.

Task 14 (row M in Table 4-1): This task did not only focus on perceiving parts of wholes, as in task 14, but also focused on spatial structuring and the ability to integrate abstract items to form new structures (Van Nes & Van Eerde, 2010). Learners needed to apply the new knowledge gained in the class discussion to develop spatial structuring abilities. With this task, 83% of the learners were able to integrate abstract items to form new structures, which means that their spatial structuring abilities had improved.

During **task 15A** (row N in Table 4-1), learners should have been able to manipulate the given images to create their own mental image in whatever way suited them the best. The task was to represent the image shown (the stimulus) in any way that would suit the learner. Therefore spatial visualisation was needed. The learners also needed the second ability, namely spatial structuring, to integrate abstract items to form their own new structures. Most learners (69%) were able to represent the graphic images on their floorplan. The 31% who did not represent the images correctly, were automatically unsuccessful in task 15B, because the response of task 15A was the stimulus for 15B. The challenge was, however, perceiving parts of wholes (Van Nes & Van Eerde, 2010) during task 15B (row O in Table 4-1). The response of task 15A was the stimulus of task 15B. Learners had to use their representations and construct the image on the computer, but they created the structure on the screen in the opposite

direction of the stimulus. Therefore nobody (0%) was correct. This demonstrates that the ability to perceive parts of wholes, congruence, symmetry and transformation was underdeveloped.

4.4.3 Components of semiotic systems

The components of semiotic systems – a set of signs, a set of rules and the relationship of signs and rules to structure meaning – (see paragraph 2.4.2) are visible in praxis as follows.

During **task 1 and 2** (rows B and C in Table 4-1), a set of signs was given (the cards on the learners' desks), and a set of rules had to be applied (all blocks were constructed on top of each other, without gaps or overlapping). Most learners (90%) were successful in these tasks. The relationship between the rules and the sign was that each block represented on the card was an image of a wooden block. During **task 3**, the cycle of the four phases of meaning structure was visible. At first the appropriation phase was applicable in response to the bigger stimulus. Secondly, transformation took place when learners tried to connect the representation of the card to the smaller wooden blocks. Learner number 8 showed us the publication phase when she asked the researcher that she wanted bigger blocks to match the representation. Conventionalisation took place when learner number 15 answered her and said that the smaller blocks could also represent the stimulus. The publication phase and the conventional phase were verbal responses of the learners. The use of semiotic systems always takes place in context. Within social settings, there are persons and their positions in relationships with social institutions (Ernest, 2008b).

During **tasks 4 to 6** (row E in Table 4-1), the learners' physical position in the class made a difference in their meaning structuring of the representation and how they incorporated the set of signs and rules. For these tasks, the stimulus was represented over a distance and learners sat about a meter or two away from the graphic images. The distance variable made a difference in the learners' meaning-making processes. Only 17% of the learners succeeded in task 4, 10% in task 5, and 3% in task 6.

By the time that **task 7** (row F in Table 4-1) took place, the learners had mastered the sets of signs and the sets of rules, but an underlying meaning structure, incorporating a set of relationships, still needed to be developed. The task was to build three different houses with four rooms each; this means three structures with four loose wooden blocks. The verbal stimulus included the set of rules, but some learners (24%) constructed four houses with three rooms each. Almost half (48%) of the learners were able to make meaning of the set of rules of the verbal instructions. The other 28% did not understand the verbal instruction and did something else, such as counting the blocks of the floorplan.

The learners' drawings were a set of signs that were used as stimuli in **task 8** (row G in Table 4-1). The learners were not used to making use of a stimulus produced by themselves. Usually learners interpreted signs (images) created by the researcher that are functional diagrams. Most learners (76%) were able to make meaning from the stimulus, but a few (21% of the class) who were not able to make meaning, ignored the stimulus and played with the blocks.

Task 9 (row H in Table 4-1) required the learners to draw the seven fixed soma blocks. This means that the learners needed to produce signs. The learners were eager to expand their set of signs by adding dimension to the drawings, but they did not know how, therefore they tried to show it by colouring or shading the blocks with their writing pencils. Only half of the learners (48%) succeeded.

At the time that **task 10** (row I in Table 4-1) was done, the researcher observed that the more the learners dealt with the set of signs, the set of rules and the relationships between the signs and rules, the "easier" it became to structure meaning. Even the learners who did not succeed in task 1 and 2, did exactly what was expected from them in task 10 (task 10 was a repetition of task 1 and 2). The researcher observed a set of signs created by the learners.

The researcher had two aims with **task 11** (row J in Table 4-1). Firstly, she wanted to expand the set of signs, but started with one of the signs that were used by the learners. Secondly, the researcher explored the visual orientation abilities of the learners. She drew a "house" on the board, with four "rooms" – the way that the learners would draw it. Only two learners did not do what was expected. All the other learners (93%) constructed the full-scale structure successfully.

During **task 12** (row K in Table 4-1), the researcher was still busy exploring the visual orientation of the learners. The images drawn on the board were the same structure, soma block 3 (see Figure 1-1), in a different orientation. The drawing was used by some learners to indicate a third dimension. This indicates that the drawing was part of some learners' set of signs. Most of the learners (90%) were able to represent the structure.

The stimulus of **task 13** (row L in Table 4-1) was a code "1 2 1" written on the board, but coding was a new sign in the learners' set of signs. Only learner number 28 was able to make meaning of the code. The other learners (97%) left spaces between the blocks.

The stimulus of **task 14** (row M in Table 4-1) was the code "4" written on the board. After intervention and discussion of the new set of rules, 83% of the learners were able to make meaning of the code and constructed the correct structure.

The stimulus for **task 15** (rows N and O in Table 4-1) was in the opposite direction as the capital letter “L” (Figure 4-7).

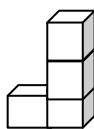


Figure 4-7: Stimulus of task 15A.

In Grade 1, the teacher taught the learners a set of rules that included that a capital letter “L” may never face this way (Figure 4-7). By November the rules for sign (letter of the alphabet) production were quite fixed. Almost all the learners (90%) kept within the set of rules taught and created a capital “L” on the screen, which is partially correct, and 10% of the learners were incorrect. In other words, 0% of the learners was correct.

4.4.4 The spatial operation capacity model (SOC)

The data in this study were also analysed according to the spatial operation capacity (SOC) model (see paragraph 2.4.3). The abovementioned categories of the SOC model were applicable to the 15 tasks done in the study.

The stimuli for the **first two tasks** (rows B and C in Table 4-1) were graphic cards of wooden structures. The perception was a graphic image (two-dimensional) that had to be transformed into a full-scale three-dimensional object (the wooden blocks). The visual processing that was needed for this task, is combined positional-structural changes. Most learners (90%) were able to transform the image into full scale.

The size of the stimulus changed during the course of **task 3** (see row D in Table 4-1). Task 3 required transformational type 2 on the SOC table, because of the change in size of the stimulus. The learners had a conversation about the size of the blocks and 90% of the learners succeeded in the task.

The stimuli in **tasks 4 to 6** (row E in Table 4-1) were, in each task, a single graphic image in the front of the classroom. The structural diagram that was used as the stimulus needed to undergo a change, structural (from bigger image to smaller blocks), and positional (from upright image to structure on a flat table), in the learners’ mind-set before it could be represented in a full-scale structure. Most of the learners (90%) were not able to make meaning of the stimuli if it was not in their reach.

Task 7 (row F in Table 4-1) made use of a verbal stimulus. The task was to build three different constructions with four loose wooden blocks. Only half of the learners (48%) succeeded in this task, because of a language barrier that some learners experienced. Learners did not know terms such as “different” and “the same”. The researcher noted that learners who could read well, succeeded in this task, because of their language skills. During task 8, there were no visual stimulus to rely on, only verbal skills.

During **task 8** (row G in Table 4-1), conventional images created by the learners served as the stimulus. Learners needed to construct the images represented on the drawings with full-scale wooden blocks. This task required the learners to construct three-dimensional structures (wooden blocks) from two-dimensional images (their own drawings). Most learners (76%) were able to make meaning of their own representations.

Task 9 (row H in Table 4-1) tested the mobility from three-dimensional to two-dimensional representations. The three-dimensional full-scale blocks were constructions with four objects and not only loose blocks, as in the previous exercises. Almost a third (31%) of the learners drew the blocks as one block and not four blocks pasted together.

Task 10 (row I in Table 4-1) was a repetition of task 1 and 2, where each learner received a real-size graphic image and loose wooden blocks. All the learners who took part, were able to make meaning of the graphic images.

The teacher drew graphic images on the board for the purpose of **task 11** (row J in Table 4-1). The drawing on the board was a two-dimensional graphic image of a structure. Learners automatically transformed the image and built the full-scale construction, and 93% succeeded. After a few months of experience with the graphic images and wooden blocks, the distance of the stimulus was no longer a problem.

Task 12 (row K in Table 4-1) was the same as task 11, but only another orientation of the structure. The findings for these two tasks were the same. The purpose of task 12 was to confirm the findings of task 11. Again 90% of the learners succeeded.

For the first time, coding was used in **task 13** (row L in Table 4-1). Iconic images were introduced now to expand the SOC components to analyse data. Only one learner made meaning of the code. The teacher used him for intervention and the boy discussed the “coding system” with his friends in his informal language.

Again, the researcher wanted to confirm the findings and gave another code as stimulus for **task 14** (row M in Table 4-1). The teacher wrote the code “4” on the board. After the intervention, 83% of the learners represented the code correctly with the wooden blocks.

Task 15A and **15B** (rows N and O in Table 4-1) took place in the school's computer class. Task 15A was to draw, code or make any note to remember the image represented in front of class. Task 15B was to look at the note and represent the structure on the computer screen. Almost 70% of the learners made correct notes of the images shown in class. The SOC category of mobility from graphic images to virtual representation was a barrier to these learners. All the learners started the construction in the top left corner of the construction box on the screen that resulted in the opposite orientation as the original graphic image.

4.4.5 Conclusion of data gathered through products of the tasks done

These abovementioned theories – spatial structuring abilities, components of semiotic systems and the SOC model – were useful tools to analyse the products of the tasks.

Tasks 1 and 2 were the first formal guided tasks after a long time of free play. The tasks were not challenging for the learners, because the stimulus (graphic card) and the response medium (wooden blocks) were the same size.

The stimulus (graphic card) used for **task 3** was bigger than the response medium. The learners had a conversation about the size of the wooden blocks, and then asked the teacher if they could use her instruction blocks (which were more or less the same size as the blocks on the graphic card). Before the teacher could answer, another learner said it was possible to structure with smaller blocks. The conversation motivated learners to try to structure the blocks. The learners were able to build the construction and used the correct number of blocks.

Tasks 4 to 6 were similar to task 3 (the graphic card was bigger than the wooden blocks), but only one card was shown in the front of the class (a distance away from the learners' bodies). The researcher noticed that the learners (who were able to count) built the structure with more blocks than was represented. This confirmed Piaget's term of nearbyness (Piaget & Inhelder, 1967). Young learners respond easier to stimuli that are close to their bodies.

Each learner had a zip-lock bag with 12 blocks. The instruction for **task 7** was to build three different structures with four blocks each. Some learners got confused and built four structures with three blocks. Other learners did not know the term "different", so the structures were the same. Many children found this task challenging and copied ideas from other learners. They used social interaction to make sense of the task (Zaporozhets, 2002a).

Task 8 was done in two sessions. During the session before playtime, the learners structured different houses with the 12 wooden blocks. The researcher instructed the learners to draw the four structures for future reference. The wooden blocks were packed in the zip-lock

bag and the learners left for break time. After playtime, the learners were instructed to build the same structure as represented in their drawings. This task confirmed the components of semiotic systems (Ernest, 2008b).

Task 9 was the first formal task using soma blocks. Learners had the opportunity to play with soma blocks before task 9 started. The instruction was to draw all seven soma blocks. Some learners attempted to create three-dimensional features to their drawings by colouring the drawing. Other learners drew only the outer lines of the wooden blocks. This indicated that the learners' insight to shape to perceive parts of a whole, still needed development (Van Nes & Van Eerde, 2010).

Task 10 was exactly the same as tasks 1 and 2. All the learners were successful in task 10. This indicates that the learners developed through experience (Fuys et al., 1988).

Learners created their own set of signs during the research sessions. The researcher drew one of the signs (created by the learners) on the board for tasks **11 and 12**. All the learners understood the sign and responded correctly to the tasks.

To expand the set of signs, the researcher wrote a code, "1 2 1", on the board for **task 13**. Only one learner made sense of the code and responded correctly. The researcher asked the learner who had responded correctly, to come to the front and explain (in a child's manner) to his peers how he had responded to the task. Vygotsky states that meaningful perceptions can only be developed through the participation of speech by combining the process of perception with the process of verbal thought (Zaporozhets, 2002a).

After the discussion of task 13, the researcher wrote another code (4) on the board for **task 14**. More learners responded correctly to the stimulus. That indicates that the learners made sense of the verbal thoughts of the "task 13 discussion".

Task 15A required the learners to draw, write or make any kind of note to represent the graphic card shown. Most learners were able to respond correctly to this task. **Task 15B** used the learners' responses to task 15A as stimuli to construct the structure on the computer screen. All the learners started at the top left-hand block of the construction box of the computer software. They represented the construction in the opposite orientation. A set of rules (rules how to write letters) of sign production, influenced this response (Ernest, 2008b). The learners wanted to create a capital letter L, instead of the stimulus represented.

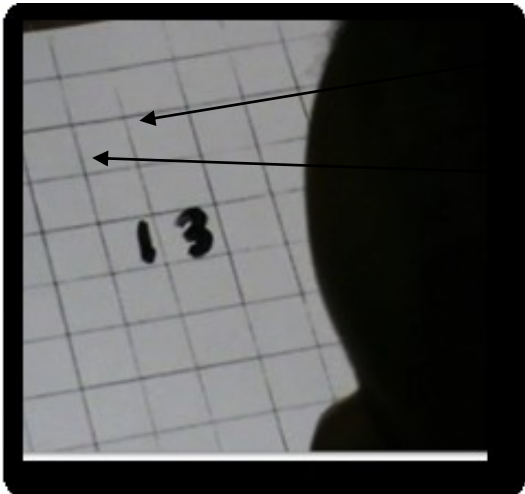
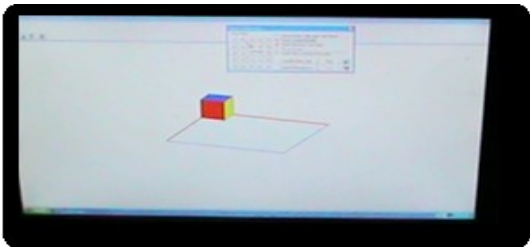
This led the researcher to study the process of sign production of Grade 1 learners.

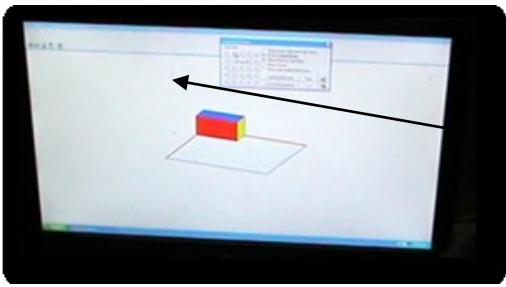
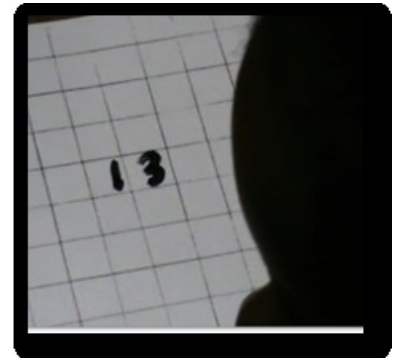
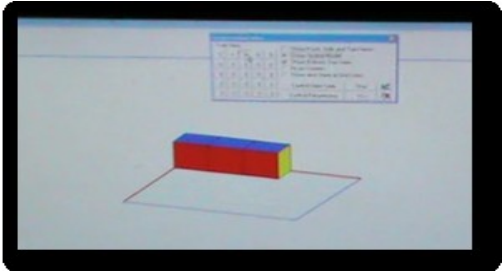
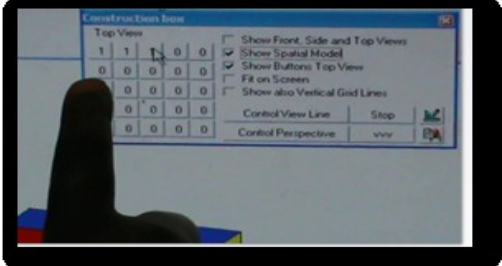
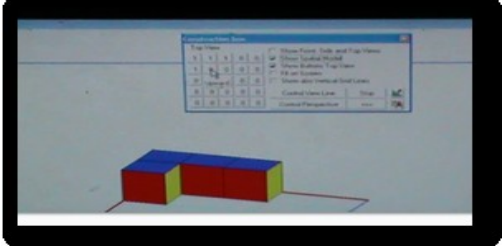
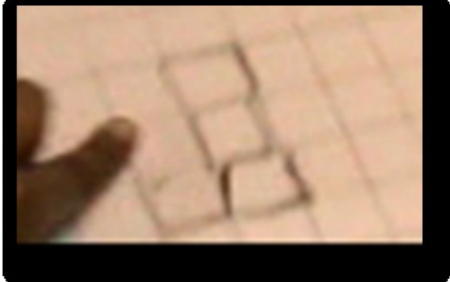
4.5 Data analysis of processes of meaning making

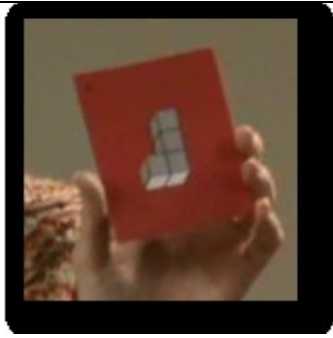
4.5.1 Data analysis though the process of the tasks done by learners

Two of the learners' processes of tasks 15A and 15B are shown in detail in Table 4-6. The researcher chose tasks 15A and 15B, because these video footages show the interactions of the learners and the transformation from two-dimensional to three-dimensional and virtual representations most clearly.

Table 4-6: Detail about the meaning-making processes of tasks 15A and 15B.

Task	Process	Comments
Task process of learner number 19		
Task 15A The researcher showed a graphic image of a wooden structure.  The task was to represent the images on paper; learners could write a code or draw a picture to remember the structure represented on the card.		Learner 19 wrote this code. The 1 represented the one block on the left. The 3 represented the three blocks next to the one block. This was the appropriation phase in the meaning-making process.
Task 15B The learners' responses to task 15A served as the stimuli to task 15B. Learners needed to build the structure		She started at the top left-hand corner of the construction box.

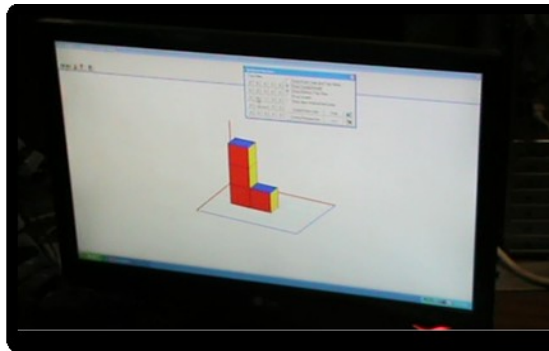
that was represented on the computer.		Then she added another block to the right. The correct response would be if she adds the last two blocks on top of this block.
		The third block was added on the right side of the second block.
		She was planning to add the next block in the second line on the left.
		This was the result of task 15B of learner number 19. The transformation phase was completed
Task process of learner number 9		
Task	Process	Comments
Task 15A The researcher showed a graphic image of a wooden structure.		He responded correctly to the task. This learner was still in the transformation phase.



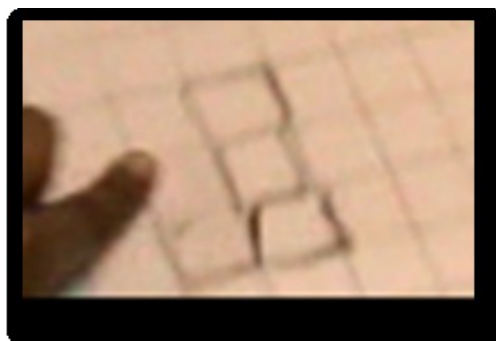
The task was to represent the images on paper; learners could write a code or draw a picture to remember the structure on the card.

Task 15B

The learners' responses to task 15A served as the stimuli to task 15B. Learners needed to build the structure that was represented on the computer.



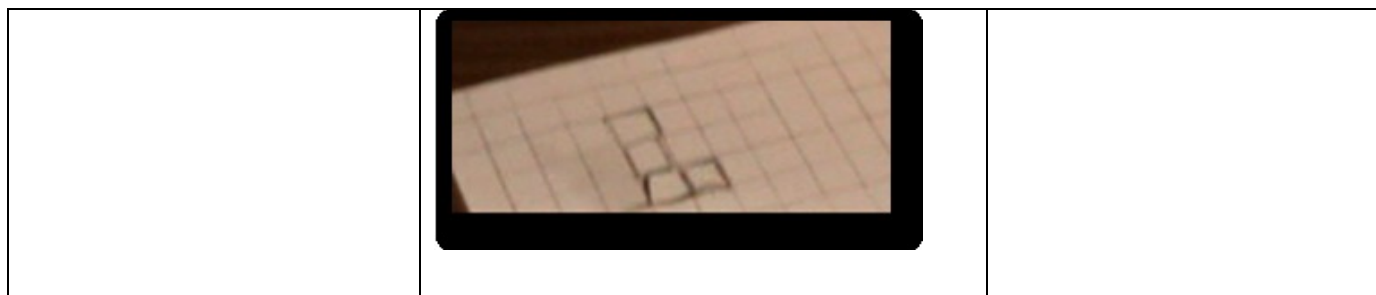
Learner number 9 built the structure in an opposite orientation as the stimulus



As he recognised that the stimulus and the response differed, he decided that the screen was correct and his drawing was wrong, so he changed his drawing.



He looked at his drawing, then he looked at his screen and felt satisfied that it was correct. This is part of the **publication and conventionalisation** phases.



4.5.2 Discussion of processes of meaning-making through agency

The abovementioned processes show how learners' agency was manifested in communicative activity in evolving sign reception and sign productions processes (Ernest, 2005) (see paragraph 2.4.2.4). Signs (semiotic systems) are adopted by the individual learners through four consecutive phases, demarcated as appropriation, transformation, publication and conventionalisation.

- **Appropriation phase:** The appropriation phase leads to a learner's own unreflective response to and imitative use of a single sign. Learners look at the stimulus (in task 15A it was a graphic card) and become aware of the immediate context and association of the sign use. The task was to create a representation of the card. In Table 4-6, learner 19 wrote a code and learner 9 drew the structure.
- **Transformation phase:** When the next stage is achieved for a particular sign, the learner usually develops personal meaning for the sign and its use (see Table 4-3). Learners represent the card in their own way. Attention, persistence and repeated performance in both sign utterances and explanatory meta-discourse evidently are manifestations of agency.
- **Publication phase:** In the third phase, the learners engage in a conversational act in publicly performing or making a sign utterance. The learners worked in pairs in the school's computer lab in task 15. The audio-video footage captured the conversations of the learners and the publication phase played an important role in the manifestation of agency. Learners were confident that their responses to task 15B were correct, but the researcher showed the original stimulus to the learners again. They realised that their structures on the computer screens were in the opposite orientation. Learners had constructed the structure like a capital letter "L". The learners started a conversation about the orientation that led to the conventionalisation phase.
- **Conventionalisation phase:** The learners came to an agreement that they needed to change the structures on the computer screens to match the stimulus. The four phases form a cycle, and the agreement that the structures needed to change was the start of

the next appropriation phase. As the learners tried to figure out how to change the structure on the computer screens, they kept their thoughts private.

4.5.3 Conclusions of data gathered through the processes of tasks done

The data for this research were gathered by various methods. Audio-video footage contributed to the quality of the data, because it included products as well as processes of meaning-making. Conversations were captured in the audio-video footage. Each audio-video clip was structured and represented into a storyboard, according to the TRAR protocol. Responses of tasks were analysed from the storyboard into Excel sheets. The researcher made use of three theories (spatial structuring abilities, components of semiotic systems and the SOC model) to analyse the data. The researcher came to a few conclusions: learners need to be in reach of the stimulus to make meaning of a representation, and images are more trustworthy to learners than text, but the computer screen is the most trustworthy. These learners always started constructing at the top left corner of the construction box on the computer.

As the researcher studied the audio-video footage, the four agency phases (appropriation, transformation, publication and conventionalisation) became clear.

4.5.4 Conclusion on data gathered through reading activities

After tasks 1 to 6, the researcher noticed a connection between reading abilities and spatial thoughts. Learners 2 and 3 were not yet able to read, and their results of tasks 1 to 6 were 0%. Learner 8, who was able to read, scored 100% in tasks 1 to 6. Learner 20, who scored 83% in tasks 1 to 6, was able to read. The Grade 1 prescribed reading books have pictures with sentences about the picture. Learner 2 and 3 looked at the pictures and memorised the sentences to pretend that they were reading. The researcher created a reading book with pictures, but the sentences underneath did not fit the picture. Most learners were confused and could not even read familiar words, such as number names. Learner 8 and 20 used phonics to make meaning of the words and were able to read the sentences. The researcher asked learner 8 if the sentence or the picture was true (right). She said the sentence should change to fit the picture and all the learners agreed. The researcher came to the conclusion that images are more trustworthy to learners than text.

CHAPTER 5 CONCLUSION AND RECOMMENDATIONS

5.1 Summary of research findings

The aim of this research was to investigate the emergent relationships between the multitude of semiotic modes of representation production that can be presented to and utilised by learners, to become mathematically literate via a multimodal approach to teaching and learning, while being vigilant about the possibilities of transferring this knowledge to other domains of literacy, such as language or scientific literacy. Table 5-1 is a summary of the task sequence and the results of each task.

Table 5-1: Summary of task sequence and results.

Task number	Dimension of stimulus to response	% correct	% partially correct	% incorrect
Task 1	2D-3D	90%		10%
Task 2	2D-3D	90%	3%	7%
Task 3	2D-3D	90%		10%
Task 4	2D-3D	17%		83%
Task 5	2D-3D	10%		90%
Task 6	2D-3D	3%		97%
Task 7	ver-bal-3D	48%	24%	28%
Task 8	2D-3D	76%	3%	21%
Task 9	3D-2D	48%	31%	14%
Task 10	2D-3D	97%		
Task 11	2D-3D	93%		7%
Task 12	2D-3D	90%	3%	7%
Task 13	2D-3D	3%		97%
Task 14	2D-3D	83%		17%
Task 15A	2D-3D	69%	21%	10%
Task 15B	2D-virtual	0%	90%	10%

Figure 5-1 is a diagram that summarises the findings that relate to the three-theoretical framework, with focus on the stimulus and response relationships.

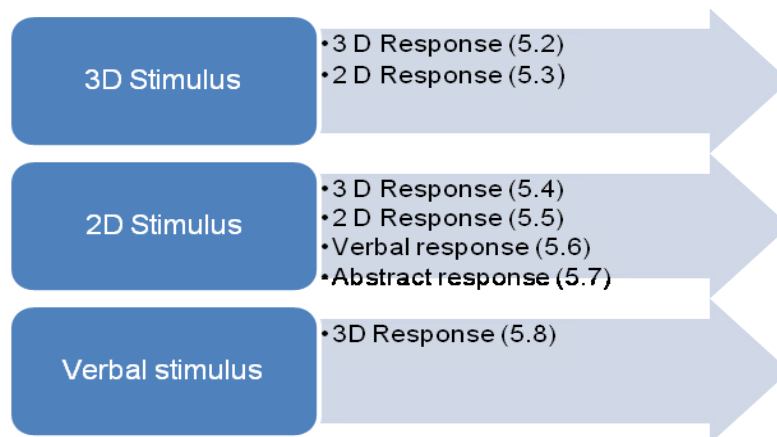


Figure 5-1: Dimension of stimulus and response.

5.2 Three-dimensional stimuli to three-dimensional responses

From January to June, learners got the opportunity for free play with all the research material. The researcher conducted preparatory activities by providing three-dimensional stimuli and learners responded with three-dimensional blocks. All the learners were 100% successful in these activities. Even learners who were not able to read were able to do these tasks. These activities were diagnostic activities to identify the Van Hiele thinking levels. All the learners were at least on level 0: visualisation of the Van Hiele thinking levels. Learners found full-scale stimuli to full-scale responses easy.

5.3 Three-dimensional stimulus to two-dimensional response

Only task 9 had a stimulus that was three-dimensional and required a two-dimensional response. Half of the learners (48%) did what was expected. The researcher expected better results, because the stimuli were close to the learners' bodies and they could touch and count the blocks. It seems that the learners' spatial abilities to perceive parts of a whole were not yet fully developed. For example, some learners (31%) traced the soma blocks as a single unit and not as four blocks. It seemed that the 14% who responded incorrectly, did not understand the instructions and did something else, such as counting the blocks on the floorplan.

5.4 Two-dimensional stimulus to three-dimensional response

The researcher made use of two-dimensional stimuli for tasks 1 to 6, 8, 10, 11, 13 and 14. Learners responded with three-dimensional blocks. Learners responded well to task 1 and 2, because the stimuli and the blocks were the same size and each learner had his or her own

card close to his or her body. The two-dimensional stimuli for task 3 were larger than the blocks, but the researcher allowed the learners to discuss the changes so that the agency process could take place. Most learners succeeded in task 3. The stimulus for task 4 was a single representation of soma block 3 (see Figure 1-1), represented over a distance. Learners constructed the responses using too many blocks. The stimulus of task 6 was a representation of soma block 5 (see Figure 1-1) that has blocks that are not visible from the front view. Only learner 8 was able to respond correctly to task 6. Learner 8's reading skills were well developed.

Task 8 was conducted in October. The two-dimensional stimuli were their own drawings. Three quarters (76%) of the learners were able to "read" their own drawings and represent them in a three-dimensional way.

Task 10 was a repetition of task 1 and 2, but task 10 was done towards the end of the year. In this instance, all the learners succeeded. Learners' reading skills had improved since January because learners practised reading in the classroom daily. This leads to the conclusion that there is an interconnectedness between reading capacity and spatial capacity. It seems from this research that the better the learners could engage with the spatial activities, the better their reading became.

Task 11 was a drawing of soma block 3 (Figure 1-1) on the writing board in front of the classroom (this drawing was made by the teacher). Most learners (93%) had no problem constructing the three-dimensional representation using the information as represented on the board. The 7% of the learners who did not succeed, were the learners who still could not read.

The stimulus of task 13 was a code (1 2 1) on the board (see Table 4-1 row L). The learners did not have experience in coding and therefore only one learner succeeded in this task. At this stage it was evident that in order to complete the agency cycle (see Figure 2-6), the learners had to be prompted to go on to the publication phase. Consequently the researcher gave the learner who had initially responded correctly to task 13, a chance to discuss it with his class mates. The publication phase was followed by the conventionalisation phase, which led to all learners making meaning of codes.

Task 14 was introduced as stimulus in order to complete the agency cycle, by giving another code on the board. Of the learners, 83% responded correctly to the task, implying that there was a successful completion of agency cycle (appropriation, transformation, publication and conventionalisation).

5.5 Two-dimensional stimulus to two-dimensional response

Learners responded two-dimensionally to the stimulus of task 15A. Learners were able to read the two-dimensional stimulus and responded (by writing, drawing or coding) the representation. The 10% who responded incorrectly would rather play on the computer than write on the floorplan. It therefore seems that either they did not comprehend the task per se, or that they were not capable to complete the task.

5.6 Two-dimensional stimulus to verbal response

The activity that dealt with this aspect happened during the free playtime when the researcher had informal conversations with learners about the blocks, as well as the activity dealing with the reading book.

The researcher noticed that learners relied on images to read in Grade 1, and all the prescribed reading books have pictures. If the images do not match the text, learners struggled to make meaning of the sentences. The researcher asked the learners if the picture or sentences were correct and all the learners agreed that the pictures were correct and that they would like to change the sentences to match the image. For these learners, images were more trustworthy than text.

5.7 Two-dimensional stimulus to abstract coding

The responses to Task 15B were abstract coding on the computer screen. The learners played on the computer before and knew the software and how it worked. The South African curriculum is still book-orientated, so learners start reading and writing in the top left-hand corner. To construct the structure represented on the stimulus, one needs to start at the bottom of the construction and build upwards. The learners responded to task 15B by constructing block 2 (see Figure 1-1) in the top left-hand corner of the construction box and then built downwards. It seems that the set of rules learned in class (start reading and writing in the left top corner) became a mental barrier to learners. All the learners built a capital letter "L" on the screen, but the stimulus was in the opposite orientation. One learner looked at the screen, satisfied, and then changed his image on the floorplan to match that of the screen. Again, here it seems that the screen is more trustworthy than images to the learners.

5.8 Verbal stimulus to three-dimensional response

Real life is a multimodal world, where we see and hear at the same time. Learners are exposed to technology such as cell phones and television that have sound and images. When learners are confronted with only verbal instructions in class, they struggle to make meaning of the task.

Especially in the case of a multilingual classroom situation, as are the majority of South African classrooms. (In this class, there were learners speaking English, Afrikaans, Setswana, Zulu and Portuguese.) An example of this statement is task 7. The instructions to this task had two variables: the first variable was that there were several houses that could be made. The second variable was that all the houses had to consist of four blocks. Less than half (48%) of the learners responded correctly. A quarter of the learners (24%) mixed the variables and 28% were totally confused without visual stimulation (the instructions were only auditory) and responded incorrectly. It seems that learners need multimodal, (especially visual) stimuli in the Grade 1 classroom to improve learning.

5.9 Conclusion about multimodality

The researcher came to the conclusion that learners initially could make meaning of full-scale objects (full-scale objects are on the far left of SOC table, while graphic images are right on the SOC table) easier, compared to graphic images such as text. Learners seemed to believe the full-scale images before they believed what the text tried to convey. In other words, full-scale objects are the absolute truth to learners.

Second in line are virtual reality images, as reflected in the activities that dealt with the computer and its screen. Learners would rather believe images seen on a screen, than printed images on paper and in books. One learner asked, “Why would the screen lie?” Then he said, “Computers don’t make mistakes”.

Most learners indicated that they rather believed the printed pictures in books than text. The learners who struggled to read, could not deal with the iconic images required in tasks 14 and 15B.

Figure 5-2 is a repetition that reflects two findings, namely:

- The general believe that learners have about the value of the stimulus; in other words, they believe a computer image (picture) before they believe the printed images of the same object.
- In general, learners seem to comprehend full-scale images before iconic images of the same object.

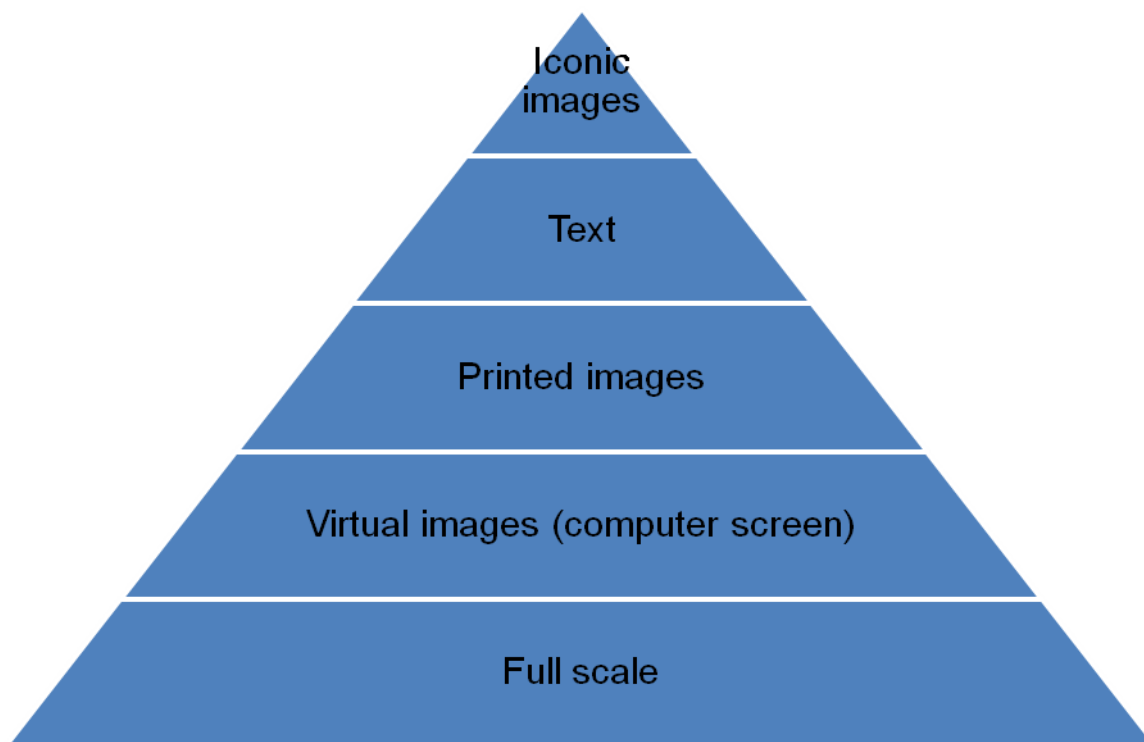


Figure 5-2: Visual stimulus pyramid.

5.10 Answering the research questions

The researcher of this study addressed these complex educational problems through research questions, of which the main research question is as follows: What is the nature of the emergence of semiotic representational reflection in a Grade 1 mathematics classroom?

In order to address this main question, the following sub-questions can be answered as follows.

Sub-question 1: What is the nature of emergence of semiotic sensemaking in a Grade 1 mathematics classroom?

In a semiotic sense, sign comprises the form of words, gestures, pictures, images and sounds (Chandler, 2007). In this research, full-scale objects emerge first and then are built up to virtual images on the computer screen. Learners find images on the computer screen more trustworthy than printed images in a book. Printed images emerge before text, and at the last end, are iconic images for sense making in the Grade 1 mathematics classroom (see figure 5.2).

Sub-question 2: What is the nature of the signs used in semiotic reflection?

The nature of signs used in semiotic reflection could be categorised into three components of semiotic systems: a set of signs, a set of rules and a set of relationships between these signs and rules (Ernest, 2008a). A set of signs are all the material (wooden blocks, graphic cards, and learners' drawings) used in the research. Each set of signs has its set of rules, for example when learners build structures it may not have gaps and the blocks may not overlap. It seems that the sets of rules get interlinked between reading and spatial thoughts, because learners constructed soma block 2 (Figure 1-1) only in a capital letter "L" orientation. So the relationship between sets of signs and sets of rules gets interwoven across the multi-literacies.

Sub-question 3: What is the role of the mobility of multimodal representations on the emergence of semiotic representations?

Representations that are mobile, such as full-scale blocks and virtual images (blocks on the computer screen) that learners can manipulate as they wish, are more trustworthy for them than fixed images. Wooden blocks, such as soma 5 (Figure 1-1), can be picked up and turned by learners to see all four blocks in the structure. Learners did not experience difficulty to represent block 5 from a three-dimensional stimulus into a three-dimensional response. Learners experienced difficulties to represent soma block 5 from a two-dimensional stimulus, because all four blocks were not visible on the graphic image.

Sub-question 4: What is the nature of the agency that learners adopt during the process of semiotic reflection?

Learners' agency is manifested in communicative activity that evolves sign reception and sign productions processes (Ernest, 2005). The researcher studied agency through four consecutive phases, demarcated as appropriation, transformation, publication and conventionalisation. These phases were visible through the research, because the researcher guided learners through the phases. The researcher allowed class conversations for the publication phase to take place. The researcher conducted tasks after the publication phase to test if the conventionalisation phase was in place.

Sub-question 5: What contribution could knowledge about the emergence of semiotic reflection make to assisting learners in the domains of reading and writing?

In the Grade 1 mathematics classroom, traces of emergent meanings are found, because of the new links among symbols. Learners are confronted with many new signs and symbols in their first year of formal schooling. In Grade 1, the learners need to learn all the letters of the alphabet in order to learn to read and write. In this research, the researcher found that learners depend on social knowledge to make sense of the set of signs (letters).

Social knowledge is written and spoken languages made by people (Kamii, 1996). In other words, to make sense of signs, the learners apply information that they have heard or seen before. The recommendation from this research question is that teachers have to provide learners with more opportunities to explore a set of signs (letters) for learners to gain more experience to apply new knowledge.

The researcher came to the summative conclusions that, firstly, because learners believe full-scale objects before virtual images, followed by printed images, followed by text and, lastly, iconic images, educators should take cognisance of this important belief. If educators are aware of these beliefs, they can provide stimuli to learners in a variety of multimodal ways. Secondly, educators should also be aware of the fact that Grade 1 learners memorise sentences associated with pictures, but when there are no pictures, reading fails in many instances.

5.11 Recommendations

In the light of the abovementioned findings, the researcher recommends the following regarding teacher and learning in Grade 1 and implications for teacher training:

5.11.1 Teaching and learning in Grade 1

- Grade 1 learners tend to believe full-scale and virtual images better and, therefore, it is recommended that educators make use of a multimodal approach (combined with technology) and not only the single mode of printed books.
- Most learners initially struggle to make meaning of a stimulus if the stimulus is a distance away from their bodies. It is recommended that educators provide learning material that is within reach of the learners, so that they can touch the material for easier learning.
- Grade 1 learners memorise sentences associated with an image and pretend to read, but when there is no image, the learner cannot read. The researcher recommends that educators teach learners to read without pictures, for example to make use of sight words on flash cards, so that learners associate text words with auditory words.
- Practise makes perfect and the more learners are exposed to a concept, the faster they will make meaning of the concept. The researcher recommends that educators expose learners to a variety of activities, and repeat activities for learners to learn.
- Grade 1 learners rely on visual stimulation and struggle if educators use only verbal instructions. The researcher recommends that educators provide auditory, visual and tactile stimuli to young learners, so that they can use more senses than only hearing to learn.

- Learners use simpler ways to describe something and therefore the researcher recommends that educators give learners opportunities for class discussion, so that learners can hear information from peers and they are given the opportunity to practise their verbal skills.

5.11.2 Implications for teacher training

The researcher recommends educational design research to young educators to become aware of the variables that influence teaching and learning. Educational design research is a bridge between theory and practice and it is (according to the researcher) a good method to learn how to teach. This method helps educators to stand on the shoulders of the “giants” (grand theories) and explore practice. The researcher recommends educational design research to future teacher training.

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ADDENDUM A: A SAMPLE OF PARENTS' CONSENT FORM



Private Bag X6001, Potchefstroom
South Africa 2520

Tel: 018 299-1111/2222
Web: <http://www.nwu.ac.za>

Faculty of Education Sciences

Tel: (018) 299-1870
Mobile: 083 3764012

Mrs M Pieters

President Pretorius Primary

Dr Kenneth Kaunda District

Potchefstroom

Dear Madam or Sir

RE: REQUEST TO PARENT OR GUARDIAN FOR PARTICIPATION IN RESEARCH

I hereby request your permission as parent or guardian of the learner in Grade 1 for research in President Pretorius Primary School in the district of Potchefstroom. Described below is the nature and the duration of the research.

Attached to this letter is a full description of the project as it was approved by the North-West University, Potchefstroom Campus.

I am looking forward to your communication.

Thank you.

Yours faithfully

A handwritten signature in dark ink, appearing to read 'M Pieters', is written over a light blue rectangular background.

Mrs M Pieters

STUDY TITLE:

The emergence of semiotic reflection through a multimodal approach to teaching and learning in a Grade 1 mathematics classroom

STUDY PURPOSE AND RATIONALE:

The overall aim of the study is to identify a teaching-learning trajectory* for teaching mathematics through the medium of English during the pre-reception and reception year at Grade 1 level.

The research objectives include:

- (i) Investigating the acquisition of emergent scientific reasoning “habits of mind” during the pre-reception and reception years of the Foundation Phase.
- (ii) Utilising a multimodal approach to representations of scientific “habits of mind” in teaching and learning.
- (iii) Focusing on the impact of the medium of instruction, namely English (which will be a second or even third language for most of the learners) on the acquisition of scientific “habits of mind” and semiotic representations.

INCLUSION/EXCLUSION CRITERIA:

The participants anticipated for the study are Grade 1 learners of President Pretorius Primary School.

PARTICIPATION PROCEDURES AND DURATION:**Venue, duration and participants**

The research will start with Grade 1 learners (approximately 35 learners) from a state school (President Pretorius Primary School) in Potchefstroom, North West Province, South Africa, which will be the focal site of the design experiment. The teacher/researcher will teach these learners for a period of one year, utilising the context of mathematics as curriculum domain.

**RESEARCH MATERIAL PRODUCTION: DEVELOPMENT AND INTERPRETATION.
THE RESEARCH METHODOLOGY IS TERMED “DESIGN RESEARCH”**

The classroom activities are video recorded as part of the gathering of research data. One such class activity takes about 45 minutes. After the recording of the activities, the information is transcribed by the researcher and the teacher who may be involved in the classroom activities.

DATA CONFIDENTIALITY OR ANONYMITY:

All data will be kept confidential and no identifying information, such as names, will appear in any publication or presentation of the data. All the names and affiliations of the learners will be protected by coding the names of participating learners, teachers and the school.

Permission to video record the learners and the production of their work will be requested per signed document from the parent/guardian of every child, as well as the headmaster and the school authority that administrates this specific school in South Africa.

STORAGE OF DATA:

All data will be kept by the researcher in paper and electronic format.

RISKS OR DISCOMFORTS:

No possible risks to participate are envisaged. However, in the event of questions that may be perceived as threatening or causing discomfort, participants may decline to answer such questions without providing any reason for doing so.

BENEFITS:

No direct benefits or compensation.

VOLUNTARY PARTICIPATION:

Participation in this research is completely voluntary. Participants may, at any stage, refuse to participate and/or withdraw at any time.

INFORMED CONSENT FORM (to be returned to the school)

CONSENT:

I, _____, (parent/guardian) agree to allow for my child

_____ (name and surname of child) to
participate in this research project, which will be video recorded as part of the data assembly.

I have had the study explained to me and my questions have been answered to my satisfaction. I have read the description of this project and give my consent that my child may participate. I understand that I will receive a copy of this informed consent form to keep for future reference. To the best of my knowledge, the participant (my child) meets the inclusion/exclusion criteria for participation (described on the previous page) in this study.

Name

Signature

Date

ADDENDUM B: ETHICS CLEARANCE FROM NWU



NORTH-WEST UNIVERSITY
YUNIBESITHI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT

Private Bag X6001, Potchefstroom,
South Africa, 2520

Tel: (018) 299-4900

Faks: (018) 299-4910

Web: <http://www.nwu.ac.za>

Institutional Research Ethics Regulatory Committee

Tel: +27 18 299 4849

Email: Ethics@nwu.ac.za

2016-07-13

ETHICS APPROVAL CERTIFICATE OF STUDY

Based on approval by the Ethics Committee of the Faculty of Education Sciences (ESREC) on 13/07/2016, the North-West University Institutional Research Ethics Regulatory Committee (NWU-IRERC) hereby approves your study as indicated below. This implies that the NWU-IRERC grants its permission that, provided the special conditions specified below are met and pending any other authorisation that may be necessary, the study may be initiated, using the ethics number below.

Study title: The emergence of semiotic reflection through a multimodal approach to teaching and learning in a grade 1 Mathematics classroom																																												
Project head:	Dr R van Niekerk																																											
Project team/ student:	ME Pieters																																											
Ethics number:	<table border="1"><tr><td>N</td><td>W</td><td>U</td><td>-</td><td>0</td><td>0</td><td>1</td><td>6</td><td>2</td><td>-</td><td>1</td><td>5</td><td>-</td><td>A</td><td>2</td></tr><tr><td colspan="3">Institution</td><td colspan="6">Study Number</td><td colspan="2">Year</td><td colspan="2">Status</td></tr><tr><td colspan="15">Status: S = Submission; R = Re-Submission; P = Provisional Authorisation; A = Authorisation</td></tr></table>	N	W	U	-	0	0	1	6	2	-	1	5	-	A	2	Institution			Study Number						Year		Status		Status: S = Submission; R = Re-Submission; P = Provisional Authorisation; A = Authorisation														
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Commencement date:	2016-07-13																																											
Expiry date:	2017-12-13																																											
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N/A																																												

Special conditions of the approval (if applicable):

- Translation of the Informed consent document to the languages applicable to the study participants should be submitted to the ESREC (if applicable).
- Any research at governmental or private institutions, permission must still be obtained from relevant authorities and provided to the ESREC. Ethics approval is required BEFORE approval can be obtained from these authorities.

General conditions:

While this ethics approval is subject to all declarations, undertakings and agreements incorporated and signed in the application form, please note the following:

- The study leader (principal investigator) must report in the prescribed format to the NWU-IRERC via ESREC:
 - annually (or as otherwise requested) on the progress of the study, and upon completion of the project
 - without any delay in case of any adverse event (or any matter that interrupts sound ethical principles) during the course of the project.
 - Annually a number of projects may be randomly selected for an external audit.
- The approval applies strictly to the proposal as stipulated in the application form. Would any changes to the proposal be deemed necessary during the course of the study, the study leader must apply for approval of these changes at the ESREC. Would there be deviation from the study proposal without the necessary approval of such changes, the ethics approval is immediately and automatically forfeited.
- The date of approval indicates the first date that the project may be started. Would the project have to continue after the expiry date, a new application must be made to the NWU-IRERC via ESREC and new approval received before or on the expiry date.
- In the interest of ethical responsibility the NWU-IRERC and ESREC retains the right to:
 - request access to any information or data at any time during the course or after completion of the study;
 - to ask further questions, seek additional information, require further modification or monitor the conduct of your research or the informed consent process.
 - withdraw or postpone approval if:
 - any unethical principles or practices of the project are revealed or suspected,
 - it becomes apparent that any relevant information was withheld from the ESREC or that information has been false or misrepresented,
 - the required annual report and reporting of adverse events was not done timely and accurately,
 - new institutional rules, national legislation or international conventions deem it necessary.
- ESREC can be contacted for further information or any report templates via Ema.Conradie@nwu.ac.za or 018 299 4656

The IRERC would like to remain at your service as scientist and researcher, and wishes you well with your project. Please do not hesitate to contact the IRERC or ESREC for any further enquiries or requests for assistance.

Yours sincerely

Prof LA
Du Plessis

Digitally signed by
Prof LA Du Plessis
Date: 2016.07.26
11:53:08 +02'00'

Prof Linda du Plessis

Chair NWU Institutional Research Ethics Regulatory Committee (IRERC)

ADDENDUM C: CONSENT FROM THE SCHOOL GOVERNING BODY



NORTH-WEST UNIVERSITY
YUNIBESITHI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT
POTCHEFSTROOM CAMPUS

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South Africa 2520

Tel: 018 299-1111/2222
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Faculty of Education Sciences

Tel: (018) 299-1870

Mobile: 083 3764012

Mrs M Pieters

President Pretorius Primary

Dr Kenneth Kaunda District

Potchefstroom

RE: REQUEST FOR THE CONSENT OF THE HEADMASTER AND GOVERNING BODY FOR PARTICIPATION IN RESEARCH

I hereby request permission to do research at the President Pretorius Primary School, Potchefstroom. Described below is the nature and the duration of the research. It would be highly appreciated if you could verify and confirm this request.

Attached to this letter is a full description of the project as it was approved by the North-West University on the Potchefstroom Campus.

I am looking forward to your communication. Thank you.

Yours faithfully

Handwritten signature of Mrs M Pieters in blue ink.

Mrs M Pieters

Handwritten signature of the Governing body in blue ink.

Governing body

Handwritten signature of Headmaster Mr JAS Fourie in blue ink.

Headmaster Mr JAS Fourie



STUDY TITLE:

The emergence of semiotic reflection through a multimodal approach to teaching and learning in a Grade 1 mathematics classroom

STUDY PURPOSE AND RATIONAL:

The overall aim will be to identify a teaching-learning trajectory* for teaching mathematics through the medium of English at a Grade 1 level during the pre-reception and reception year.

The research objectives include:

- (i) Investigating the acquisition of emergent scientific reasoning “habits of mind” at the pre-reception and reception year of the Foundation Phase.
- (ii) Utilising a multimodal approach to representations of scientific “habits of mind” in teaching and learning.
- (iii) Focusing on the impact of the medium of instruction, namely English (which will be a second or even third language for most of the learners), on the acquisition of scientific “habits of mind” and semiotic representations.

INCLUSION/EXCLUSION CRITERIA:

The participants anticipated for the study will be Grade 1 learners of the President Pretorius Primary School.

PARTICIPATION PROCEDURES AND DURATION:**Venue, duration and participants**

The research will start with Grade 1 (approximately 35 learners) in a state school (President Pretorius Primary School), Potchefstroom, North West Province, South Africa, which will be the focal site of the design experiment. The teacher/researcher will teach these learners for the period of one year, utilising the context of mathematics as curriculum domain.

**RESEARCH MATERIAL PRODUCTION: DEVELOPMENT AND INTERPRETATION.
THE RESEARCH METHODOLOGY IS TERMED “DESIGN RESEARCH”**

The classroom activities are video recorded* as part of the gathering of research data. One such class activity takes about 45 minutes. After the recording of the activities, the information is transcribed by the researcher and teacher who might have been involved in the classroom activities.

DATA CONFIDENTIALITY OR ANONYMITY:

All data will be kept confidential and no identifying information, such as names, will appear in any publication or presentation of the data. All the names and affiliations of the learners will be protected by coding the names of participating learners, teachers and the school.

Permission to video record the learners and the production of their work will be requested per signed document from the parent/guardian of every child, as well as the headmaster and the school authority that administrates this specific school in South Africa.

STORAGE OF DATA:

All data will be kept by the researcher in paper and electronic format.

RISKS OR DISCOMFORTS:

No possible risks to participation are envisaged. However, in the event of questions that may be perceived as threatening or causing discomfort, participants may decline to answer such questions without providing any reason for doing so.

BENEFITS:

No participant will receive any direct benefits or compensation.

VOLUNTARY PARTICIPATION:

Participation in this research is completely voluntary. Participants, or the parents or guardians of participants, may at any stage refuse to participate and/or may withdraw at any time.

ADDENDUM D: CONSENT FROM NORTH WEST DEPARTMENT OF EDUCATION



Education and Sport Development

Department of Education and Sport Development
Departement van Onderwys en Sport Ontwikkeling
Lefapha la Thuto le Tšhepo le Mefuta e Fapaneng

NORTH WEST PROVINCE

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d O.R. Tambo Street, Potchefstroom
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Potchefstroom 2520
Tel.: (018) 299-8216
Fax: (018) 294-8224
Enquiries: Mr H. Motara
e-mail: hmotara@mepg.gov.za

DR KENNETH KAUNDA DISTRICT OFFICE OF THE DISTRICT DIRECTOR

21 April 2016

Mrs M Pieters
North West University – Potchefstroom Campus

PERMISSION TO CONDUCT RESEARCH ON "THE EMERGENCE OF SEMIOTIC REFLECTION THROUGH A MULTIMODAL APPROACH TO TEACHING AND LEARNING IN A GRADE 1 MATHEMATICS CLASSROOM" AT PRESIDENT PRETORIUS PRIMARY SCHOOL IN TLOKWE AREA OFFICE - DR KENNETH KAUNDA DISTRICT

The above matter refers.

Permission is hereby granted to you to conduct your research at President Pretorius Primary School in Tlokwe Area Office - Dr Kenneth Kaunda District under the following provisions:

- The activity you undertake at the school should not tamper with the normal process of learning and teaching; and will take place after school hours.
- You inform the principal of your identified school of your impending visit and activity;
- Teachers and learners are told prior to the interview that it is not compulsory but voluntary.
- You provide my office with a report in respect of your findings from the research; and
- You obtain prior permission from this office before availing your findings for public or media consumption.

Wishing you well in your endeavour.

Thanking you

**MR H MOTARA
DISTRICT DIRECTOR
DR KENNETH KAUNDA DISTRICT**

cc: Ms S S Yssel – Area Manager, Tlokwe