An investigation of teachers' experiences of a *Geoboard* intervention programme in Area and Perimeter in selected Grade 9 classes: A case study

A thesis submitted in partial fulfilment of the requirements for the degree of

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by

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ABSTRACT

The study was undertaken with three Grade 9 teachers at three selected schools which are part of RUMEP's Collegial Cluster Schools' programme that I coordinate. Collegial clusters are communities of teachers who aim at improving their practice by working on their own professional development.

The purpose of this study was to investigate the selected Grade 9 teachers' experiences of a *Geoboard* intervention programme. It also wanted to investigate the role that a *Geoboard* can play in the teaching and learning of area and perimeter of two-dimensional shapes. The research was a case-study within the interpretive paradigm.

A variety of data collection techniques was used. These included baseline assessment tasks, observations during the intervention programme, post intervention assessment tasks and semi-structured interviews with the participating teachers and a few learners from each participating school. The collected data was analysed using both the quantitative and qualitative methods.

My research findings reveal that a *Geoboard*, as a manipulative, developed confidence in the participating teachers. In the interviews with teachers, it transpired that teachers' skills in teaching area and perimeter of two-dimensional shapes had been sharpened. According to the interviews with learners, the use of a *Geoboard* led to better conceptual understanding of the area and perimeter, as learners no longer had to rely on formulae. Kilpatrick et al. (2001) refer to conceptual understanding as an integrated functional grasp of mathematical ideas. The post intervention assessment task showed a positive shift in learners' performance. The average learner performance improved from 29% in the baseline assessment task to 61% in the post intervention assessment task. This shows that the use of a *Geoboard* led to meaningful learning of area and perimeter of two-dimensional shapes.

The overall research findings reveal that the use of manipulatives has a positive impact in the teaching and learning of area and perimeter. Learners' responses to the interview questions showed that there was better understanding of the two concepts, which enabled them to construct their own knowledge. They further said the *Geoboard* allowed them to be hands-on, which contributed to their active involvement in the lesson.

ACKNOWLEDGEMENTS

A number of people contributed to the success of this project. Their support made it possible for me to complete the project. I therefore extend my sincere gratitude to them. They include the following:

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My supervisor, Professor Marc Schäfer, for his unwavering support and understanding especially during difficult times. Without his unfailing support and guidance, I would not have been able to complete my studies.

The three teachers who agreed to participate in this project- they really made me proud. They have proven to me that the country still has committed and dedicated teachers. They have revived my hope for quality teaching and learning. I thank them for the extra mile they ran to make this research a success. Had it not been for their willingness to partake in the study, my goals and dreams would not have been realised.

Percy Brooks, whose computer skills contributed significantly to the writing up of my thesis.

There were times I had to work on my thesis until late at night, neglecting my duties as a spouse and a mother. Even during such times, my family never gave up on me. They supported me and walked this journey with me. A word of sincere gratitude goes to my husband, Roland Mlindeli "Mzala" for his acceptance, love, support, trust and accompaniment during this difficult journey. My children, Babalo, Babalwa and Kuhle cannot be forgotten for their encouragement and understanding.

Above all, I thank God Almighty who, during challenging and difficult times, strengthened me and made it possible for me to carry on with my studies. When I could not see any light at the end of the tunnel, He became my light. When I was about to fall on my face, He lifted me up and told me "it's nearly over" and walked with me to the end of this journey.

DEDICATION

This thesis is dedicated to my family for their financial, emotional and psychological support as well as love they displayed throughout my study period.

DECLARATION OF ORIGINALITY

I, Fezeka Felicia Mkhwane (Student Number – 13M7836), declare that this thesis, entitled: "An investigation of teacher experiences of a *Geoboard* intervention programme in Area and Perimeter in selected grade 9 classes: A Case Study", is authentic. Where I have drawn on others' ideas and opinions, acknowledgements have been made using the reference practices according to the Rhodes University's Departmental Guidelines.

___________ December 2017

Fezeka Felicia Mkhwane (Signature) Date

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ACRONYMS AND ABBREVIATIONS

1. AMESA :Association of Mathematics Education of South Africa
2. CAPS : Curriculum and Assessment Policy Statement
3. DoE : Department of Education
4. RUMEP : Rhodes University Mathematics Education Project
5. NCTM : National Council of Teachers of Mathematics
6. FGLI : Focus Group Learner Interviews
7. TAL1 : Teacher A Lesson 1
8. TAL2 : Teacher A Lesson 2
9. TBL1 : Teacher B Lesson 1
10. TBL2 : Teacher B Lesson 2
11. TCL1 : Teacher C Lesson 1
12. TCL2 : Teacher C Lesson 2

CHAPTER 1

INTRODUCTION AND OVERVIEW

1.1 INTRODUCTION

In this chapter, I present the background of my research. This is where the use of manipulatives in the teaching and learning of area and perimeter of two-dimensional shapes is discussed. The research problem and the rationale of my study are also discussed. In addition to this, I discuss the context of my research study and its philosophical underpinnings. A brief overview of the research methodology as well as the design followed, are then discussed. Lastly, an overview of the research study is presented.

1.2 BACKGROUND OF THE RESEARCH STUDY

The area and perimeter of two-dimensional shapes form part of measurement, which is one of the Content Areas in mathematics. Learners' performance, particularly in measurement, needs serious attention (Department of Education [DoE], 2014). The kind of performance displayed by learners in this area raises concerns, not only about learning on the part of learners, but also about the effectiveness of the instruction they receive from their teachers. Goos, Brown and Makar (2008) also ponder the connection or quality of teaching that produces quality learning. This suggests that sometimes learners have no control over their learning, but that their teachers contribute to the type of learning that takes place. When learners are exposed to the type of teaching that requires them to master skills, the result is learning without meaning. Learners, for example, showed mastery of the formula for the area of a rectangle. When asked to find one dimension, when given area and the other dimension, learners simply multiplied the given values, which showed learning without meaning. When learners are taught the performance of skills, using certain procedures, they do not attach meaning to what they have learnt (Van de Walle, 2004). It is important that learners understand area and perimeter, because this is information needed in real life, when tiling or fencing or in the construction industry etc. It is a topic that is also connected to a number of topics in mathematics, like transformation, congruency, similarity, ratio and fractions.

I argue that the use of manipulatives, and in particular the *Geoboard*, would help address the challenge of poor learner performance in the concepts in question. Learners so often confuse area with perimeter, so the use of the *Geoboard*, not the formulae, can help learners differentiate between the two concepts and the misconceptions attached thereto. Van de Walle (2004) refers to a manipulative as any object on which the relationship between concepts can be explored. Manipulation of objects and shapes is an important facet of doing Geometry. The use of a manipulative like the *Geoboard*, facilitates learning and makes the abstract more real. According to Heddens (1997), the use of manipulatives can enhance and enrich teaching and learning. Heddens believes that it can help concretely conceptualise mathematical concepts.

The learner performance referred to above is also mirrored in the RUMEP's 2013 Annual Report, as reflected by the pre- and post-benchmark test analysis. RUMEP is an in-service programme that seeks to support and help mathematics teachers to improve the teaching and learning of mathematics at the primary and secondary level. I am a Collegial Cluster Programme Coordinator, which is one of RUMEP's programmes. It supports communities of teachers who collaboratively work on their own professional development to improve their practice. I am therefore well placed to implement the intervention programme.

1.3 THE RESEARCH AIMS AND QUESTIONS

Among other things, measurement involves conceptual understanding of area and perimeter. The use of a *Geoboard* as a manipulative to enhance the teaching and learning of the area and perimeter of two-dimensional shapes, forms part of the intervention programme that is at the core of this study. This research study aims at investigating the experiences of selected grade 9 teachers in a *Geoboard* intervention programme. The study also aims at exploring the role that a *Geoboard* can play in the teaching and learning of area and perimeter in grade 9. This study was conducted against poor grade 9 ANA results of 2014 and against the 2014 ANA report which recommended explicit use of manipulatives (ANA Report, 2014). The research questions that framed this study are:

RQ1- What are the experiences of selected grade 9 teachers in participating in a *Geoboard* intervention programme?

RQ2- What roles can the *Geoboard* play as a medium for instruction for teachers?

1.4 CONCEPTUAL FRAMEWORK

The intervention programme that frames my research project is an activity-based approach. This aligns well with a social constructivist paradigm to teaching and learning. The use of a *Geoboard* allows learners to share ideas as they interact with each other. Social Constructivism according to Golafshani (2003), is knowledge construction in and out of interaction between human beings and their world. The use of manipulatives in a constructivist paradigm activates real-world knowledge and enhances learning through activity and physical action. This forms the basis of my research, because teachers and learners use a *Geoboard* to manipulate geometric shapes, as they explore area and perimeter of two-dimensional shapes.

1.5 RESEARCH PROCESS

This study is oriented in an interpretive paradigm. A qualitative approach is used to make knowledge claims based on multiple meanings of individual experiences that the participants (teachers) constructed and shared with me. This research is a case study of three grade 9 teachers at three different RUMEP Collegial Cluster schools. One school is in the Dutywa district, while the other two are in the Sterkspruit district in the Eastern Cape Province of South Africa. Yin (2009) defines a case study research method as an empirical enquiry of a single unit. I have decided on a case study, because it allows me to study a particular aspect of a problem in depth, which is the area and perimeter of geometric shapes. In this study, the grade 9 teachers use a *Geoboard* for the teaching and learning of area and perimeter of geometric shapes. The unit of analysis in this case study is the teachers' use of the *Geoboard* in their lessons and their experiences of the *Geoboard* intervention programme.

The research study is designed around five phases namely:

Phase 1: Administration of the baseline assessment task for grade 9 learners of the participants' schools.

Phase 2: A three-hour workshop on how to use a *Geoboard* to teach area and perimeter of two-dimensional shapes was conducted for the participants. A learning intervention programme which was informed by the results and misconceptions of the baseline assessment task was designed.

Phase 3: Implementation of the intervention programme and observations. A number of lessons were observed, but only two lessons per teacher were video-recorded. The aim was to capture how teachers used the *Geoboard* as a teaching medium.

Phase 4: Learners wrote a post-intervention assessment task, which was on the same lines as the baseline assessment task. The aim was to check if there was a shift in learners' understanding of area and perimeter. Some of the learners at one of the participating schools, who did not take part in the study, also wrote the post-intervention assessment task. The aim was to assess the impact of the use of the *Geoboard* on learning the concepts in question.

Phase 5: Semi-structured interviews were conducted with the participants to investigate their experiences of using the *Geoboard* to teach area and perimeter. Such interviews were also conducted with six learners from the three schools, that is, two learners from each school.

1.6 DATA ANALYSIS

The researcher drew bar graphs to quantitatively analyse the results of the two assessment tasks (baseline and post-intervention). The results were also qualitatively analysed by comparing the baseline assessment task to the post-intervention task.

The observations from the lessons were analysed by looking for evidence of how teachers used the *Geoboard* with the types and nature of activities they designed as well as their engagement with the learners during the lessons.

The transcripts of the interviews with the teachers were analysed by looking for themes about the teachers' experiences of engaging with the *Geoboard* during the intervention. In the interview transcripts for learners, the researcher looked for themes about their experiences of using the *Geoboard* to learn area and perimeter.

1.7 ETHICAL ISSUES

According to Stake (2000) and Quah and Sales (2000), it is important for researchers to adhere to good ethical practices. Based on this, the following ethical practices were adhered to:

(i) Letters were written to the Eastern Cape Department of Education and to the principals of the three schools, seeking permission to conduct the research.

(ii) Participants were informed about the purpose of the study and were told that their participation was voluntary and that they were free to withdraw from the study whenever they wanted to.

(iii) For purposes of confidentiality and anonymity, the participants' identities were concealed by using coding.

(iv) Participants were assured that the data collected would be made available only to the supervisor.

(v) Participants were made aware of how the study would benefit them.

(vi) Lastly, a good rapport with the participants was built, which was as a result of respect, trust, empathy and commitment to the participants' well-being.

1.8 SIGNIFICANCE OF MY RESEARCH STUDY

The use of manipulatives plays a significant role in the teaching and learning of mathematical concepts in general. Although the study was conducted at three Collegial Cluster schools, this could benefit other schools that are also part of the Collegial Clusters. The misconceptions identified during the study would also help inform my intervention with other clusters. The participants indicated even before the end of the study that they wanted to share the knowledge they had acquired with their colleagues within the district, even though they were not cluster members. This could increase the number of teachers who would like to improve their practice by joining Collegial Clusters and more teachers could register for the RUMEP BEd. programme.

1.9 LIMITATIONS

The sample that I had of three teachers was small and would therefore make it difficult to generalise the results beyond the confines of this study. The focus of this study was on only one mathematical aspect, that is, measurement, with special reference to area and perimeter. The research was limited to only RUMEP Collegial Cluster schools. Due to financial constraints and the distances between the researcher's workplace and the participants' schools, the number of lessons observed had to be limited.

1.10 THESIS OVERVIEW

This study is organised as follows:

1.10.1 Chapter one

In Chapter one, I present the background of the study which includes (i) the research problem and rationale, (ii) research process and design of the study, (iii) data analysis, (iv) ethical issues, (v) significance of the research study, (vi) some limitations of the study and (vii) the overview of the study.

1.10.2 Chapter two

In Chapter two, literature relevant to my study is explored.

1.10.3 Chapter three

Chapter three discusses the research design, which entails the methods used to collect data, selection of participants, sampling techniques applied, and description of data gathering instruments.

1.10.4 Chapter four

Chapter four presents the analysis and interpretation of the findings of the study. The chapter specifically examines teachers' experiences of using the *Geoboard* to teach area and perimeter as well as the role that the *Geoboard* plays in the teaching and learning of area and perimeter of two-dimensional shapes.

1.10.5 Chapter five

Chapter 5 presents a summary of the main findings of this research study. It also discusses limitations of the study and offers recommendations and ideas for further research study.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter reviews literature relevant to my study, which focuses on the role of concrete manipulatives in the teaching and learning of measurement. My particular focus is on the area and perimeter of two-dimensional shapes in grade 9. Various types of virtual and concrete manipulatives are reviewed. This chapter also reviews what the various researchers write about the area and perimeter of geometric shapes. The significance of teaching and learning of mathematics when manipulatives are used, is also explored. The importance of geometry in the study of mathematics and what it does to help learners learn mathematics with understanding is also discussed. Since the intervention in this project is through professional development, what this entails and a discussion of its benefits in the study of mathematics, is also reviewed. A brief overview of RUMEP, the organisation I work for, and where this project is located, is discussed. Lastly, the chapter looks at the South African context with regard to the use of manipulatives. I also analyse what the curriculum says about the use of manipulatives for effective teaching and learning of mathematics.

I argue that the use of manipulatives is crucial at the elementary and foundational stages of mathematics learning. This is supported by Seefeldt and Wasik (2006) who state that the foundation for children's mathematical development is established in the early years of schooling where manipulatives are used most. This is the stage when learners connect what they learn to real-life objects that they are familiar with. They further argue that children need hands-on experiences that are mathematics-related, in order to have opportunities to learn mathematics.

2.2 BACKGROUND

The Department of Basic Education (DBE), with effect from 2011, embarked on an assessment programme, which *inter alia* seeks to identify the problem areas within the curriculum and inform ongoing curriculum revision and design (South Africa, DoE, 2013). In order to determine these challenging areas and gauge the extent to which the basic education system is impacting on the critical areas of numeracy and literacy, an Annual National

Assessment (ANA) was introduced. The ANAs were introduced on the heel of poor performance of the South African Grade 8 and 9 learners in the Trends in International Mathematics and Science Study (South Africa, DoE, 2011). It was hoped that the results of the ANA would provide the DBE with valuable and meaningful insight into key learning areas that needed improving (South Africa, DoE, 2013). The DBE used the ANA results to measure annual progress in learner achievement in relation to the national 2014 goal of ensuring that 60% of learners in South Africa achieved acceptable levels in Literacy and Numeracy (South Africa, DoE, 2011). The ANA was premised on the principle that effective testing would give learners an opportunity to show relevant skills and understanding and also assist in diagnosing learner shortcomings. (South Africa, DoE, 2014).

The 2014 ANA Report revealed that the average learner performance in Mathematics in the senior phase (grades 7 – 9) was 14%. The report also revealed that learners in grade 9 were generally unable to identify geometric shapes. They also struggled to identify the properties of 3-D objects. This is despite the curriculum directive which specifically states that learners should develop clear and precise descriptions and classification categories of geometric figures and solids (South Africa, DoE, 2011, p.15).

Learners' poor performance in geometry is also reflected in the report by the Human Sciences Research Council of the Trends in International Mathematics and Science Study (TIMSS), which was conducted in 2011 with Grade 9 learners. The South African learners' performance stood at 20% in geometry as against 30% in numbers and algebra. The report further showed that from the cognitive levels that were assessed, which entailed knowing, applying and reasoning, the latter was at 25%. Since logical reasoning is needed for the understanding of geometry, learners' poor performance in geometry could be attributed, amongst other factors, to a lack of reasoning skills. It is from this background that my study focuses on geometry, with special reference to measurement.

2.3 THE ROLE AND NATURE OF MANIPULATIVES

Bouck and Flanagan (2010) define manipulatives as instructional tools that are used to learn abstract mathematical concepts, mathematical properties or processes. Manipulatives can be used as teaching tools to engage students in the hands-on learning of mathematics (Smith, 2009). Manipulatives can be used to connect the concrete informal world to the formal world of abstract mathematics, in order to make the learning of mathematics more meaningful and understandable. The use of manipulatives helps learners develop conceptual understanding of mathematics ideas by representing the ideas in multiple ways. When manipulatives are used, the senses such as sight and touch are brought into the classroom. Learners can touch and move objects to make visual representations of mathematical concepts. Besides affording learners an opportunity to learn best, manipulatives afford teachers new ways of visiting a topic. Incorporating different teaching strategies and manipulatives can enrich and deepen learners' understanding; however, reliance should not solely be on manipulatives as a means of instruction.

For any manipulative to be good, it should be used for what it is intended and must fit the child's developmental level (Smith, 2009) as well as his/her mathematical ability. Children at pre-school for example, do not use the same kind of manipulative as children at primary or secondary school. Smith (2009) further states that in order to achieve the goal of using a manipulative, the complexity of the manipulatives children are provided with, should increase as children's thinking and understanding of mathematical concepts increase. Seefeldt and Wasik (2006) are also of the opinion that manipulatives for mathematics should be appropriate to the learners and that they must be chosen to meet a specific objective of the concept being taught.

Manipulatives have no meaning on their own; this implies that learners need teachers to help them make connections between the manipulatives and the abstract symbols they represent (Kilpatrick, Swafford, and Findell, 2001). This is true for both physical and virtual manipulatives. Using manipulatives can facilitate the construction of sound representations of geometric concepts, but they must be used wisely (Clements and Battistia, 1992). According to Clements (1999), manipulatives should be used in a considered manner, otherwise learners will merely learn rote manipulations.

Manipulatives, as tools for teaching come in two forms; namely, virtual and concrete/physical and the differences and similarities between the two are outlined below.

2.3.1 Virtual Manipulatives

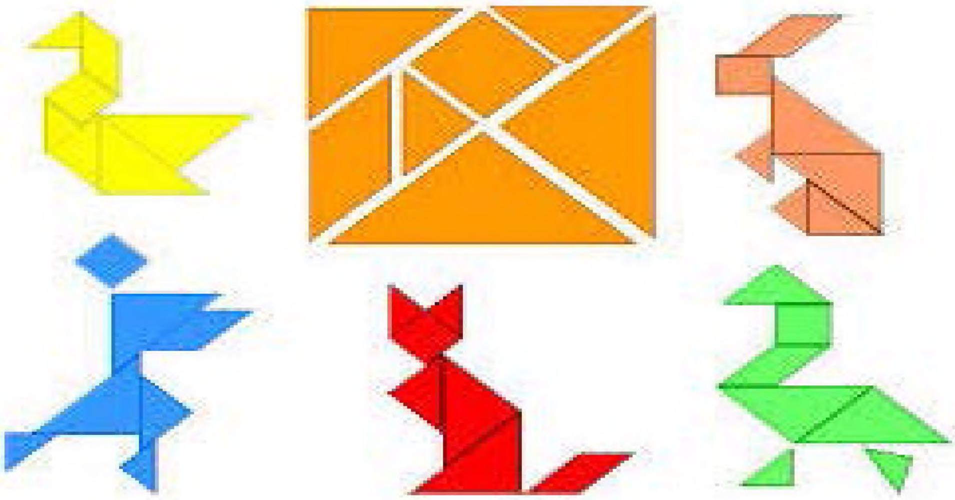

Figure 2.1 Tangrams and Tangram images (Source: Bohning and Althouse, 1997)

Virtual manipulatives emerged as a result of innovations in technology and the prevalence of the Internet as well as the increasing availability of computers at homes and in classrooms. Virtual manipulatives, as reflected in Figure 2.1, are computer-generated images that appear on a monitor and are intended to represent concrete objects. Petit (2013) refers to virtual manipulatives as visual representations of concrete manipulatives. According to Moyer, Bolyard and Spikell (2002), virtual manipulatives are digital representations on the World Wide Web and other digital devices. Virtual manipulatives can be pictorial images only or a combination of pictorial and numeric images, simulations and concept tutorials, which in turn may be pictorial or numeric with instructions and feedback (Moyer-Packenham, Salkind and Bolyard, 2008). Some virtual manipulatives are modelled on concrete manipulatives which include among others base-ten blocks, tangrams, fraction strips, *Geoboards*, geometric solids and coins, as shown in Figure 2.2 below.

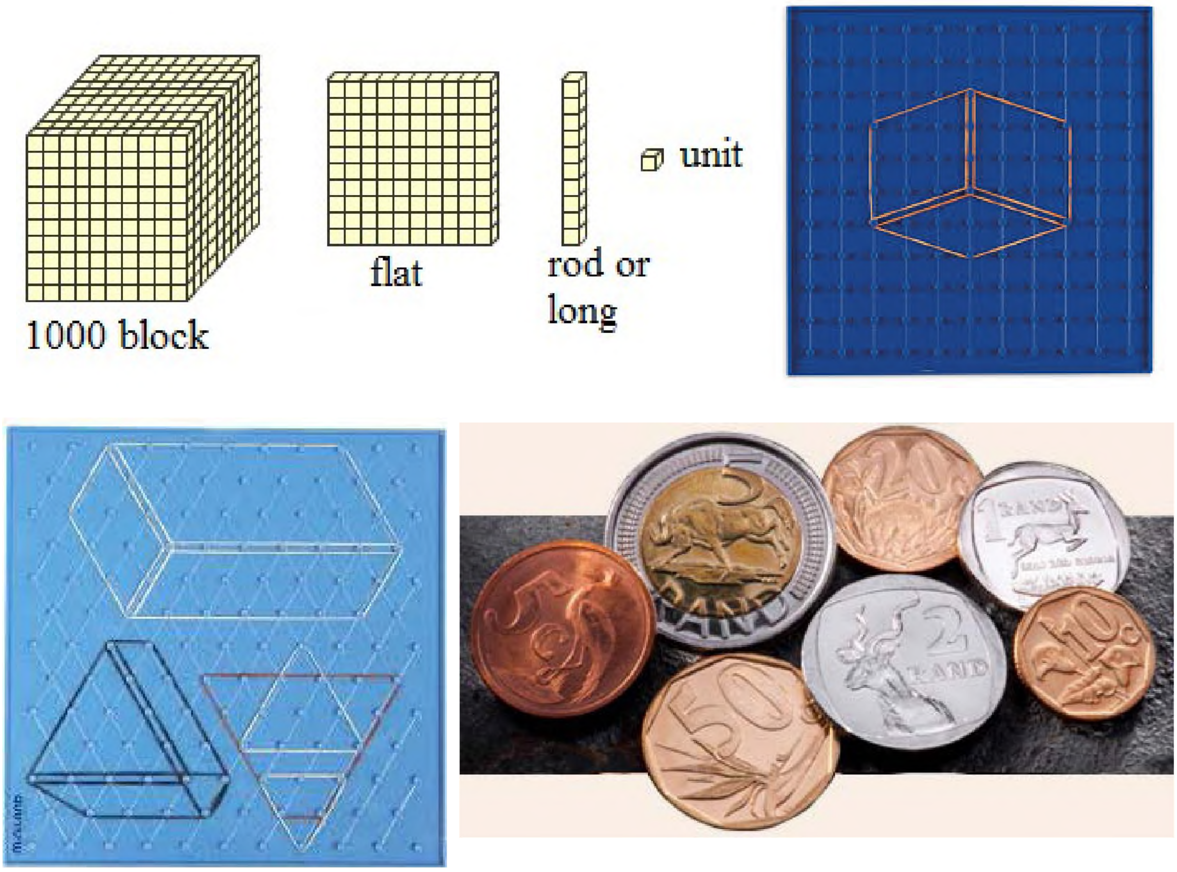

Figure 2.2 Base-ten blocks, Geoboards and Coins (Source: Fuson and Briars, 1990)

According to Spicer (2000), some virtual manipulatives can be static or dynamic visual representations of concrete manipulatives. Static visual representations are pictures and are associated with pictures in books, sketches on a chalkboard or drawings on an overhead projector. They cannot be manipulated or transformed through flipping, sliding or rotation as is the case with concrete manipulatives. Moyer et al. (2002) refer to them as not true virtual manipulatives. In contrast, dynamic visual representations of concrete manipulatives are visual objects on the computer and can be manipulated in the same way as concrete manipulatives. Learners can slide, flip and rotate them just as they do with concrete materials. This is done using a computer mouse (Moyer et al., 2002). The ability to manipulate the visual representations or objects on the computer provides the user with an opportunity to make meaning and see connections as a result of his/her own actions.

Virtual manipulatives can be great assets to teaching and learning in the classroom, in supporting learners' understanding of mathematical concepts, because they rely on discovery- and inquiry-based types of learning. Virtual manipulatives such as virtual *Geoboard*s, pattern blocks and tangrams encourage investigation and skills strengthening. Such manipulatives can link iconic and symbolic notations to other resources on the World Wide Web. According to Dorward and Heal (1999) virtual manipulatives also foster as much engagement as physical manipulatives do, and they allow free access to schools that are online. They are constantly available for busy teachers and learners who have limited or no time to get to these sites during lessons; with a web connection, these sites are available anywhere, anytime and to anyone. Learners are allowed, for example, to add lines or points to figures, a feature that would be useful for marking or counting the sides of a polygon to determine its shape or perimeter. Virtual manipulatives therefore allow for alterations. Through the use of virtual manipulatives, learners at all levels of ability are offered an opportunity "to develop their relational thinking and to generalise mathematical ideas" (Moyer-Packenham et al., 2008, p.204).

For virtual manipulatives to be effective, teachers should know how to design effective mathematics lessons where learners will be required to use technology. Reimer and Moyer (2005) suggest that teachers themselves should be comfortable with technology. They should be prepared for situations where the Internet connection is 'down', i.e. temporarily unavailable. Sometimes virtual manipulatives take time to download, which may be frustrating; it is during such times that teachers should display good organisational skills.

Moyer-Packenham et al. (2008), in their research on the use of virtual manipulatives to achieve good mathematical results, found that learners using virtual manipulatives alone, or in combination with physical manipulatives, demonstrate gains in mathematics achievement and understanding. Some learners learn better with a single strategy, while others learn best when multiple teaching strategies are used.

2.3.2 Concrete/physical manipulatives

Concrete mathematics manipulatives include among others, pattern blocks, as in Figure 2.3, fraction pieces, three-dimensional models, and *Geoboards*. Manipulatives can be purchased, or they can be hand-made by learners with the teachers' guidance, but they are generally low in cost. These concrete mathematical objects can be used to introduce various mathematical concepts or remediate certain mathematical misconceptions.

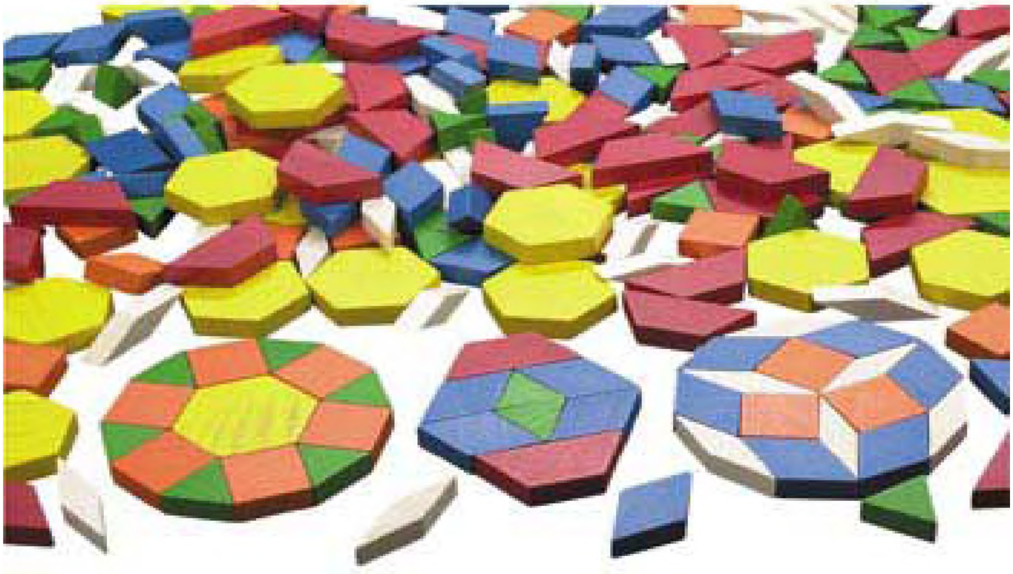

Figure 2.3 Pattern Blocks Source: Jones, Jones and Jones, 2002

Concrete manipulatives afford learners an opportunity to model a situation as a way of showing understanding of what they are taught. According to Jones, Jones and Jones (2002), the aim of using manipulatives is to enhance learners' conceptual understanding of mathematics, as opposed to increasing their efficiency in calculations. Kilpatrick et al. (2001) refer to conceptual understanding as an integrated functional grasp of mathematical ideas. Conceptual understanding helps learners make connections within and across mathematics. In other words, conceptual understanding helps them integrate topics and not treat them in isolation. Clements (1999) also states that concrete manipulatives help learners build, strengthen and connect various representations of mathematical ideas. This, according to Jones (2000), is the direct opposite of the absorption theory, which perceives learners as passive subjects that simply store information as a result of drill, practice, memorisation and reinforcement. Traditionally children were not encouraged to think out of the box for them to become better problem solvers. With the use of concrete manipulatives, learners are encouraged to think critically and abstractly to show understanding. According to Bouck and Flanagan (2010), children should not just be told about mathematics, but should be actively involved in the teaching and learning of mathematics. Fraction strips in Figure 2.4 below are an example of concrete manipulatives, as an aid to understanding the concept of fractions.

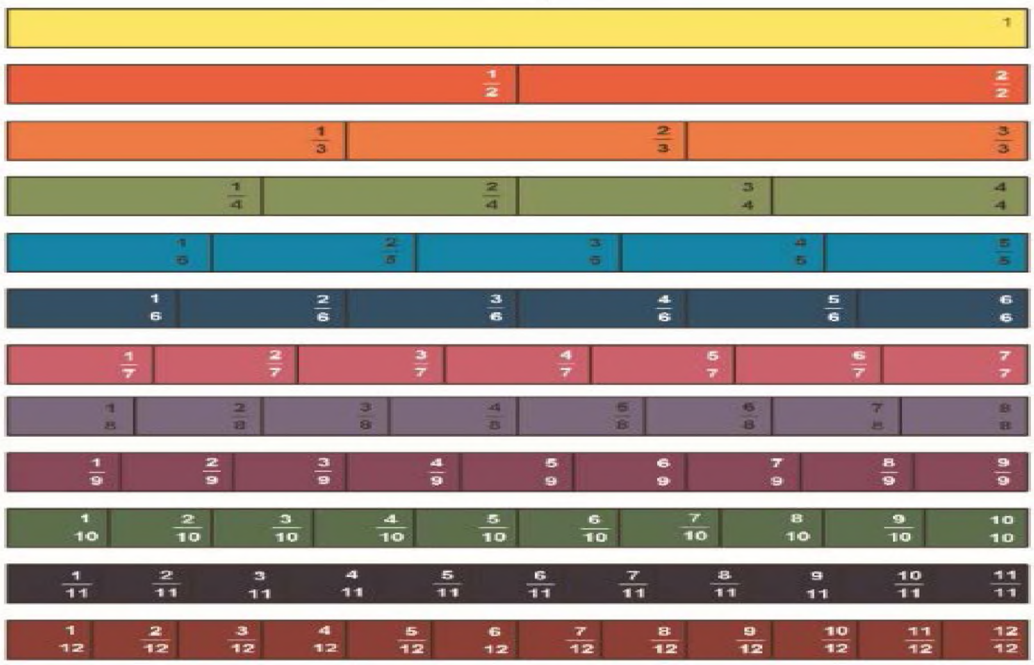

Figure 2.4 Fraction strips (Source: Bohning and Althouse, 1997)

Learners are able to see that one-quarter, for example, is obtained when a whole is divided into four equal parts. They can also compare one-quarter to other fractions. Through such objects, children might acquire an informal understanding of fractions. This is an initial insight which can form the base for learning more about fractions and their written representations (symbols). According to Kennedy and Tipps (1994), concrete manipulatives make the concepts in mathematics, which are perceived as difficult, easier for learners to understand. Mathematics educators all over the world have found mathematics to be better learnt by learners who experience it through concrete manipulatives (McNeil and Jarvin 2007). Clements and Bright (2003) also support the idea that manipulatives are a means of improving performance of all levels of learners ranging from the developmentally-delayed to the gifted. Loong (2014) refers to the use of manipulatives as a cure for learners' anxiety about mathematics, which in turn leads to better understanding of mathematics concepts.

Virtual and concrete manipulatives help learners connect the new concepts to previously acquired knowledge. In terms of measurement, which is the focus of this study, with the appropriate use of manipulatives, teaching can change from focussing on how to measure to focussing on what it means to measure (Clements and Bright, 2003). For purposes of this research project, a *Geoboard* is a manipulative that is used to explore perimeter and area of 2-dimensional geometric figures with selected learners in a Grade 9 class. A *Geoboard* is a mathematical manipulative used to explore basic concepts in plane geometry such as perimeter, area and the properties of shapes and numeracy concepts. It consists of a wooden board with a square–lattice/array of nails half driven in, around which one can span rubber bands. Learners stretch rubber bands around the nails to form line segments and polygons to explore shapes and properties such as perimeter and area. A *Geoboard* is cheap and easy, and does not require complex technology or complicated skills, to construct. Figure 2.5 below shows an example of what a *Geoboard* looks like:

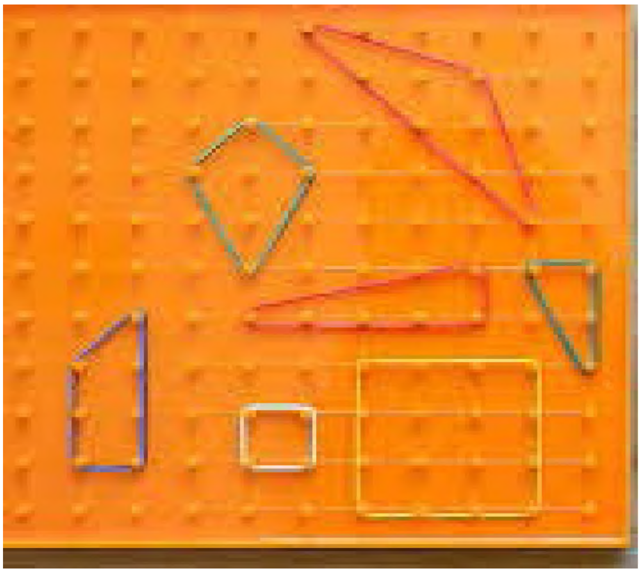

Figure 2.5 Geoboard (Source: Bohning and Althouse,

According to Murty and Thain (2007), the Pick's theorem states that, if a polygon has vertices with lattice points, then its area is ½ p + (i -1), where "i" is the number of lattice points (nails) inside the polygon and "p" is the number of lattice points on the perimeter of the polygon.

The areas of the shapes in Figure 2.5 are:

Example 1: The surface of the trapezium is covered by 2½ squares, so its area is 2.5 square units.

Using Pick's theorem, the area of the trapezium is:

½ of outer dots + (inner dots -1)

$= \frac{1}{2} \times 7 + (0 - 1)$

$= 3.5 - 1$

$= 2.5$

Example 2: When counting the squares, the kite has an area of 3 square units. According to Pick's theorem the area of the kite is: ½ of outer dots + (inner dots -1)

$$= \tfrac{1}{2} \times 4 + (2 - 1)$$

$$= 2 + 1$$

$$= 3$$

Example 3**:** The perimeter of the small original square is 4 units. The square is then enlarged by a scale factor of 3 to give an image which is a 3 × 3 square as shown on the *Geoboard.* Its perimeter is 12 units, which is 3 times as much as the perimeter of the original square.

Using Pick's theorem, the area of the original square is: ½ × 4 outer dots + 0 inner dots -1

$$= 2 - 1$$

$$= 1$$

thus, the area is 1 square unit

The area of the image is: ½ × 12 outer dots + 4 inner dots -1

$$= 6 + 3$$

$$= 9$$

thus, the area is 9 square units

The area of the image is 9 times the area of the original square and not 3 times bigger. The ratio of the area of the original shape to that of the image is 1: 9. This shows that when a shape is enlarged, the area of the original shape is not simply multiplied by the scale factor.

2.3.3 Benefits and weaknesses of concrete and virtual manipulatives

Although manipulatives are good to use for meaningful understanding, they also have weaknesses. Table 2.1 shows the benefits and weaknesses of both concrete and virtual manipulatives.

Table 2.1 Benefits and weaknesses of concrete and virtual manipulatives

Concrete manipulatives	**Virtual manipulatives**
They are concrete teaching tools that are used to engage learners in hands-on learning of mathematics.	They are cognitive technological tools that are visual representations of physical manipulatives. They rely on computer software programmes and/or Internet accessibility.
They need storage space and have to be carried around from one class to the other.	They are built-in in the computer. One does not have the burden of having to carry them around.
Concrete manipulatives do not need electricity to be used.	In order to function, virtual manipulatives depend on technology, which relies heavily on the availability of electricity.
The size and shape of concrete objects cannot be interfered with. The objects stay the same in terms of shape, colour and size, as had been made or bought.	They allow the user an opportunity to rotate, slide or flip them and even enlarge or reduce their size.
They are cost effective, because they are cheap to make.	They are costly and not every school or learner can afford them.
They are easy to manipulate and to work with, as long as learners have been shown how to use them.	The user needs to be computer literate to be able to use a virtual manipulative successfully.
They bring more meaning to learners about the mathematics concepts they learn. Through them learners are able to make connections between mathematics and the real world.	They are also a means of helping learners make links between the mathematics they learn and the real world to make it more meaningful.
Learners can work with them even in the absence of a teacher to get more practice.	Learners can work with them even at home and through practice their confidence can be enhanced.
They encourage learners to discover things themselves, for example the formula for finding the area of a rectangle.	Virtual manipulatives also develop learners' investigative skills, for example, the relationship between sides of the bases of prisms and their edges.

2.4 LEARNING AND TEACHING WITH MANIPULATIVES

The use of concrete objects brings the real-world into the classroom, they thus help bridge the gap between mathematical ideas and real-world situations. Manipulatives help learners learn with meaning and make connections of what they learn to what they already know. Learners can easily recall knowledge to which they had made connections. According to Cain-Caston (1996), manipulatives improve learners' long-term retention of mathematics concepts. Lasting learning does not take place where learners are not actively involved in constructing their own knowledge (Andrews, 2004). The use of manipulatives can make the teaching and learning environment to be learner-centred. According to Jones (2000), teachers at secondary level get frustrated with learners who rely on algorithms and struggle with basic concepts. He believes that the use of manipulatives would be helpful in making learners learn with meaning. Research shows that when learners manipulate objects, they are taking the first steps towards understanding mathematics processes and procedures.

Manipulatives can also help learners gain confidence in their mathematics skills and knowledge, which they share with peers through cooperative learning. Learning is seen as a social process in which learners learn from those around them (Jones, 2000). Learners' understanding of mathematics is enhanced. Constructivists believe that through experiencing things, learners are able to construct their own understanding and knowledge of the world. The use of manipulatives gives rise to meaningful and valuable learning (Andrews, 2004). Learners therefore become autonomous and self-motivated in their own learning.

According to Seefeldt and Wasik (2006), manipulatives should foster children's concepts of numbers and operations, patterns, geometry, measurement and data analysis, problem-solving, reasoning, connections and representations. Solid geometric models, for example, can be used to learn about spatial reasoning, that is, investigation of their vertices, faces and edges. Some manipulatives are used to draw parents' attention to what the school does, which in turn gets parents involved in their children's learning of mathematics (Bjorklund, 2014).

The use of manipulatives should not end in the classroom in the presence of a teacher; children should use manipulatives even during their spare time. Toys, which learners enjoy playing with, can also be used as manipulatives for the teaching and learning of mathematics. The strategic use of toys as manipulatives for teaching can play a significant role in the early learning of mathematics. This will help learners see manipulatives no longer just as toys, but as learning materials. According to Smith (2009), after learners have explored the toys, they cease to be toys and they take over their rightful place in the curriculum as teaching and learning aids.

Learners should be given an opportunity to work with manipulatives without any pre-set goals. McNeil and Jarvin (2007) support the notion that teachers should allow learners to work with manipulatives with open-ended objectives. Such opportunities help learners explore their own questions and they may come up with a variety of strategies or answers. They further state that the opportunities learners have from using manipulatives help them think about their world differently. Learners also get to understand that there are various strategies that one can use to solve a problem. Generating multiple strategies for solving a problem is, according to constructivists, an essential strategy in mathematics (Ernest, 1998).

Teachers, however, should still guard against making manipulatives into learners' crutches. According to Loong (2014), educators should not overly rely on manipulatives at the expense of helping learners master basic skills. Manipulatives should be used to develop basic understanding of mathematical concepts and as aids to develop learners' abstract thinking. Learners must eventually transit from concrete or visual representations to internalised abstract representations.

2.5 MEASUREMENT

French (2004) refers to measurement as one of the most critical areas in mathematics. He further states that measurement connects important concepts of early mathematics, geometry and numbers with one another. Before learning to measure length and angles, for example, learners need to recognise shapes and be familiar with their properties.

The mathematics curriculum is divided into five content areas, one of which is Measurement, an area within the domain of Geometry. Measurement plays a crucial role in developing learners' critical and logical abstract thinking. Learners, through Measurement, are given an opportunity to work with hands-on activities and this enhances their memory. It is through such activities that co-operative learning takes place, where children learn to solve problems together. This may impact positively on learners' future successes in mathematics learning. Maccini and Gagnon (2000) say that learners' problem-solving skills should be developed as early as possible in the child's learning of mathematics. They also say that as children grow older, their lack of problem-solving and organisational skills can serve as a significant impediment to their future success in mathematics.

2.5.1 Area and perimeter

Area and perimeter are topics within measurement, which according to the South African mathematics curriculum coverage, is the fourth content area that needs to be taught in all grades in the General Education and Training Band (GET). The GET band includes learners from grade R to grade 9. Like all other mathematics topics, the understanding of area and perimeter requires abstract and logical thinking. According to Moyer (2001) perimeter is the distance around a closed figure, while area is the amount of surface of a geometric figure. Area is measured in square units.

Learners can be helped to make sense of mathematical problem situations if they are provided with contextualised problems that are rich in various representations of mathematical concepts. Using manipulatives can help bring clarity to the two concepts. The use of different representations of mathematical concepts gives learners many opportunities to develop intuitive, computational and conceptual knowledge. The classroom visits I have conducted have shown that learners have difficulty explaining or illustrating ideas of area and perimeter, because their understanding of these concepts rests only on procedures.

Reinke (1997) argues that learners tend to confuse area and perimeter. I concur with him, because when learners are asked about the area of a shape, they quickly say it is length multiplied by the breath. If learners' understanding of area and perimeter rests only on formulae, the meaning of the two concepts may be lost. When meaning is attached to each of these concepts, confusion can be eliminated because the measures are different. Learners think that if two shapes have the same area, then their perimeters are also the same. Learners should be made to understand that shapes may have the same areas yet different perimeters, as illustrated in Figure 2.6.

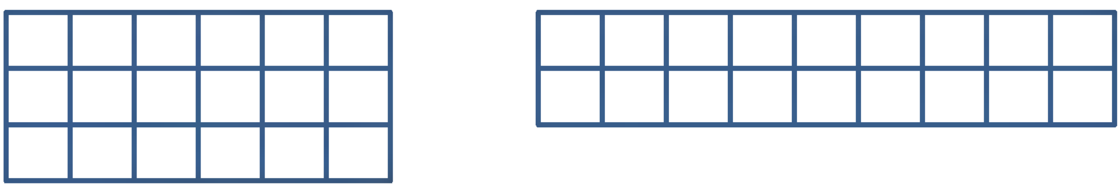

Figure 2.6 Rectangles with the same area but different perimeters

The shapes in Figure 2.6 have the same area of 18 square units, but different perimeters. The first figure is a 6 × 3 rectangle, so its perimeter is 18 units. The second shape is a 9 × 2 rectangle, which makes its perimeter 22 units.

Shapes may have the same perimeters but different areas, as illustrated in Figure 2.7 below.

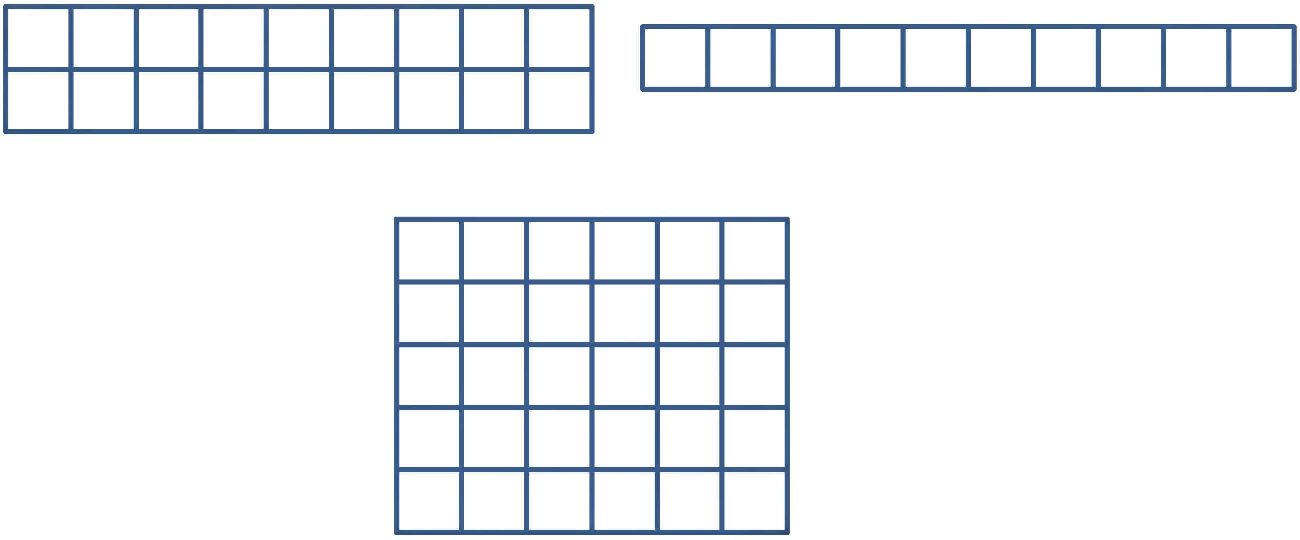

Figure 2.7 Rectangles with the same perimeter but different areas

In Figure 2.7, the shape on the top left has an area of 18 square units and a perimeter of 22 units. The top right shape has an area of 10 units and the same perimeter of 22 units. The bottom shape has its perimeter as 22 units, but its area is 30 square units.

The use of the *Geoboard* can enhance learners' understanding of area and perimeter. It can clear up the confusion learners have about the two concepts. It can also help learners become knowledgeable and confident about area and perimeter. Feldman (2002) calls for a mathematics reform that motivates learners to acquire problem-solving skills and self-confidence in mathematics. He further states that it should be a kind of reform that encourages learners to construct their own knowledge by solving complex real-life problems. In order to achieve this, the teacher's role in a classroom should change; they should encourage learners to participate in the lesson. According to Matthews (1998), teachers should act as co-learners to create mathematical communities that promote learner-talk regarding mathematical reasoning.

Teachers often use regular and semi-regular quadrilaterals to present formulae for determining the area and perimeter of figures. Examples of such shapes are a square and a rectangle respectively. It then becomes difficult for learners to find areas of irregular shapes and shapes with more than four sides. This is due to the lack of understanding of the two concepts. Moyer (2001) states that learners are often unable to distinguish between area and perimeter formulae because they do not clearly understand what attribute each formula measures. Reinke (1997) states that teachers themselves rely on formulae to explain area and perimeter and I have experienced that with some of the teachers I interact with. According to Moyer (2001), learners display their lack of understanding by simply memorising formulae and plugging in numbers they are given. When asked, for example, to find the length of a rectangular shape with an area of $60m^2$ and a breadth of 6m, learners simply find the product of $60m^2$ and 6m. Learners do not know when to use square units or units, when calculating area and perimeter. A good understanding of these concepts could lead teachers to use more flexible approaches in the classroom.

2.6 GEOMETRY

Geometry is a branch of mathematics that includes the visual study of shapes, their sizes, patterns and positions. The study of geometric relationships is used in fields ranging from architecture to landscaping, according to Schwartz-Shea and Yanow (2012), who state further that an ability to specify locations and describe spatial relationships is required in everything from navigation to shipping, transportation and construction. Symmetry and transformation are useful in a range of projects from packaging to artistic expressions.

According to NCTM (2011), geometry helps develop a number of skills in learners, which include reasoning, visualisation and sense-making skills. It is the most elementary science that enables people, through intellectual processes, to make predictions about the physical world. Geometry "helps learners represent and make sense of their real world" (NCTM, 1989, p.112). The Council further states that geometry is important because it develops learners' deductive reasoning skills and their acquisition of spatial awareness. Geometry is a very practical and visual mathematical domain that allows learners to engage in hands-on activities, according to Groth (2005), who states further that geometry allows learners an opportunity to connect geometric ideas with algebra through modelling and problem-solving.

Geometry is a central component of the school mathematics curriculum (South Africa, DoE, (2003) and French (2004)). Clements and Battistia (1992) regard geometry as a basic skill in mathematics that helps learners function successfully as informed consumers, concerned citizens and competent members of the workforce. Understanding geometry is therefore a very important mathematical skill that learners need to acquire, because the world we live in is inherently geometric (Clements and Sarama, 2014).

The geometry that this study focuses on is plane geometry, which is the geometry of two dimensions, commonly referred to as Euclidean geometry. Borowoski & Borwein (2005) refer to plane geometry as geometry that investigates the properties and the relationships between plane figures. Plane figures are two-dimensional shapes described by straight lines or curves. This study deals with the area and perimeter of rectilinear shapes. Rectilinear shapes are those bounded by straight lines and are either concave or convex, as shown in Figure 2.8. Convex shapes have all their angles less than 180^0, while concave shapes have at least one of their angles greater than 180^0.

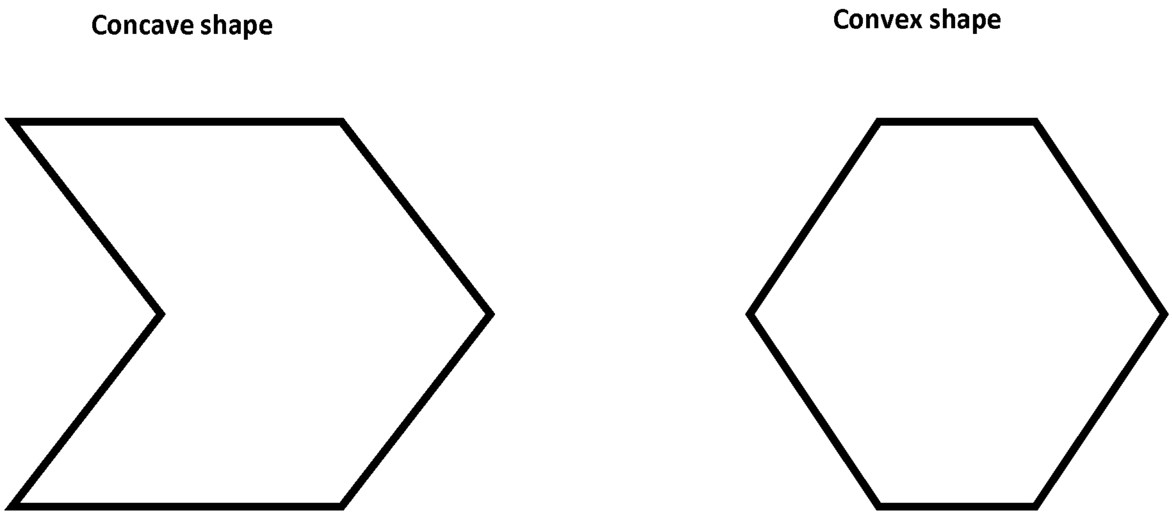

Figure 2.8 Concave and convex shapes

Most teachers find geometry difficult; they get frustrated when they have to teach this area of mathematics, because they never learned it with understanding. They simply memorised the formulae, procedures and the theorems. Porter (2000) attests to this when he says that teachers spend virtually no time teaching geometry. Some people have less or no fond memories of learning geometry, they only remember the proofs they had to learn at high school, according to Hersh and John-Steiner (2011) who go on to say that for most people this was an unpleasant experience, because they had to memorize every trivial statement in a particular sequence. Not only was it unpleasant for them, but they also saw little purpose in learning it. According to Nickerson (2010), only those learners with good memories remember learning shapes and their properties, but they still did not understand why it was important for them to learn geometry. There was no conceptual understanding of what they learnt, hence only memorization.

Studying geometry provides many foundational skills and helps build logical thinking, deductive reasoning, analytical reasoning and problem-solving skills. Manipulation of objects and shapes is an important facet of doing geometry. Using manipulatives such as the *Geoboard* facilitates learning and makes the abstract more real.

2.7 PROFESSIONAL DEVELOPMENT

The Rhodes University Mathematics Education Project (RUMEP) is a teachers' professional development in-service programme for mathematics teachers, which supports and helps teachers improve their practice. As one of RUMEP's programmes, the Collegial Cluster programme supports teachers who work on their own professional development, even though they run their activities independently (RUMEP's Annual Report, 2013). Teachers get content-based workshops and lesson demonstrations, using various strategies and skills to teach mathematics in a meaningful way. The programme works in collaboration with the Eastern Cape Department of Education to help improve teachers' pedagogical content knowledge.

RUMEP administers benchmark tests from which learners' problem areas on mathematics content and misconceptions are identified, hence the research on area and perimeter. Benchmark tests therefore influence RUMEP's intervention. This research aims at helping learners learn area and perimeter with understanding, through the use of a *Geoboard* as a manipulative. It is hoped that teachers' classroom practices in teaching the two concepts, that is, area and perimeter of two-dimensional shapes, will be transformed. Professional development encourages teachers to reflect on their practice, which can help teachers know in which areas to improve, for effective teaching and learning to take place. If teachers are able to reflect on their teaching and use their interpretations to shape their instruction, then instruction becomes more focussed, clear and effective (Kilpatrick et al., 2001).

According to Yoon, Duncan, Lee, Scarloss and Shapley (2007), professional development affects student achievement in a number of ways. It enhances teacher knowledge, skills and motivation. This is supported by Bishop, Clements, Keitel, Kilpatrick and Leung (2003), who state that professional development and pre-service teacher training are the key, formal venues for the growth of teacher knowledge. According to Ball (2010) and Fullan (1993), professional development attempts to improve classroom practices. Ball and Cohen (1999) and Garet, Porter, Desimone, Birman and Yoon (2001) believe that professional development should be planned, content-focussed, intensive, sustained, well defined and strongly implemented. According to Smith (2009), professional development increases teachers' capacity for change in classroom practice and improves student achievement in mathematics. Professional development does not only focus on content knowledge; it can also help teachers understand learners' thinking about what and how learners learn. This is supported by Desimone, Porter, Garet, Yoon and Birman, (2002), who state that high quality professional development is characterised by a focus on content and learners' learning. Teachers are required to consistently develop themselves to improve their skills and knowledge. Professional development can also help teachers keep abreast with curriculum changes and requirements.

The Collegial Cluster programme encourages teachers to work as a team so as to learn from each other. Desimone et al. (2002) strongly believe that professional development that focuses on a team of teachers can have a substantial, positive influence on teachers' classroom practice and learner achievement.

2.8 SOUTH AFRICAN CONTEXT

2.8.1 General

South Africa is facing a challenge with achievement in school mathematics as well as the number of quality students who pursue careers in mathematics. According to Howie (2003) and Reddy (2005), education reformers in South Africa are concerned about the teaching of mathematics in South Africa. They say this is due to the apparent inability of South African learners to compete successfully with their peers from other countries in international mathematics tests. International studies show that South African pupils rate at the bottom of all countries in the world with regard to literacy and numeracy development (Heugh, 2001). This became evident when South African learners displayed poor performance in one

International study that was conducted for grade 8 learners. They scored the lowest for most indicators amongst the 46 countries that participated in the assessment. Gonzales, Guzman, Partelow, Pahike, Jocelyn, Kastberg and Williams (2004) state that, based on these results, there is great need for improvement of the foundations of mathematics in schools. Engelbrecht and Harding (2008) say that this concern stems from the fact that society requires mathematical knowledge in order to survive and prosper. This raises serious concerns for the socio-economic development of the country and suggests that mathematics teaching has not kept abreast with the advancement of technology. Modern people are increasingly faced with life situations that require problem-solving skills and knowledge of everyday mathematics, which our learners are lacking (Pretorius and Naude, 2002).

For learners to perform well at secondary level, learners must have been taught mathematics in a meaningful manner from the lower grades, and this is posing a challenge to teachers. Teachers are struggling to cope with meaningful teaching of mathematics because they seem not to be sure of the roles they are supposed to play (Graven, 2002). The use of manipulatives and better content knowledge can make this possible, because children learn better with concrete materials. South African learners have been urged by the Department of Education (DoE) to become critical citizens in a mathematically democratic society and this could be achieved through proficient mathematics learning. The underlying reason is that if learners are well taught in a gatekeeper subject like mathematics, there is a high probability of them climbing up the social ladder. Public and private sectors have made major investments in mathematics and science. Through mathematics and science knowledge, rare skills like engineering, accounting, architecture, entrepreneurship, and surveying can be pursued, and this would boost the country's economy,

2.8.2 Manipulatives in the South African curriculum

Manipulatives are used to help learners grasp a variety of abstract concepts that include among others, area and perimeter. Most of the learners in South African schools come from disadvantaged backgrounds and their schools do not have computers. This suggests that learners at such schools may therefore not have access to virtual manipulatives, because computers are costly. Concrete manipulatives that are cheap and easy to obtain, should therefore be used in South African schools.

Mathematics provides learners with opportunities to develop mathematical reasoning and creative skills (South Africa, DoE, 2011). Mathematical Literacy, on the other hand, helps learners become independent citizens who are capable of contributing to and participating in the workforce of the country (South Africa, DoE, 2003). Such a transition can be realised if manipulatives that represent mathematical concepts in a manner that brings conceptual understanding, are used. The use of manipulatives is perceived by the South African Education System as an essential tool for teaching and learning, especially at elementary level. Roodt and Conradie (2003) also claim that the use of different approaches to the same problem as an alternative to the routine approach of "talk and chalk" teaching, enriches both learners and teachers. Hughes (2009) also supports the use of different approaches to learning because this encourages learners to become active in their learning and affords learners opportunities to demonstrate the extent of their thinking and creativity.

Research has been conducted that reveals that children between the ages of five and seven respond well to concrete learning experiences (Peterson and McNeil, 2013). This suggests the importance of manipulatives being included in the teaching and learning of mathematics, especially in the foundational learning phase. During this phase manipulatives help learners with number sense development, which expands learners' ability and potential to solve mathematical problems in a number of contexts. Ananiadou, Jenkins and Wolf (2004) refer to numeracy as an essential skill that learners need to acquire in order to function effectively in the society or at the workplace. Geary (2004) argues that if learners have not acquired number sense by the time they leave the foundation phase, such learners would encounter challenges in acquiring mathematics skills. A solid mathematics foundation contributes positively to learners' mathematics learning with understanding later in life. This is supported by Kersaint and Chappell (2001), who state that it is of critical importance to intervene early in children's schooling life so as to lay a foundation for further schooling. The Department of Basic Education recommends the use of manipulatives such as place-value cards, fraction pieces, and number rods for number sense development (South Africa, DoE, 2011). It further recommends the use of models for teaching the properties of two- and three-dimensional objects.

Learners may find it difficult for example, to derive the formulae for the area of a triangle and a parallelogram, using already acquired knowledge on the area of a rectangle, if concrete shapes are not used. Learners may not be able to form connections between the various shapes. The incorporation of shapes into the lesson, where learners are afforded an opportunity to explore various transformations between rectangles, parallelogram and triangles on a *Geoboard*, would simplify learning.

Manipulatives are beneficial to both learners of regular intelligence as well as those with learning disabilities. Since the South African Department of Basic Education advocates inclusive education, learners with learning disabilities would also benefit from learning where manipulatives are used. According to Naidoo (2012), manipulatives play a significant role in communicating mathematical ideas as well as supporting the process of reflection. According to the new curriculum, learners are required, among other things, to acquire the skill of working as a team in order for effective learning to take place (South Africa, DoE, 2012). Manipulatives can help learners acquire this skill. According to Remillard (2005), manipulatives influence the way in which mathematics is taught. The use of different approaches, including manipulatives, to the same problem, enriches both learners and teachers (Roodt and Conradie, 2003). Manipulatives make abstract mathematics concepts more relevant and memorable to the learners.

The South African education system advocates for learner involvement in the teaching and learning of mathematics, meaning that instruction should be more learner-centred than teacher-centred. Learners' active involvement in teaching and learning enables them to move from the concrete stage where they explore concepts using physical manipulatives, to abstract thinking. This would be the case in the learning of area and perimeter of polygons using the *Geoboard*. Learners are then taken through a representational stage where they visualise and communicate the concepts at a pictorial level, to the abstract level where mathematical symbols are used to represent the concepts. Manipulatives, when used properly and relevantly, develop learners' critical and abstract thinking skills. Learners are encouraged by the Department of Education to become critical in their mathematical thinking, which would enable them to contribute positively to the country's economic growth (Naidoo, 2012).

The CAPS stresses that counting should not only be thought of as verbal counting; learners should use concrete materials such as counters, counting beads, number grids and place-value cards. These manipulatives, and many others, help learners to be hands-on and encourage them to be actively involved in the lesson. It further states that learners should not only do context-free calculations, but should also solve problems in context. The solving of problems in context helps learners become confident and independent thinkers. Approaches that promote learners' active involvement provide learners with opportunities to demonstrate their understanding and creativity (Hughes, 2009). Naidoo (2012) also states that the use of concrete materials creates an exciting and interesting mathematics classroom, which is conducive to learning.

South African Education Policy requires that teaching should be designed such that it allows learners to work collaboratively (Mji and Makgato, 2006). This means that learners are encouraged to become active participants in the classroom and share ideas with one another. In other words, the Education Policy is aligned to the constructivist approach that regards learners not as empty vessels, but as having knowledge that they can connect to the newly acquired knowledge to make sense of what they learn. Learning, especially in geometry, which is the main focus of this study, should be hands-on, so as to enable learners to construct their own knowledge. It is therefore advised that, for effective learning to take place, the teacher should understand learners' learning and thinking. This is supported by Fennema (1996) who also claim that teachers should develop an understanding of their own learners' mathematical reasoning and development.

2.9 THEORETICAL CONSIDERATION

From a constructivist perspective, learning is an interactive and a constructive process of mathematical knowledge and understanding. Learning can be made possible through the use of mathematical manipulatives like the *Geoborad*, the focus of this research. The construction of knowledge occurs as learners interact with the manipulatives and with their peers within the classroom environment. Learners share their different experiences with peers, building on already existing knowledge, allowing for collaborative learning. The already existing knowledge here could be the polygons and their properties, as well as the formulae for finding area and perimeter of polygons. The *Geoboard* in particular, helps them learn area and perimeter with meaning. Learning here involves social interactions and this is where co-operative learning takes places. Learners learn from one another by sharing ideas and learning strategies (Fall, Webb and Chudowsky, 2000). With the help of the manipulatives, learners are able to discuss what they see and connect it to what they know. They make meaning of the shapes they see on the *Geoboard*, for example. Collaborative learning involves developing explanations that are meaningful to somebody else (Fall et al, 2000). An example here would be linking Pick's theorem to the formulae for finding areas of polygons. They further say that collaboration involves listening to peers' explanations, trying to make sense of what they say and asking for clarity where necessary. This should produce learners who are critical thinkers and self- motivated. It produces learners who strongly believe that their mathematics knowledge does not come from their teachers, but from their own explorations, thinking and participation in the classroom. Learners develop skills of working as a team and this builds their confidence and respect for others' opinions. Fall et al. (2000) state that learners' interaction with others gives rise to crucial learning opportunities and this is achieved through groups or pairs. From a constructivist's perspective, learning is an interactive and a constructive process, so mathematics learning is both an individual constructive activity as well as a human social activity.

Constructivism believes that learners construct or generate knowledge through experience-based activities rather than direct instruction (Roblyer, 2006). Constructivists advocate that knowledge is not passively received through senses or by way of communication, but is actively built up (Boyle, 2000). Manipulatives allow learners to be actively involved in knowledge construction. Through their explorations from using the *Geoboard,* learners are able to make links with what they know. Carpenter (2003) supports the idea that children construct their own mathematical knowledge, instead of receiving it as a finished product from their teacher or books. According to Liu & Matthews (2005), knowledge is constructed by the individual who develops tests and refines cognitive representations to make sense of the world he sees. It is therefore imperative for learners to have different materials which will help them construct their own mathematical knowledge. For example, with the use of a *Geoboard*, learners should be able to make connections between the perimeter and area of a shape and that of its image after enlargement or reduction. They should also be able to see a link between the ratios of the areas and perimeters of the original shape to its image. Learners should be able to handle and deal with new, but highly connected information. The notion of actively involving learners is supported by Kilpatrick's model of teaching for mathematics proficiency, which suggests that learners must be active participants in the development of their own understanding (Kilpatrick et al. 2001).

The construction of own knowledge helps in memory and retention of information. Kilpatrick et al. (2001), in their model of teaching for proficiency, also state that connected information that is acquired with meaning can be more easily retrieved than disorganised knowledge that focuses on rote learning. The area of shapes on the *Geoboard* could be connected to the area of their classrooms or homes. With rote learning, learning occurs in a vacuum, there is rare or no connection to the real world. That could be one of the reasons why learners confuse, for example, the perimeter of a shape and its area. The formulae are just memorised, without any meaning attached. In order to learn mathematics with understanding, the teacher should engage learners and build on learners' acquired knowledge. The use of manipulatives would bring more meaning.

The use of manipulatives should make teachers shift from a traditional approach of direct teaching to facilitation of learning by the teacher. Through the use of manipulatives, learners do not absorb ideas as presented to them by their teachers; they create their own learning to make sense of what they learn. This should make teachers develop confidence in their learners. It is hoped that the same thing will happen when learners use the *Geoboard* to explore the area and perimeter of two-dimensional shapes. More exploration with manipulatives would encourage learners to think. As learners interact with manipulatives while doing mathematical tasks with peers, abstract and intuitive thinking develops. The teacher simply guides learners in their learning. The teacher should therefore be skilled enough to create an intellectual and social climate in a classroom that enables learners to discuss, reflect and make sense of their learning.

Constructivism promotes reflection; thus a teacher would know whether the use of a particular manipulative has been effective or not. He/she is able to reflect on learners' constructed knowledge. The quality of instruction depends also on how the teacher interprets and uses the information gathered about learners' understanding. After analysing and interpreting learners' work and understanding, teachers should use their interpretations productively in making instructional decisions. Van de Walle (2004) says through reflective thought an integrated network of connections between ideas is created.

Constructivists also emphasise reflection on planning, because it helps one know where and how to improve for effective teaching and learning to take place. Planning does not mean mathematics content only, it also involves the intervention strategies that a teacher intends to use. A single instruction approach should be substituted by a multiple instruction approach, for effective teaching and learning to be realised (Van de Walle, 2004). Manipulatives enhance learners' thinking and drawing of conclusions during problem-solving (Kamii, Lewis and Kirkland, 2001). In order to enhance meaningful learning, learners should be allowed to apply various problem-solving strategies, which provide for discovery learning. Learners should be allowed to investigate the formulae for area and perimeter of polygons in order to make sense of it. Kilpatrick et al. (2001) further argue that learners need to be helped with manipulatives so that they see their relevant aspects and to link those aspects to appropriate symbolism and mathematical concepts and operations.

2.10 CONCLUSION

It has clearly emerged from the literature that manipulatives have always been there in the teaching and learning of mathematics. It is for this reason that the Department for Basic Education advocates the use of concrete materials for meaningful teaching and learning of mathematics. Appropriate and relevant use of manipulatives is very important in producing the desired outcomes. I also learnt that for manipulatives to be effective they must be relevant to learners' cognitive and conceptual understanding.

In the next chapter, I present my research design and methodology.

CHAPTER 3

RESEARCH DESIGN AND METHODOLOGY

3.1 INTRODUCTION

This chapter provides a detailed description of the research design employed in my study. I describe, amongst other things, the research methods used to collect data and the selection of participants for the study. It also gives a description of the research tools that were used for data gathering. Lastly, the chapter describes the design of the research tools used and why such tools were used in this study.

3.2 RESEARCH PARADIGM

The study is oriented in an interpretive paradigm. According to Babbie & Mouton (2001), the interpretive paradigm offers an opportunity to engage with in-depth descriptions and understandings of actions and events, which in this case, are the teachers' experiences of using a *Geoboard* as a teaching and learning aid. It is believed that reality is about people's own experiences of their environment, that is, what happens around them. This is supported by Walsham (1995), who states that reality is socially constructed. Barret and Walsham (2004) argue that interpretivists believe that reality is created through social constructions like language, shared consciousness and meanings. An interpretive paradigm relies on observations, and interpretations of such observations. Observation is the collection of information about researched events, while interpretation is making sense of the observed interpretations by drawing inferences or judging the connection between the information and abstract patterns (Rowlands, 2005). The qualitative approach used enabled me to make informed claims based on multiple meanings of individual experiences that the participants (teachers) constructed and shared with me.

3.3 RESEARCH QUESTIONS

The research questions of this study are:

(a) What are the experiences of selected grade 9 teachers in participating in a *Geoboard* intervention programme?

(b) What roles can the *Geoboard* play as a medium for instruction for teachers?

3.4 RESEARCH METHODOLOGY

This research is a quantitative and qualitative case study of three grade 9 teachers at three different RUMEP Collegial Cluster schools, situated in an interpretive paradigm. Yin (2009) refers to a case study as "an intensive investigation of a single unit". Leedy and Ormrod (2010) define a case study as research where data is collected directly from a particular group of people, with the aim of studying their interactions, attitudes or characteristics within their environment, which in this instance is a school or classroom. Stake (1995, p.8) adds that a case study is a study of particularity and complexity of a single case. He further states that a case study involves an interpreter who observes the operations of the case. This case study gave me an opportunity to study teachers' experiences of *Geoboard* use in teaching and learning of area and perimeter. These are mathematics teachers who are teaching grade 9. I observed them while they taught their lessons on area and perimeter to grade 9 learners at their schools. Cohen, Manion and Morrison (2000) also state that a case study begins with the participants that are engaged in a particular context, which is a real-life situation.

The unit of analysis of this case study was the three participating teachers' perceptions and experiences of using a *Geoboard* in their teaching of area and perimeter of two-dimensional shapes, as well as their experiences of the *Geoboard* intervention programme. These experiences include the teachers' thoughts and feelings on the use of the *Geoboard* as a manipulative in the teaching and learning of mathematics. A further unit of analysis was learner performance which was analysed using descriptive statistics.

As a means of gathering data on teachers' experiences, I used various data collection instruments, which included observations using a video recorder, and interviews where I used an audio recorder. To analyse performance of learners, I also used the baseline and post-intervention assessment tasks that learners wrote. My case study focussed on current events, where I observed teachers while in action, in other words, while they were teaching.

3.5 RESEARCH DESIGN

I am employed at RUMEP and my designation is to coordinate Collegial Clusters. My research was therefore conducted at three RUMEP Collegial Clusters in the Eastern Cape, which are part of the clusters that I coordinate.

Collegial Clusters are communities of teachers that come together with the aim of working on their own professional development (RUMEP's Annual report, 2015). These are platforms where teachers share information regarding mathematics content as well as planning of mathematics lessons and activities. All these activities aim at improving the teaching and learning of mathematics at schools.

3.5.1 Sampling and Participants

The research sites of this study are two clusters in the RUMEP Collegial Clusters, referred to above. Linden, Trochim and Adams (2006) define sampling as the process of selecting units, which could be people or organisations. The two clusters were purposefully and conveniently selected from the RUMEP Collegial Clusters. Leedy and Ormrod (2005) refer to purposeful sampling as sampling that is designed such that it picks a small number of cases that would yield the most information about the phenomenon. Since I am a Collegial Cluster Coordinator, I have good access to these clusters and I am familiar with them. Although the two clusters are in the deep rural areas within the Eastern Cape Province, they are well organised, which made it possible for the intervention to take place. The participants in the study come from three schools that are part of the two Collegial Clusters. Two of these schools are in the Joe Gqabi District Municipality, while the third is in the Mnquma District Municipality.

According to Patton (1990, p.169), the "logic and power of purposeful sampling lies in selecting information-rich cases". Information-rich cases are those cases from which one can gain a lot of information about issues of central importance to the purpose of the study. I was able to collect as much information as required, because these clusters are central to my work at RUMEP. I managed to engage with the participants over a sustained period of time, due to the regular nature of my visits to the clusters.

The selection of the three grade 9 teachers from the two RUMEP clusters was done in consultation with the District Managers of the Education Department at Sterkspruit and Dutywa. The teachers as well as their schools were chosen because of their high level of commitment to quality teaching and learning. The principals of the three schools were also consulted and made aware of the research. The three grade 9 teachers were asked to volunteer to participate in the intervention programme. One of the teachers came from the Dutywa cluster and two teachers came from the Sterkspruit cluster. I initially intended to include the Grahamstown cluster, but the school I had chosen was affected by rationalisation, so grades 8 and 9 had been phased out. This was the only cluster school out of two schools that had grade 9 in the Grahamstown cluster. There was therefore no option left, but to choose a third school from another RUMEP cluster. The two clusters have been in operation for quite a while and are part of the eight RUMEP clusters where good rapport has been established.

3.5.2 Research phases

The study is divided into five phases as explained below:

Phase 1

In this phase, a baseline assessment was administered to my experimental group of learners and a control group. The latter consisted of a grade 9 class, which did not participate in my intervention, but covered similar content in their class. The aim of the assessment was to check what knowledge learners had about area and perimeter of two-dimensional shapes. It consisted of 15 questions, all based on area and perimeter. The first section of the assessment had four open-ended questions, which assessed learners' knowledge of area and perimeter. In the second section of the baseline assessment, learners were given eleven multiple choice questions, where they applied the knowledge they had previously acquired on area and perimeter of two-dimensional shapes (see Appendix 2).

The first four questions were open-ended questions. The first two questions required learners to explain in their own words what they understood about area and perimeter. In questions 3 and 4, learners were asked to show their understanding of area and perimeter respectively, where they had to use diagrams to support their response to the first two questions. Questions 5 to 15 were multiple choice questions. Questions 5, 6, 7, 10 and 14 required learners to use routine or complex procedures to arrive at the solutions. Questions 8, 9 and 11 assessed learners' understanding of area and perimeter, but involved similarity and dilations of two-dimensional shapes. Questions 12, 13 and 15 involved ratio, perimeter of a circle and conversions respectively.

Phase 2

In this phase, a three-hour workshop was conducted for the participants at each of the three schools. The workshop aimed at introducing the participants to the *Geoboard.* Different sized *Geoboards* were manufactured at the workshop. The boards used were already cut out and the teachers only had to hammer in the nails. Teachers were shown the possible uses of a *Geoboard* for the teaching and learning of area and perimeter.

I developed a detailed and focussed teaching and learning intervention programme for the topic in question (see Appendix 4). This was done with the aid of the CAPS document that prescribes per grade, the content to be taught. The design of the teaching and learning programme was also informed by the baseline assessment task, which revealed learners' errors and misconceptions in working with area and perimeter. The intervention programme aimed at assisting teachers with their planning around area and perimeter of two-dimensional shapes. The teaching and learning intervention programme covered the various skills and knowledge that learners needed to have on area and perimeter of two-dimensional shapes.

Altogether there were six lessons planned; these included the investigation of the formula for calculating the area of a rectangle and triangle. There were three lessons on the calculation of the area of the different polygons using different strategies, for example, counting of squares, Pick's theorem, decomposition of shapes, as well as the use of formulae. There was a lesson that integrated area and perimeter with transformation of polygons, with special reference to dilations and translations. In another lesson, learners investigated the relationship between the area and perimeter of the original shape and that of its image. The last lesson was based on the investigating whether rectangles with the same areas, would also have the same perimeters and vice versa. Each lesson was an hour in length.

Phase 3

During this phase each of the participating teachers rolled out the planned intervention programme in their individual classes with their learners. Teachers planned their lessons as per the learning programme, which had been designed during the workshop in the Phase 2. The planned lessons were then taught by the various participating teachers at their respective schools. It was during this phase that schools were visited to observe some of the lessons that teachers had planned and implemented, and a lesson observation tool was used (see Appendix 5). Only two lessons per teacher were observed during this phase and each lesson was video recorded.

As part of an introduction, learners were given worksheets that assessed their understanding of the two concepts of area and perimeter. Learners calculated the area and perimeter of the shapes they drew as per teachers' instructions. This activity also aimed at checking whether learners confused area with perimeter. Learners investigated the area of a rectangle, a square and a triangle by counting the squares on the surfaces of the shapes they drew. They then found the relationship between the squares they calculated and the dimensions of the shapes they drew. Learners were also given problem-solving activities that required them to apply their knowledge of area and perimeter. Teachers showed learners the various strategies of calculating the area of polygons and these included the use of formulae, counting of squares, decomposition of shapes, as well as Pick's theorem. In order to do this, learners were asked to make different types of polygons on a *Geoboard*, using rubber bands. Learners also transformed shapes through dilations and translations. Learners further investigated the relationship between the area and perimeter of the original shapes and that of their images.

Phase 4

During this phase a post- intervention assessment task was administered to the experimental and control groups. The main purpose of this assessment was to measure the effect of the intervention programme on learners' learning. In other words, the test aimed at assessing whether learners' understanding of area and perimeter of two-dimensional shapes had improved. The format and the test items were the same as the baseline assessment that learners wrote before the intervention programme (see Appendix 3). The assessment task consisted of 15 questions in two sections: section one had open-ended questions, while the second section had 11 multiple choice questions. The first four questions assessed learners' understanding of area and perimeter. The remaining 11 questions involved application of learners' knowledge of area and perimeter, where learners were required to use routine and complex procedures in order to decide on the right solution. Questions 8, 9 and 11 involved area and perimeter, but were integrated with similarity and dilations. Questions 12, 13 and 15 also involved area and perimeter, but required the understanding of ratio, circle parts and conversions.

Phase 5

In this phase, semi-structured interviews were conducted with the teachers as well as the learners who participated in the intervention programme. The interviews were a means of acquiring information on the participants' experiences of using a *Geoboard* to find area and perimeter of two-dimensional shapes. The interviews with the three teachers were recorded and transcribed. In the case of learners, I asked two learners per school to volunteer to form a focus group. In this focus group, learners were interviewed on their experiences of using a *Geoboard* to learn area and perimeter of two-dimensional shapes. The interviews with learners were also recorded and transcribed.

3.6 DATA COLLECTION TECHNIQUES/ TOOLS

A variety of data collection techniques were employed, including baseline and post-intervention assessments, observations and semi-structured interviews. The employment of various data collection methods is defined by Cohen, Manion and Morrison (2000) as triangulation. The aim of using triangulation, as supported by Flick, von Kardorff and Steinke (2004), was to obtain answers to the research questions from different sources. Below is the description of the different research tools that I employed to gather data.

3.6.1 Baseline Assessment task

The Baseline Assessment task was administered to my experimental and control group of learners before the intervention programme. This assessment task tested learners' conceptual understanding of area and perimeter of geometric figures, and helped me to identify learners' misconceptions in this field. The test was a one-hour assessment task with two sections. The first section comprised of four open-ended questions. In questions 1 and 2, learners explained in their own words what they understood about area and perimeter respectively. In questions 3 and 4, learners drew diagrams to illustrate their understanding of area and perimeter.

The second section comprised of eleven multiple choice questions. It covered many cognitive levels such as knowledge, routine procedure, complex procedure and problem solving as suggested in CAPS Assessment Guidelines. The second section assessed learners' knowledge of calculating area and perimeter. It also assessed learners' reasoning and creative thinking skills. These were assessed through the problem-solving activities where learners had to apply their already acquired knowledge of the two concepts. The results obtained from the test informed me about learners' understanding of the mathematics content that pertained to the intervention programme.

3.6.2 Observation

The participating teachers taught their six lessons as suggested in the intervention programme designed during the second phase of this study. Of the six lessons that were taught by each of the three teachers, only two lessons per teacher were observed. The main purpose of observing the lessons was to record and capture how teachers used the *Geoboard* as a manipulative to teach area and perimeter of shapes. In order to cover as much content as possible, each of the two observed lessons was about two hours long. The lessons involved hands-on activities that demanded learners' involvement and understanding. I gave guidance where necessary, especially in cases where the teacher herself had challenges. The observed lessons were video-recorded and analysed. The video recordings were used as data to answer Research Question 1.

3.6.3 Post-Intervention Assessment task

This assessment was done after the observation phase, that is, after teachers had taught their lessons on area and perimeter of two-dimensional shapes, using a *Geoboard*. The assessment aimed at assessing learner gain i.e. to check whether learners' understanding of the two concepts had improved. The questions were similar to the baseline assessment. The mathematics content covered in the questions was the same as in the baseline assessment.

3.6.4 Semi-structured interviews

The purpose of the semi-structured interviews with teachers was to reflect on the use of the *Geoboard* during the intervention, and to explore the teachers' experiences with using a *Geoboard* as a manipulative in the teaching and learning of area and perimeter of geometric shapes. All three teachers were interviewed at their respective schools. Each interview lasted about 15 minutes. The interviews had open-ended questions, which in some instances were followed up with further probing questions. The questions were left open-ended to accommodate both the interviewee and the interviewer in detailed discussions. Keats (2001) adds that follow-up questions either give clarity to the original question or they are different questions based on the responses to the original question. As alluded to earlier in this chapter, two learners per school were also interviewed on their experiences of using the *Geoboard*. The interviews with both teachers and learners were video-recorded and then transcribed.

Since my research was a case study, I thought interviews would be an appropriate method to extract the teachers' and learners' experiences on the use of a *Geoboard*. According to

Gillham (2000), interviews are mostly employed in case studies, which meant they were appropriate for my study. Interviews are a means of accessing the thoughts inside a person's mind, and of getting to know about the person's feelings regarding a particular event.

3.7 DATA ANALYSIS

My research study involved both a quantitative and a qualitative analysis. According to Creswell and Clark (2007), a quantitative analysis approach includes closed-ended data that is based on attitudes, behaviours and performance instruments, while a quantitative analysis approach consists of statistically analysed scores. A qualitative analysis approach, as suggested by Creswell (2009), entails closed-ended data obtained through interviews, observation of participants or collection of audio-visual materials.

For the quantitative analysis, I analysed the baseline and post-intervention assessment tasks. I used descriptive statistics in my analysis and illustrated the results by using bar graphs.

For the qualitative analysis, I analysed the video recordings from observations, the interviews with teachers, and the interviews with learners.

3.8 ETHICS

My research supported the ethical principles as set out in the Ethics Guideline of the Faculty of Education at Rhodes University. The principles are:

Respect and dignity

Teachers were assured of confidentiality throughout the study. This entailed ensuring the anonymity of the schools, teachers and learners. Gillham (2000) states that, the essence of anonymity is that the information acquired from participants should not reveal their identity. Teachers participated voluntarily, and it was also explained to them that they were free to withdraw from the study, should they at any time feel uncomfortable about the study.

Transparency and honesty

The study, as indicated earlier, involved teachers and learners, who are all part of the Department of Education. A letter seeking permission to conduct the study was therefore written to the District Managers of the two districts where the study was conducted (see Appendix 1B). The purpose of the study was fully explained in the information letter (see

Appendix 1A). The principals of the schools that participated in the study were also made aware of the research and their permission to conduct the study at their schools was also sought, after which they signed a consent letter, granting me permission to conduct the research (see Appendix 1C). The details and purpose of the study were explained to all the teachers who participated in the study.

After a detailed explanation regarding the research, teachers were asked to sign the consent letter, agreeing to voluntarily take part in the study (see Appendix 1D). Ruane (2005) supports the idea of obtaining participants' consent. He states that the principle of obtaining consent is about the right of an individual to indicate for themselves whether or not they want to be part of the study.

It was also explained to teachers that the information gathered would not be disclosed to other people, unless they themselves granted me permission to do so.

Accountability and responsibility

I explained to the participants that the research would not only be used for personal gain and my own empowerment, but that it would also benefit and empower them. Winstanley and Woodall (2000) stress that, researchers should act ethically in all they do, especially in a situation where humans are involved. I fully concur with them that participants should be treated with respect and dignity and nothing should be hidden from them. I also allowed them to raise their concerns around the study.

Integrity and academic professionalism

I made it a point to conduct my study in a professional manner. The methods for collecting data were explained to teachers. Teachers were aware that they would be observed and that their lessons would be recorded. The reasons for doing all this were explained to the participants. The aim was to avoid a situation whereby teachers would think that their content knowledge was being assessed or judged or reported.

Positionality and power

Although I interacted regularly with cluster teachers, I still felt it necessary that I explain everything regarding the research. I wanted them to participate freely without any reservations. As somebody who had been working with them for a number of years, teachers were not reluctant to participate in the study, due to the rapport that had been established over the years. I listened to and respected the participants' views and ideas. This made it easy for the participants to freely express their concerns whenever a need arose. They did not feel inferior to me because of the position that I held. Rapport-building involves active listening, showing respect and empathy, being truthful, and showing a commitment to the well-being of the community or individual (Winstanley and Woodall, 2000).

3.9 VALIDITY

As a means of ensuring validity, both the baseline and post-intervention assessment tasks were given to my colleagues and my supervisor for scrutiny. They checked whether the assessment tasks were valid and relevant and appropriate to grade 9. According to Denzin and Lincoln (2000) and Johnson (1997), validity determines whether the research measures what it is intended to measure.

The use of different data collection methods, that is, video-recordings, observations and interviews led to a reliable and valid construction of ideas. According to Johnson and Johnson (1997), the use of triangulation, which is a combination of data collection techniques, strengthens the study, and this is supported by Patton (2002). The engagement of multiple methods, such as observation, interviews and recording leads to more valid, reliable and diverse construction of realities (Cresswell, 2009).

For the baseline and post-intervention assessment tasks, I involved a control group of learners from a grade 9 class that did not participate in the intervention programme. This strategy added to the validity of my results.

For ethical reasons, at the completion of my study, I will repeat my intervention programme with the control group and its teacher.

3.10 CONCLUSION

In this chapter, the methodological framework that underpinned my study and guided my research design was discussed in detail. This included the description of the research methods used as well as the data collection techniques that were employed in the research. The data collection tools used in the five phases of my research were answers to the research questions posed in my study. The four phases that my study was divided into were discussed. Finally, the chapter considered how validation threats were addressed as well as how ethical practices were adhered to. The next chapter analyses and discusses the data collected.

CHAPTER 4

DATA ANALYSIS AND DISCUSSION

4.1 INTRODUCTION

This chapter details the analysis of the data I collected, and presents the findings of the research. The chapter begins with a brief introduction and description of the three participating schools in the clusters. I then present the findings of each school individually. This is followed by a general discussion of the overall results across the three schools.

4.2 INTRODUCTION TO EACH SCHOOL

A brief summary of the background of each of the three schools is outlined below:

4.2.1 School A

The school was situated in the Sterkspruit District. It had a total enrolment of about 900 learners, with three streams of grade 9. Although the school was not far from town, most of its learners came from rural areas and an informal settlement around the school. There was a mathematics teacher for each grade, unlike other schools where mathematics teachers were allocated a phase to teach. Teachers at the school were very willing to take part in anything that involved professional development. In my observations, learners at the school were not deprived of opportunities to take part in anything that improved their learning. For example, they participated in many maths competitions. This was one of the best performing cluster schools in the study.

4.2.2 School B

This was a school in the deep rural area of the Dutywa District. It had a total enrolment of about 400 learners. The school was situated in a poor community, where the majority of community members depended solely on social grants. The two mathematics teachers in the Intermediate and Senior phases worked as a team. They planned lessons together, shared ideas, skills and best practices. Learners at this school were encouraged, from grade 5 to grade 9, to participate in any form of competition that helped them to improve their performance. The school had good results in Maths Olympiads for grade 9s. Through the help of these teachers, the two learners who were placed first in the Maths Olympiads in 2011 and 2013 achieved distinctions in Mathematics in grade 12. They enrolled for B Com. Accounting and B Pharmacy respectively at Rhodes University. This clearly showed the dedication and commitment of mathematics teachers at this school.

4.2.3 School C

School C was in the Sterkspruit District and had an enrolment of about 1000 learners. It was also located in a rural area, where most of the community members were unemployed, yet very supportive of their children's education. It was one of the few schools where learners were integrated with learners that had learning barriers. Some learners were mentally challenged, while others were physically challenged. Some of the learners who wrote the baseline and post-intervention tasks were learners with such barriers. Despite the challenges the school had, it was still among the top 5 cluster schools. Like School A, the school allocated a mathematics teacher to each grade, which lessened the burden on the teachers, especially when it came to planning the lessons. Mathematics teachers, together with the principal, worked co-operatively to improve the teaching and learning of mathematics at the school. The district mathematics Subject Advisor was a mathematics teacher at the school as well as a cluster member. The school was a member of the Association of Mathematics Education of South Africa (AMESA), which clearly showed the school's keenness on professional development.

4.3 ANALYSIS OF THE BASELINE AND POST-INTERVENTION ASSESSMENT TASKS OF EACH SCHOOL

As indicated earlier, there was both a baseline and a post-intervention assessment task administered to grade 9 learners of the three schools.

The figures below show how each school fared in each question in both the baseline and the post- intervention assessment tasks.

4.3.1 School A

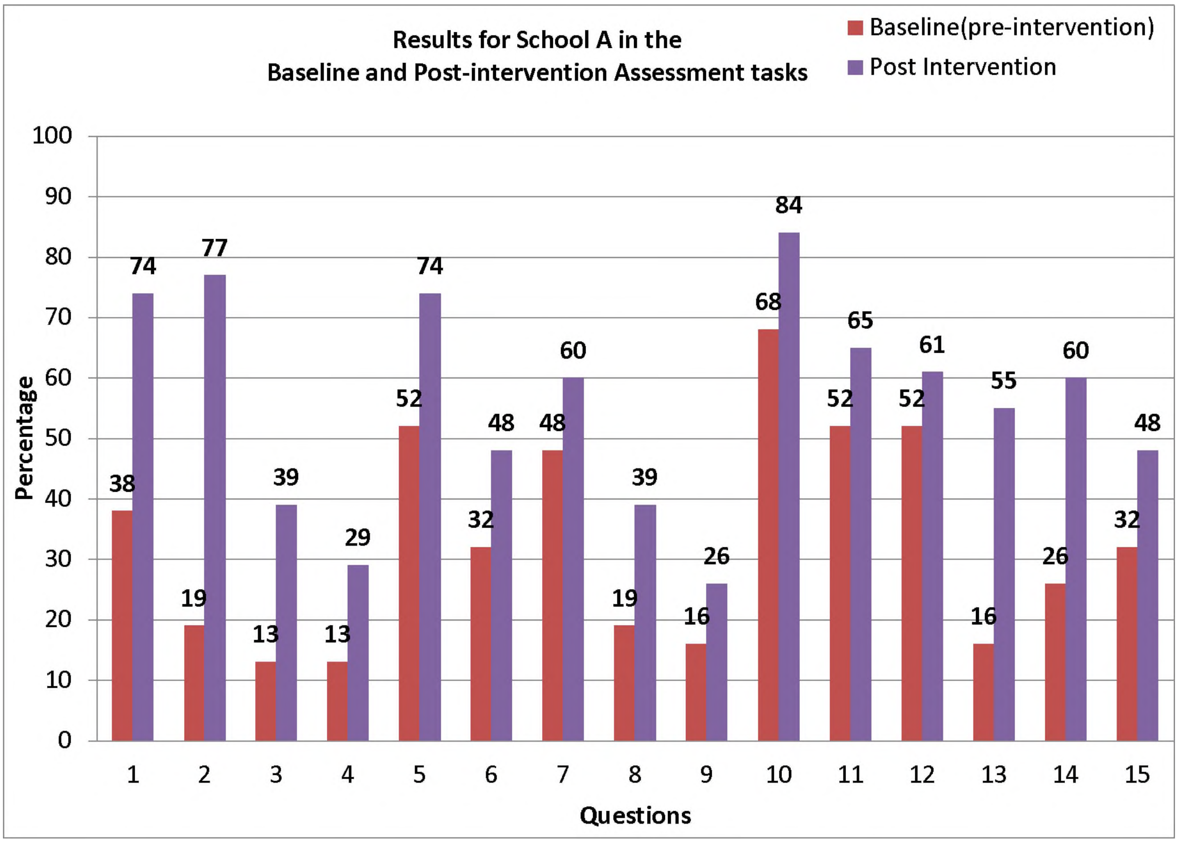

Figure 4.3.1 Results of School A's learner performance per question in the baseline and post-intervention assessment tasks

A total of 31 learners from School A wrote both the baseline and the post-intervention assessment tasks. Learner performance in the post-intervention assessment task, as compared to the baseline assessment task, showed improvement. In questions 1 and 2, learners were asked to define in their own words what they understood about area and perimeter respectively. Only 38% of the learners in the baseline assessment could correctly define area. This figure increased by 36% in the post-intervention assessment task. This means 23 learners out of 31 learners got the correct answer, unlike in the baseline assessment where only 12 learners managed to define area. In question 2, 77% of the learners in the post-intervention assessment task could define perimeter, while 19% of learners in the baseline assessment defined perimeter correctly.

In questions 3 and 4 learners were required to illustrate by means of drawings, their understanding of area and perimeter respectively. In the baseline assessment, learner performance in both questions was 13%, while 39% of learners in the post-intervention could draw diagrams that showed an understanding of area. In the post-intervention assessment task, only 29% of the learners drew clear diagrams showing their understanding of perimeter.

Question 5 asked learners to find the area of a rectangle, where length and breadth were given. Learners got 52% and 74% in the baseline and post-intervention assessment tasks respectively. In question 6, learners were given the area of a square and had to find the length of each side. Learner performance in the baseline and post-intervention assessment tasks was 32% and 48% respectively. Question 7 required learners to find the area of a triangle, given the height and the base. Only 48% of the learners in the baseline assessment task got it right, while 60% in the post-intervention assessment task got the correct answer.

Questions 8, 9 and 10 were based on area and perimeter, but involved similarity. Question 8 had two triangles, each with missing dimensions for the third side. Learners had to find the perimeter of the second triangle, which entailed finding a connection between the two triangles. Learner performance in the baseline assessment task stood at 19% and 39% in the post-intervention assessment task. In question 9, there were two similar rectangles. In both shapes one dimension was given and the area was given for one of the shapes. Learners had to use this information to find the area of the other shape. Only 16% of the learners in the baseline assessment task saw the connections in the two shapes, while learner performance was 26% in the post-intervention assessment task. Question 10 had two similar regular pentagons and the length of one side in each shape was given. Looking at the connections between the two shapes, learners had to find the perimeter for one of the shapes. 84% of learners in the post-intervention assessment task were able to see the connection and got the right answer. In the baseline assessment task, the learner performance was 68%.

In question 11 there were two regular hexagons, with one hexagon as the image of the other. The original hexagon was given the length of one side and learners had to find the length of each side of the image, using the given scale factor. In the baseline assessment task, 52% of the learners got the correct answer while 65% of learners in the post-intervention assessment task got it right. Question 12 was based on the previous question. Learners were required to find the ratio of the perimeter of the original shape to that of the image. 52% of the learners in the baseline assessment task managed to compare the two shapes. Learner performance in the post- intervention assessment task increased by 9%.

Question 13 required learners to find the circumference (perimeter) of a circle with the given diameter. Only 16% of the learners had a correct response, while 55% of the learners got the correct answer in the post-intervention assessment task.

In question 14, learners were given an area of a rectangular plot and one of the sides. Learners had to find the second side. In the baseline assessment task, 26% of the learners were able to find the length of the second side. This figure increased to 60% in the post-intervention assessment task. In question 15 learners had to convert the area they were given in the previous question to centimetres. In the baseline assessment task, 32% of the learners could do conversions, while learner performance in the post-intervention assessment task was 48%.

In all the questions, learners showed a gain in learning. The percentage increase in all the questions was 10% and above.

4.3.2 School B

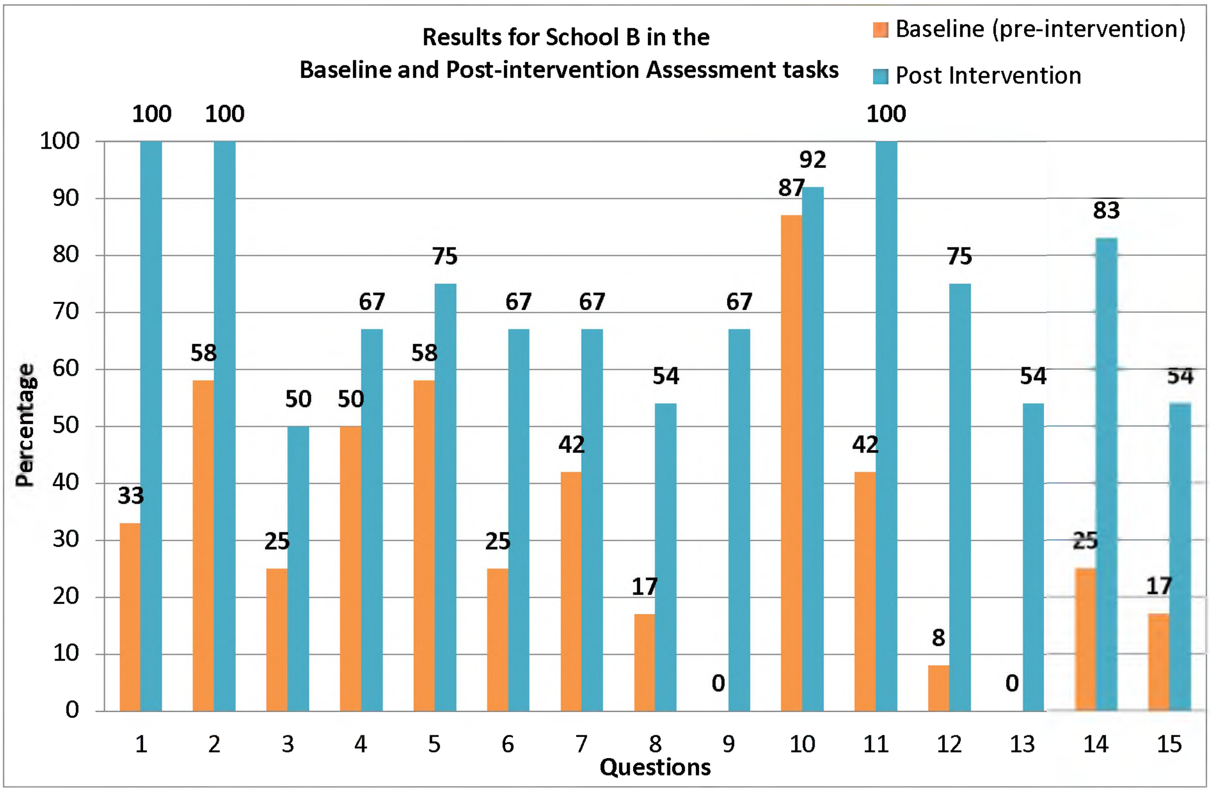

Figure 4.3.2 Results of School B's learner performance per question in the baseline and post - intervention assessment tasks.

A total of 12 learners from School B wrote the baseline and post-intervention assessment tasks. In questions 1 and 2 in the baseline assessment task, learners achieved 33% and 58% respectively. In the post-intervention assessment task learner performance stood at 100 % in both questions. This is where learners explained in their own words what they understood about area and perimeter respectively. In questions 3 and 4, learners showed their understanding of area and perimeter by means of diagrammatic illustrations. In the baseline assessment task 25% and 30% of learners respectively got the two questions right. The post-intervention assessment task showed improvement in both questions, with 50% and 67% respectively.

Question 5 required learners to find the area of a rectangle, given both dimensions. More than 50% of the learners in both tasks got this question right. In the baseline assessment task, 58% of the learners had the correct answer, while 75% of learners in the post-intervention assessment task got the question right.

In question 6 learners were given the area of a square and had to find the length of its sides. Learners needed to understand what a square is as well as what is meant by an area of 196 square units. In the baseline assessment task, only 25% of the learners got this right, while 67% of the learners in the post-intervention assessment task got this right. There was therefore an increase of 42% in learner performance. In question 7, learners were given a triangle with a base and height and had to find its area. Learner performance in the baseline assessment task was 42% and 67% in the post-intervention assessment task.

Questions 8, 9 and 10 were based on similarity. The main aim here was for learners to see the connection between area, perimeter and similarity, and not to treat these concepts in isolation. In question 8 there were two triangles, each with the length of the third side missing. Learners had to find the connection in the given sides of the two triangles and then find the perimeter of the second triangle. In question 9, learners were given two similar rectangles and each rectangle had the length of one dimension given. The area of one of the rectangles was also given and learners had to use all this information to find the area of the second rectangle. In question 10, learners were given two regular and similar pentagons with one pentagon having the length of one side given. Learners had to find the perimeter of the second pentagon. Learners' performance in these questions in the baseline assessment task was 17%, 0% and 83% respectively. An improvement was observed in the post-intervention assessment task, with learners getting 54%, 67% and 92% respectively in the three questions. In all the questions there was an increase of more than 35%.

In question 11 there were two regular hexagons, one the mirror image of the other. The length of one of the sides in the original shape was given. The original shape was enlarged with a given scale factor. Learners had to interact with all this information in order to find the length of each side of the image. For question 12, learners had to find the perimeters of the two shapes and then find the relationship between the two perimeters. In the two questions, learners respectively got 42% and 8% in the baseline assessment task. Learners' performance in the post-intervention assessment task improved tremendously. All the learners got question 11 right, while 75% of the learners managed to see the relationship in the two figures in as far as perimeter was concerned.

In question 13, learners were required to find the perimeter/circumference of a circle, given its diameter. This was just to check how much learners knew about area and perimeter of a 2-D shape like a circle. None of the learners got this question right in the baseline assessment task, while 54% of learners in the post-intervention assessment got the correct answer.

In question 14 learners were given the area of a rectangular plot as well as one of its dimensions. Learners were required to find the other dimension. Only 25% of the learners in the baseline assessment task could find the dimension, while this figure increased to 83% in the post-intervention assessment task. In question 15, learners were asked to convert the area they were given in metres in the previous question to centimetres. Only two learners in the baseline assessment task were able to do conversions, while in the post-intervention assessment task 54% of the learners could do conversions.

School B's learner performance improved from an average of 41% in the baseline assessment task to 92% in the post-intervention assessment task.

4.3.3 School C

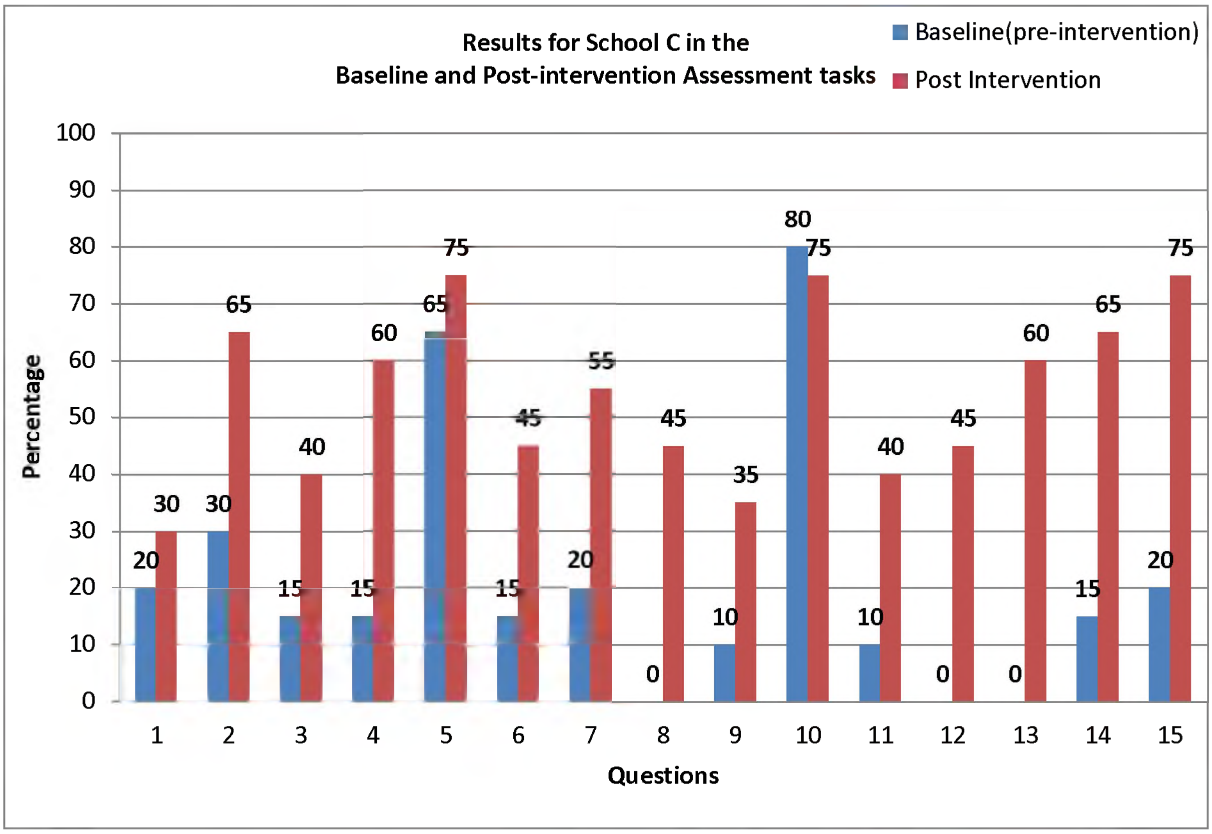

Figure 4.3.3 Results of School C's learner performance per question in the baseline and post-intervention assessment tasks.

The graph above shows the results of learner performance of 20 learners in both the baseline and post-intervention assessment tasks. The first four questions of the tests were open-ended, meaning that learners explained area and perimeter in their own words. In questions 1 and 2, learners were asked to explain in their own words what area and perimeter were, respectively. Only 20% of the learners in the baseline assessment task clearly defined *area* in question 1, while this figure increased to 30% in the post-intervention assessment task. Question 2 of the post-intervention assessment task revealed improvement in learner performance, with 65% of the learners getting the right answer, while learners achieved 30% in the baseline assessment task.

To show their understanding of area and perimeter, in questions 3 and 4, learners were asked to show by means of illustrations what they understood about area and perimeter respectively. In the baseline task 15% of the learners could illustrate their understanding of area and perimeter. In the post-intervention assessment task, 40 % and 60% of the learners respectively got questions 3 and 4 right.

Question 5 was similar to the questions learners normally get, where they were asked to calculate area when given length and breadth of a rectangle. This was evident in learner performance in both the baseline and post-intervention assessment tasks where 65% and 75% of the learners respectively mastered the question. In question 6, learners found the length of each side of a square, given its area. Learners seemed unfamiliar with this kind of question. Only 15% of the learners in the baseline assessment task got this question right, while this figure increased to 45% in the post-intervention assessment task. In question 7, learners were given a triangle with two dimensions, the base and the height. They had to find the triangle's area. In the baseline assessment task, learner performance was only 20%. In the post-intervention assessment task, learner performance increased to 55%.

Questions 8, 9 and 10 involved not only area and perimeter, but also the understanding of similarity of shapes. It became clear from learners' performance that similarity is a topic that is not familiar to learners. In question 8, learners were given two similar triangles, each with 2 dimensions. They had to establish the connection between the two figures, which would then help them find the perimeter of the second figure. In the baseline assessment task, none of the learners saw the connection. The post-intervention assessment task showed a different picture, with 45% of the learners getting the right answer. In question 9, learners were given two similar rectangles, each with one dimension, and one of the rectangles with a given area. Looking at the connections in the two rectangles, learners had to find the area for the other rectangle. Learner performance in the baseline assessment task was 10% and this increased to 35% in the post-intervention assessment task. Question 10 had two similar pentagons and in each pentagon, the length of one side was illustrated. Learners were required to find the perimeter for the other pentagon. The question appeared easy, because learners got 80% and 75% in baseline and post-intervention assessment tasks respectively, despite a small drop in performance.

In question 11, learners were given two regular hexagons, one being the image of the other. The length of one side in the original shape was given and the original shape was enlarged with a scale factor. Learners had to find the length of each side of the image. The learner performance in the baseline assessment task was 10%, compared to 40% in the post-intervention assessment task. In question 12, learners were asked to compare the area of the original shape to that of its image in the previous question. In the baseline assessment task, none of the learners got the right answer, while 45% of the learners in the post-intervention assessment task saw the relationship between the two shapes.

Question 13 appeared to be a challenge to learners. In this question, learners were asked to find the circumference / perimeter of a circle with a given diameter. None of the learners in the baseline assessment task got the question right. A significant improvement of 60% in learner performance in the post-intervention assessment task was observed. The recapping on the area of a circle during the intervention programme could have led to the improvement in learner performance.

Question 14 was based on the area of a rectangle where learners were given the area of a rectangle and one dimension. Learners had to find the length of the other dimension. In the baseline task, learner performance was 15% while in the post-intervention assessment task it was 65%. The area that learners were given in the previous question was in metres, so in question 15 learners were asked to convert this to centimetres. Learners got 20% in the baseline assessment task and 75% in the post-intervention assessment task.

The results in all three schools showed significant improvement. Some learners said "The *Geoboard helped us develop a sense of independence, because we would only call the teacher when we got stuck."* (FGLI).

4.4 GENERAL ANALYSIS OF PERFORMANCE ACROSS THE SCHOOLS

4.4.1 Average learner performance

The results of the average learner performance of the three schools are represented in the graph below and then discussed.

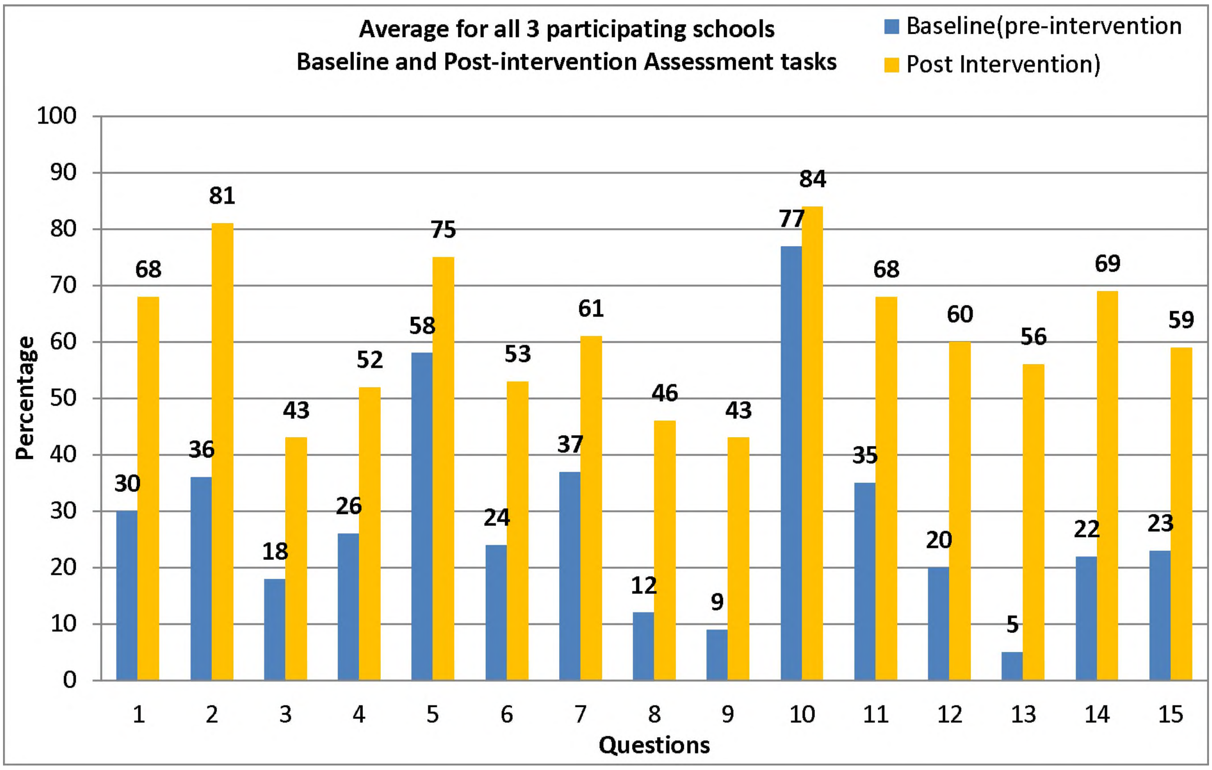

Figure 4.4.1 Results of the average learner performance in the baseline and post-intervention assessment tasks.

The results in Figure 4.4.1 above show a positive shift in learners' understanding of area and perimeter. This suggests that the intervention may have had a positive impact on teaching and learning of area and perimeter of two-dimensional shapes. The analysis of these tests looked at how learners translated what they had learnt during Phase 3 (Intervention stage) to the post-intervention assessment phase. This helped me see whether learning took place in the intervention programme. Learners were given the same questions for both the baseline and the post-intervention assessment tasks.

A total of 63 learners wrote both the baseline and the post-intervention assessment tasks. In questions 1 and 2, learners were required to define area and perimeter and in both questions, there was an increase in performance of 38% and 45 % respectively. In the post-intervention assessment task, learners managed to show their understanding of area and perimeter as required in questions 3 and 4. This showed they had not memorised the definitions, but had learnt them with meaning. Learner performance increased by 25% in question 3 and 26% in question 4. Learners were then able to apply their understanding of area and perimeter to solve problems in all the other questions in the post-intervention assessment task.

It appeared that the focus on what area and perimeter entailed, rather than on how to find area and perimeter using formulae, contributed immensely to learners' understanding of the two concepts. Clements and Bright (2000) support this idea when they state that knowing what measurement entails is more important than knowing how to measure. The improvement in learners' performance could be attributed to the use of a *Geoboard*. This came out clearly when learners were interviewed. One learner said, "*I no longer have to memorise the formula to calculate area*" (FGLI). The use of different strategies to calculate area, in particular, also contributed to a shift in learning, because learners did not have to rely on formulae, which they forgot at times. Improvement in learner performance proved that the confusion between area and perimeter that had existed for the learners, was eliminated. It also showed that learners' reasoning and logical thinking skills had improved, because learners could construct their own knowledge.

4.4.1.1 Analysis of open-ended questions 1 to 4

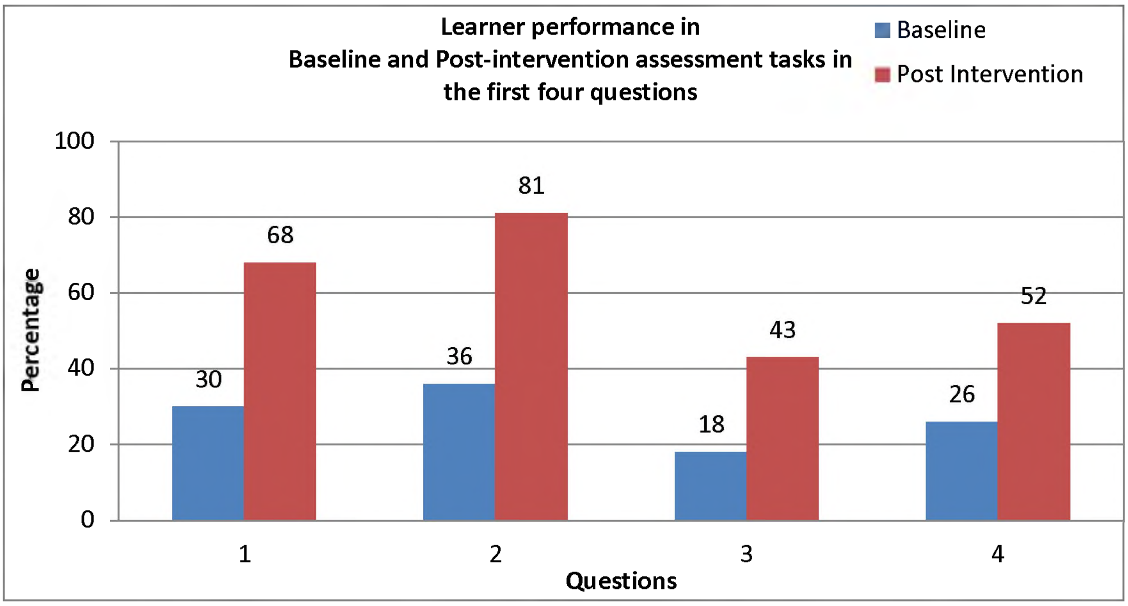

Figure 4.4.1.1 Average learner performance in the first four questions in the baseline and post-intervention assessment tasks.

In questions 1 and 2 of the baseline assessment task, 70% and 64% of learners could not define area and perimeter respectively. The post-intervention assessment task showed improvement in learner performance in the two questions. There was an increase of 38% and 45% respectively, in learners who could explain area and perimeter. In questions 3 and 4, learners were required to show their response to questions 1 and 2 by means of diagrams. In the baseline assessment task 82% of learners could not show their understanding of area as reflected in question 3, but this figure decreased to 57% in the post-intervention assessment task. Learner performance in question 4 of the baseline assessment task increased from 26% to 52% in the post-intervention assessment task. The post-intervention assessment task, as shown on the graph, showed improvement in both questions 4 and 5. It appeared that the *Geoboard* had helped the learners. In the interviews with the learners there was general consensus that the *Geoboard* had helped them see and count the squares on the shapes' surfaces and then relate them to the dimensions of the given shapes.

4.4.1.2 Analysis of questions 5, 6, 7, 10 and 14

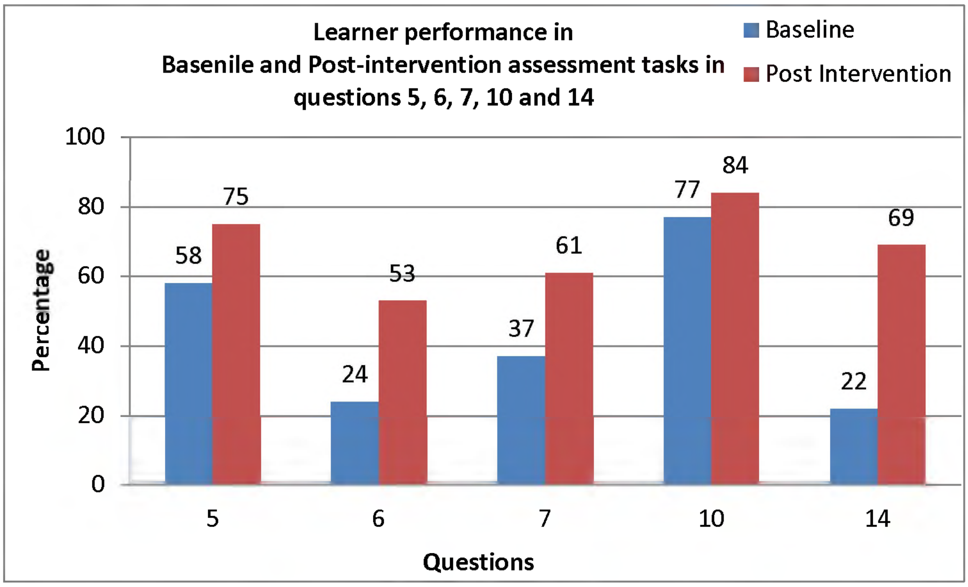

Figure 4.4.1.2 Average learner performance in certain questions in the baseline and post-intervention assessment tasks.

Figure 4.4.1.2 above shows learner performance in certain questions of both the baseline and post-intervention assessment tasks. In questions 5 and 7, learners were given dimensions of shapes and had to find the area and perimeter respectively. In the baseline assessment task leaners used the formulae to get their answers. In questions 6 and 14, learners were given the area of a square and a rectangle respectively. Learners were required to find the dimensions of each shape. The results in questions 5 and 7 showed that learners were used to situations where dimensions would be given and they would just use the formula to find area. In the baseline assessment task, it would appear that learners found it difficult to find the dimensions when given area, possibly because they were used to questions that require knowledge and routine procedure. It would appear learners were not familiar with questions that required constructive thinking. Simple procedure questions do not invoke leaners' creative thinking skills.

4.4.1.3 Analysis of questions 8, 9 and 11 as areas of concern

During the analysis of the baseline and post-intervention assessment tasks, a number of areas of concern were identified. Figure 4.4.1.3 below shows learner performance in such areas, in both the baseline and post-intervention assessment tasks.

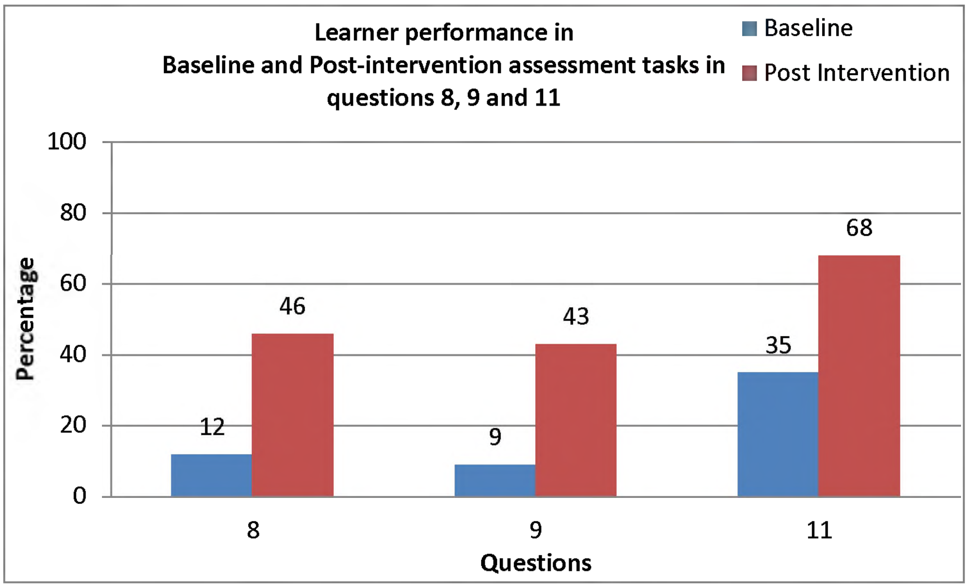

Figure 4.4.1.3 Average learner performance in questions of concern in the baseline and post-intervention assessment tasks.

Questions 8 and 9 were based on similarity and question 11 on enlargement, but still involved area and perimeter. The integration of similarity with area and perimeter was done so that learners could see the connection in mathematics topics. As reflected in Figure 4.3.4, the baseline assessment task showed poor learner performance in these areas. In questions 8 and 9 learners had to find perimeter and area of similar figures using the given information. The questions demanded some critical thinking, which learners seemed not to have. It appeared learners could not link area and perimeter to similarity. Such poor learner performance could mean that learners did not learn the topic with understanding. Although all the schools showed improvement in the post-intervention assessment task in these questions, more intervention in these topics is needed.

4.4.2 Analysis of control group performance

Figure 4.4.2a below shows the overall results of the experimental group's average performance in the baseline and post-intervention assessment tasks, compared to those of the control group. The aim of this analysis was to validate my analysis and add testimony to my claim that there indeed was a positive shift in performance as a result of my intervention programme.

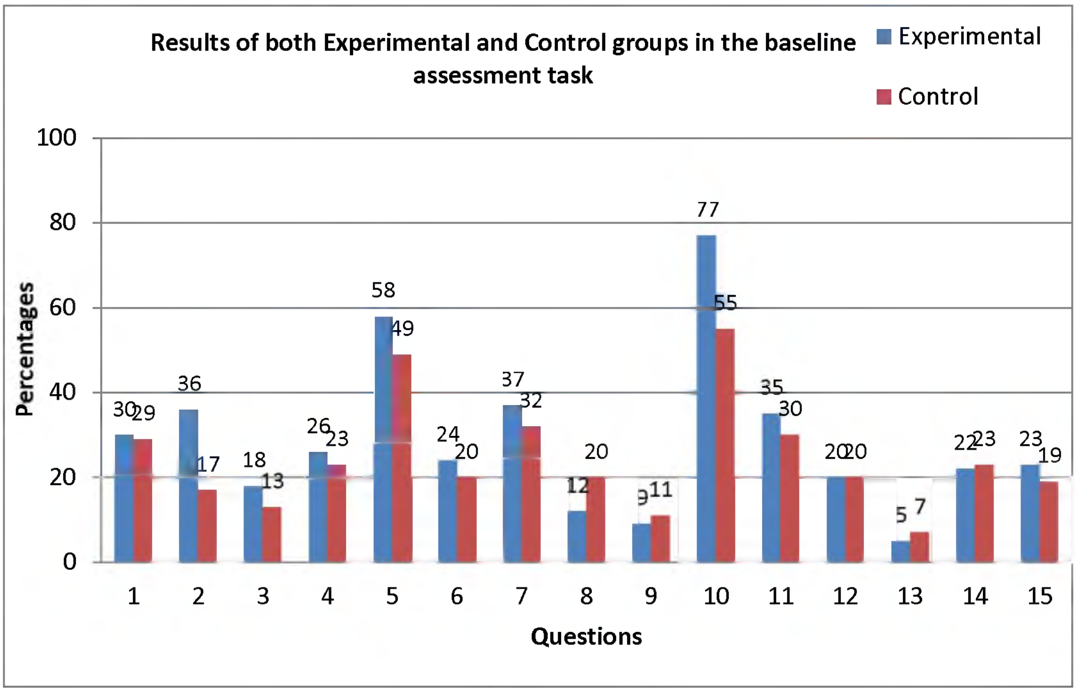

Figure 4.4.2a Results of the experimental and control groups' average learner performance in the baseline assessment task.

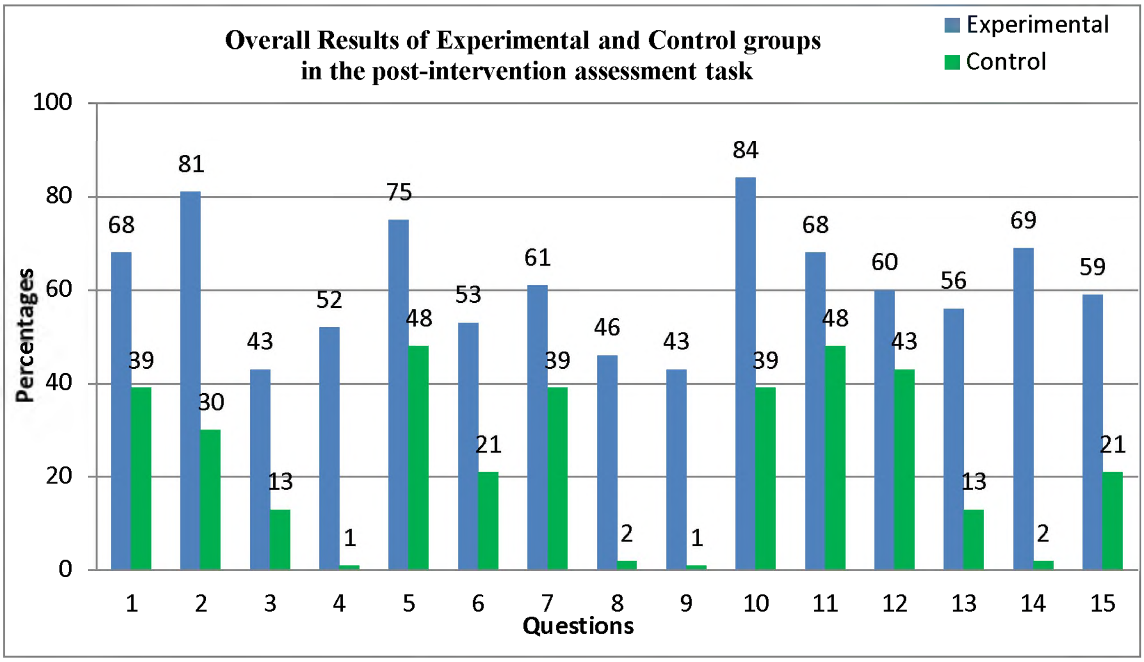

Figure 4.4.2b Results of the experimental and control groups' average learner performance in the post-intervention assessment task.

4.5 DISCUSSION OF THE PRE-INTERVENTION PROGRAMME

4.5.1 Brief description of the workshop

During Phase 2, a workshop was conducted for the participants at their respective schools and a learning programme was designed. A number of activities on area and perimeter were done with the participants. The aim of the workshop was to show teachers how to use the *Geoboard* to teach area and perimeter of two-dimensional shapes. A learning programme, as a guide for teachers, was also designed during this phase (see Appendix 4). In this section, I present how teachers engaged with the *Geoboard* as a manipulative during the workshop. The findings are based on my observations during the workshop as well as the information that I gathered during the design of the learning programme.

4.5.2 Some observations and reflections

The amount of work that teachers covered on area and perimeter before the intervention, as reflected in the learners' books, showed that the topic of area and perimeter was not taught properly. Since the topic starts in the Intermediate phase, teachers perhaps assumed that learners knew the concepts and therefore did not give the topic the attention it deserved. I discovered that more focus was put on the area of a rectangle, triangle and square. The CAPS document expects grades 8 and 9 learners to progress to the area of other two-dimensional shapes. I observed from my interaction with teachers that the CAPS document which prescribed the content to be taught per grade, was not always used by teachers. I discovered this when I asked teachers what CAPS prescribed for grade 9 with regard to area and perimeter. One of the teachers said, "*It's only Total Surface Area that grade 9 learners do*". Another said, "*it is the area of a triangle and circle that learners should know*". Only when they consulted their policy documents did they discover the amount of content on area and perimeter which they had omitted from their teaching.

As we designed the learning programme, I asked teachers about the background knowledge that learners should have, which would assist them to understand area and perimeter. One teacher said, "*learners should know the types of two-dimensional shapes*". She could not tell me what, on the topic of shapes, learners needed to know. From this, I gathered that the assessment of learners' prior knowledge, which would inform the teachers' intervention, was omitted by some teachers. This meant that there was no connection of topics. Teachers treated mathematics topics in isolation and this was how learners also learnt mathematics. As we designed the learning programme, the participants wondered how area, perimeter, transformation and similarity could be connected. One teacher said, "*I never knew that there was a connection between transformation and area and perimeter*". Another said, "*I have always thought that similarity is connected to congruency".*

Teachers would design learning activities in a fashion that did not arouse learners' curiosity and reasoning. For example,*" find the area of a rectangle with a length of 12cm and a breadth of 7cm"*, was a type of question teachers would ask. That is why when learners are asked for area, they often say "*it's length x breadth.*" The participants were puzzled to find that instead of giving learners dimensions to find, for example the area of a rectangle, they could actually be given an area and be asked to make many rectangles with the given area, as shown in Figures 4.5.1 and 4.5.2.

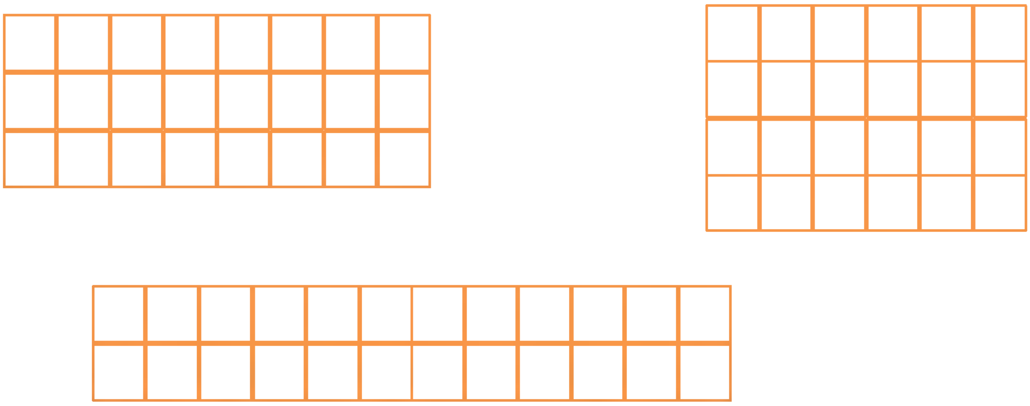

Figure 4.5.1 Rectangles with the same areas, but different perimeters

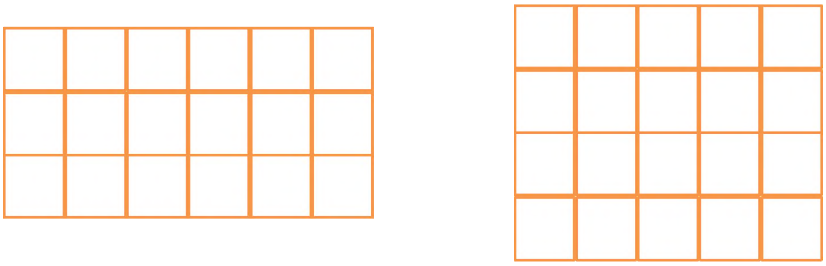

Figure 4.5.2 Rectangles with the same perimeters, but different areas

Teachers were given five minutes to do this activity, but they took about 15 minutes to complete the activity. Teachers struggled to make the shapes on the *Geoboard*, using the given information. The activity demanded some form of thinking and reasoning. There was an assumption from the teachers that if areas are the same, then perimeters should also be the same. *"I have always thought that shapes with the same area, have the same dimensions, hence the same perimeter. I have never asked learners to investigate the relationship between rectangles with the same areas and their perimeters or vice versa, because I never knew they would be different"*, one teacher said.

When doing activities on transformation, i.e. enlargement, I discovered that two teachers could not enlarge shapes using a scale factor. When the scale factor was 2, they simply extended each side by 2 units as shown in Figure 4.5.3.

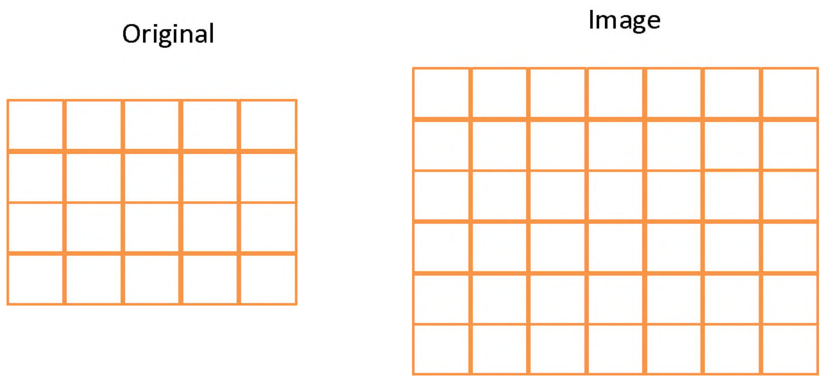

Figure 4.5.3 Misconceptions identified in enlargement

This meant that the area and perimeter of the image was not correct and as such the relationship between area and perimeter of the original shape and its image could not be established. The area and perimeter of the original shape was 20 square units and 18 units respectively, while the image had an area of 42 square units and a perimeter of 26 units. The participants could not connect the area and perimeter of the image to that of the original shape.

Another teacher had a challenge when the scale factor was less than 1, that is, when she had to reduce a shape. When given a scale factor of ½, she did not use the ½, but just divided each side of the original shape by 2 as shown in Figure 4.5.4 below.

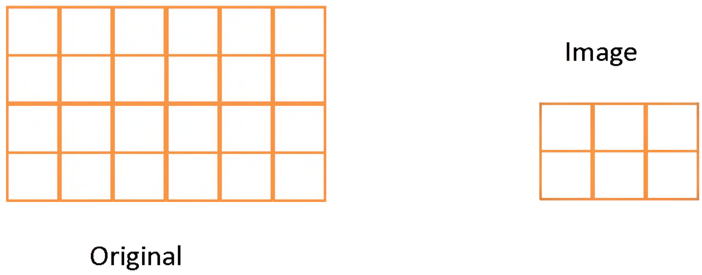

Figure 4.5.4 The original shape and its image after enlargement

The above teacher was adamant that she was correct, even though I tried to show her how reduction was done. It was only when she used the dimensions of both the image and the original shape to find the scale factor, using the scale factor formula, that she realised she was wrong. This showed how important sharing of ideas with other people was, because she could have continued imparting wrong information to learners, thinking she was correct.

Teachers unanimously agreed that they used concrete materials only when they taught fractions, 3-dimensional objects and place value. They all said it was the first time they had seen a *Geoboard*. The teachers saw the importance of using manipulatives to develop conceptual understanding of mathematical concepts. It became clear that teachers had never used any strategy other than the formulae for finding area and perimeter. They were excited to discover that there were other strategies like Pick's theorem and decomposition that could be used to calculate area. They admitted that learners should be exposed to as many strategies as possible and should be allowed to decide for themselves on the strategy they understood best. The different strategies helped teachers become more innovative as they planned their lessons. The investigation into the relationship between the area and perimeter of an original shape and that of its image, led them to designing other thought-provoking activities. In one activity, learners were asked to investigate the relationship between the scale factor used and the area of the image. This was something I had not thought of, meaning I had also learnt from them. Co-operative learning did not only take place between learners, but also between us as colleagues.

Before my intervention, I observed during the classroom visits I conducted that teachers would prepare two to three lessons on area and perimeter, but from the learning programme and the lessons the participants designed, they realised that more was involved in teaching area and perimeter. It became evident to them that in order to teach for understanding, they needed more than just three lessons. The learning programme also informed teachers about the concepts that learners needed to know before they were taught area and perimeter, which would have to be revised first. This, on the other hand, equipped them with the skill of planning their lessons for other topics. I also observed the enthusiasm of teachers when they had to teach the lessons as well as the confidence they had gained after the workshop, which inspired them to want to share the knowledge they had acquired not only with their learners, but also with other teachers. Teacher A said," *the knowledge I gained made me develop confidence in the teaching of area and perimeter"*. They asked if they could workshop other teachers on area and perimeter. Teachers' active involvement in designing the learning programme and in planning their lessons was an indication that they wanted to improve their learners' performance in this topic.

4.6 ANALYSIS OF THE FINDINGS OF THE INTERVENTION PROGRAMME

During Phase 3, the implementation phase, teachers presented their lessons to their learners. In this section, I present my findings on the intervention programme. I managed to observe four lessons per teacher, but for purposes of the study, the report covers only two of the lessons where the *Geoboard* was used. All the lessons were thoroughly prepared. Before teachers taught their lessons plans, they sent the lessons to me for scrutiny. Again, this showed that they were not the type of teachers who did not want other people to see or know what they did. They were open to suggestions and positive criticism as they believed this would help them improve their skills.

The teachers were excited by the activities they did during the workshop and this influenced their planning. It was observed that teachers put a lot of effort into the preparation of their lessons; the activities they designed for learners were testimony to that. Teachers did not only do the activities that we did together during the workshop, they also designed their own activities. This proved that they understood what we had done during Phase 2, when the workshop was conducted. It also showed their keenness for professional development as well as their positive attitude towards improving the teaching and learning of mathematics. Below is a brief description of what each lesson by the participants entailed.

4.6.1 Teacher A

Lesson 1

This lesson was about 2 hours long. The main focus of the lesson was the investigation of the area of a rectangle, square and triangle by using a *Geoboard.* A variety of strategies to find areas of two-dimensional shapes, including Pick's theorem, decomposition, and counting of squares and formulae, were used. What I liked most about Teacher A was the fact that she assessed learners' prior knowledge on area and perimeter. Learners could explain area and perimeter, because this had been done in the previous lesson. As a means of addressing learners' misconception on area as capacity, the teacher explained to learners what capacity is, by using a 500ml bottle. Learners explained to each other what they understood area to be.

To introduce her lesson, the teacher asked learners to identify the dimensions of the shapes they were given, which they struggled to do, because they did not know what the term "dimensions" meant. This prepared learners for the shapes they made on the *Geoboard*, where they were given different dimensions for each shape. The teacher drew different shapes, including a triangle, on the board and asked learners to mark their dimensions. Learners struggled to identify the height of the triangle. They referred to any of the three sides as a height. Through a number of questions such as, "*What should the height be in relation to the base?"* (TAL1), learners were able to identify the height. Learners were given dotted grids, where they drew different types of triangles and had to identify their heights.

Continuing the lesson, learners, in their groups, were asked to make triangles and quadrilaterals on the *Geoboard*. Learners counted the squares that covered the surface of each shape they made. They found the relationship between the squares on the surface of the shape and the shape's dimensions. This activity aimed at allowing learners an opportunity to think critically. It was not difficult for learners to see the connection between the dimensions of a square and a rectangle and the squares on their surfaces. For example, with a 4 × 4 square made by one group on a *Geoboard*, they answered 16 as the number of squares on its surface, which was its area. Learners were then asked what needed to be done to the sides to get 16 and members of one group agreed that 4 should be multiplied by 4 to give 16. All the groups that had made squares came to the same conclusion. From this, learners reached an understanding of why the formula for calculating the area of a square is side × side. Some of the learners confessed that they did not know how to investigate this formula. They said they always memorised the formula.

Learners had a challenge finding the area of a triangle. They counted half squares as full squares. For example, in the triangle below, all the groups gave 3 square units as the area.

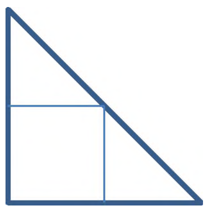

Figure 4.6.1a Calculating area by counting squares in a triangle

When asked to point at the squares, they also counted the small triangles as squares. The teacher took them back to the properties of a square. She asked the learners about the number of sides in a square. It was then that the learners realised they had made a mistake. The teacher further asked about the shape that would be formed if the two small triangles were tessellated. One learner said, *"Each triangle is half of a square, therefore the two triangles form a square*" (TAL1*)*. Learners could then see that the triangle's surface was covered by two squares. Learners struggled to see the relationship between the triangle's dimensions and the squares that form the area of the triangle. When asked to find the area of the triangle using the formula, all learners got 2 square units. This suggested that learners learnt the formula without meaning; hence they could not see the relationship between the dimensions and squares on the surface.

In order to address this challenge, the teacher asked learners to complete the different triangles they had made in their groups, to form quadrilaterals. She asked them to identify the quadrilaterals formed, which happened to be rectangles and squares. She further asked the groups to find the areas of these quadrilaterals. When the area of each quadrilateral was compared to the areas of the triangles that had formed it, learners discovered that the area of the quadrilateral was twice the area of each triangle that formed it. I heard one of the learners say, "*oh so it's half base x height*" (TAL1). This meant that even though learners knew the formula for calculating the area of a triangle, they did not know how it was derived.

Learners were asked to make rectangles with a given area, for example, a rectangle with an area of 24 square units. The aim here was to make learners aware that they would not always be given dimensions to find area or perimeter. As I moved around, I discovered that each group had made just one rectangle. The dimensions of the rectangles differed from one group to the next. The groups had formed 8 × 3; 6 × 4; 12 × 2 rectangles. When the groups presented their rectangles to the rest of the class, learners were amazed to discover that they could have come up with so many rectangles. It then became clear to them that shapes could have the same area, but have different dimensions. Learners were more amazed to discover that even the perimeters of their shapes were different. They then understood that the area of the shapes may be the same, but the dimensions would differ, and that would lead to the shapes having different perimeters. It was easy for learners to see the difference in perimeters, because the shapes were in front of them.

In addition to the counting of squares to get the area, learners were also introduced to Pick's theorem, which they were excited to know. After a number of activities with the teacher, learners mastered this strategy. They discovered that using different methods, i.e. Pick's theorem, counting the squares, or using the formula, all yielded the same answer. The teacher then asked them to make the triangle in Figure 4.6.1b on their *Geoboards*. She asked them to find its area using Pick's theorem. When I checked the groups, they had all given 3 as the answer, and they saw that this was different from what they had previously answered. When I asked them how they had reached their answer, one learner said, "*I counted the outer dots and I got 6 and then I halved 6 and I got 3. There are no inner dots, so I added 3 and 0 and I got*

3" (TAL1). The teacher tried to show the learners where they had gone wrong by doing the activity on the board. As she did it, learners realised that they did not subtract 1 from the inner dots, which was supposed to be (0–1) = -1. The difference of -1 was then added to 3 to give 2.

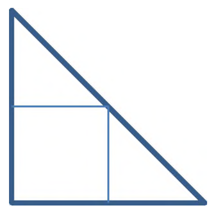

Figure 4.6.1b Calculating area by using Pick's theorem

Learners were asked to make both concave and convex shapes on their *Geoboards*, these included among others, trapezia, hexagons and pentagons. The teacher wanted learners to investigate whether Pick's theorem would work with such shapes. Learners found the areas of the shapes they had made on their *Geoboards*, using Pick's theorem. They then deconstructed the shapes and found the area of each portion. When they added up the areas of the portions, they reached the same value as when they used Pick's theorem. Learners saw that Pick's theorem worked with all types of shapes. This exercise showed the importance of exposing learners to many strategies. It also sharpened learners' investigative skills.

As some form of consolidation, learners did various activities where they used the acquired strategies to find areas of the shapes they made on the *Geoboards*. Learners shared ideas as they went through the various activities they were given, and they were happy to get the activities correct. Learners were so excited to have learnt the strategies, which meant they did not need to memorise any formulae. One learner, speaking on behalf of the class said, *"thank you very much for the Geoboard and these strategies, especially Pick's theorem, because now we do not have to memorise formulae"* (TAL1).

Lesson 2

The lesson, lasting about 2½ hours, was based on finding the area of both the original shape and its image and finding the relationship between the two areas. Learners made shapes on their *Geoboards*, which they then enlarged using a given scale factor. They found the areas of the two shapes, i.e. the original shape and its image. They further investigated the relationship between the original shapes and their images.

As part of her introduction, the teacher recapped the lesson on areas; making shapes on the *Geoboard*, she asked learners to use any strategy to find their areas. The confusion learners had had about area and perimeter became evident here. One of the learners found the area by counting the units on the boundary of the shapes, but this was corrected by other learners. Some learners calculated perimeter by counting the squares on the shape's boundary. This showed how important the assessment of prior knowledge was. This kind of misconception was rectified by the learners themselves. They used the *Geoboard* to show other learners the difference between the two concepts. This was an indication that co-operative learning took place.

To develop the lesson, learners were shown two figures, where one was an image of the other after enlargement. Learners were asked to find the relationship between the corresponding sides of the two shapes. Learners saw that the sides in the original shapes were multiplied by 2 to give the corresponding sides in the image. Learners found the areas of the two shapes using any of the strategies they had learnt. It surprised me to discover that none of the learners used the formula for calculating the area of a rectangle. They all used Pick's theorem to find the area and they displayed a high level of competency in doing so.

The challenge arose when learners had to investigate the relationship between the area of the original shape and that of the image. Although the question was rephrased several times, learners did not understand the question. After a number of thought-provoking questions, one of the learners said, "*the area of figure 2, which is the image, is 4 times the area of figure 1*" (TAL2). This learner tried to explain to others, but in vain. I intervened by asking a number of questions such as, "*What fraction is figure 1 of figure 2? How many shapes in figure 1 can cover the surface of figure 2?", a*fter which the learners saw what was meant by the relationship between the two areas. One learner said, "*the original shape is a quarter of its image*" (TAL2). Another learner said, "*to cover the surface of the image, we will need four shapes that are the size of the original shape*" (TAL2). Learners were given more activities of this nature and they could see the connection between the areas of the image and its original shape.

As further development, learners were given *Geoboards* on which shapes and their images had been made. They were asked to find the scale factor that had been used. Learners did not know how to find the scale factor until one learner looked at the corresponding sides and said, *" the sides of the original shape are multiplied by two to give the sides of the image, which means the scale factor is 2".* When asked to come up with another strategy of finding the scale factor, none of the learners could think of one, until one learner came to the board to show how he got 2 as the scale factor. He divided the lengths of the image by the corresponding lengths of the original shape, which were 6 ÷ 3 = 2 and 4 ÷ 2 = 2. I was quite impressed by the fact that there were learners who could find the scale factor, which showed that their critical and creative reasoning skills had been sharpened. I liked the investigative approach that the teacher used, because it made learners think and not depend on their teacher. Learners easily saw the relationship between the perimeters of the two shapes. They saw that when the scale factor was ½, the perimeter of the image was half that of the original shape.

Continuing the lesson, learners made their own shapes on the *Geoboard*, which they enlarged using the given scale factor. Learners in all the groups said the perimeter of the image was half that of the original shape. I asked them several questions to make them think deeply about what they were saying, but they still did not see that the order of their ratio was wrong. Only when they multiplied the dimensions of the original shape by the scale factor they had obtained, did they realise this did not give the dimensions of the image, as shown in Figure 4.6.1c.

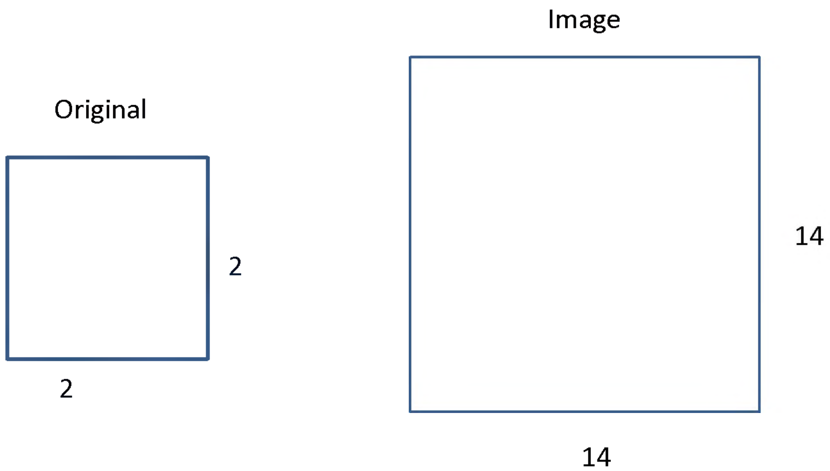

Figure 4.6.1c Misconception on finding the relationship between the perimeter of original shape and its image

Learners found the ratio of the dimensions of the original shape to the dimensions of the image as $2 : 14 = 1 : 7$. As a fraction the ratio became $\frac{1}{7}$. When learners multiplied the dimensions of the original shape by $\frac{1}{7}$, they discovered that the product did not give them the dimensions of the image, which was 14 units. They instead got $\frac{2}{7}$. Learners realised how important it was to write the ratio in the right order. When they expressed the ratio as the dimensions of the image to the dimensions of the original shape, they got the right scale factor.

To assess learners' understanding, the teacher swopped the dimensions of the image with those of the original shape, as shown in Figure 4.6.1d.

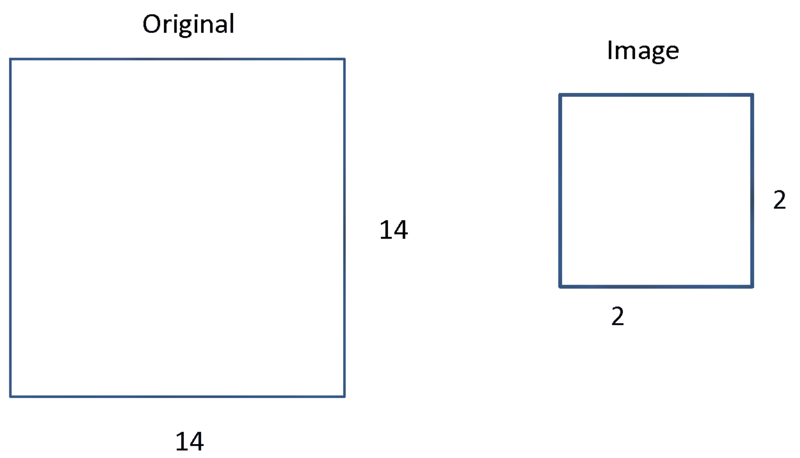

Figure 4.6.1d Finding the ratio of the dimensions of the original shape to those of the image

Learners found the ratio of the dimensions of the original shape to the dimensions of the image, but when they multiplied the ratio by the dimensions of the original shape, they did not get the dimensions of the image. They tried again by changing the order of the ratio; this led them to realise that they had to follow this order whenever they wanted to find the scale factor.

As part of problem-solving, the teacher asked the learners to investigate the relationship between the scale factor, the area of the original shape and the area of the image. Learners struggled to do this activity. One learner said, "*to get the area of the original shape the scale factor must be squared*" (TAL2). When this was tried out, it did not give the area of the image. After trying all the rules that learners came up with, and proving them wrong, the teacher asked a number of leading questions. Some learners saw that the scale factor was squared, but still could not connect that to the area of the original shape and its image. The teacher encouraged them to think critically. Learners were allowed some time to discuss in their groups and through the sharing of ideas, they were able to see the connection. One group came up with the rule: to get the area of the image, the square of the scale factor should be multiplied by the area of the original shape. When learners checked this against all the shapes they had made, the rule held true. Learners could see the connection because the shapes were on the *Geoboard* and they could relate them to what was under discussion.

To consolidate the lesson, the teacher made several shapes and their images on different *Geoboards*. She asked learners to determine the dimensions of both the original shapes and their images. Learners then determined the relationship that existed between the area and perimeter of the images to the area and perimeter of the original shapes. Since the dimensions of both shapes were given, it was not difficult for them to determine the relationship between the area and perimeter of the image to that of the original shape. The teacher and I circulated among the groups to see if cooperative learning had taken place. From the responses we got from the learners, we concluded that learning had indeed taken place and the teacher was happy that learners had understood.

4.6.2 Teacher B

Lesson 1

In this lesson, lasting two hours, learners were introduced to the different strategies of finding the areas of two-dimensional shapes, including both concave and convex shapes. Their understanding of area and perimeter had been assessed in previous lessons.

As part of the introduction, learners were asked to make different shapes on their *Geoboards*. They were then asked to find the areas of the shapes they had made. I found that all the learners used the formulae to find the area of a square, rectangle and triangle. They did this by counting the units on the vertical and horizontal sides of the shapes they had made. Learners had no problem finding the areas, since they had already done this in previous lessons. The only challenge they had was finding the areas of concave shapes. They said they could not find the length and the breadth of these shapes.

As a means of addressing the problem, the teacher first asked learners to count the squares on the shapes' surfaces. She started with easy convex shapes like the square, rectangle and triangle. Learners accurately counted the squares, but took time to see the relationship between the number of squares and the dimensions of the shapes. After a number of probing questions by the teacher, learners were able to see the connection between the dimensions and the squares on the surface of each shape. A problem arose where some squares were not full squares and some shapes were concave. Learners could not find the area of such shapes; they did not know what to do. Learners were asked to identify parts that they could put together or tessellate to get full squares. Learners found it easy to put half squares together, but were challenged when it came to other fractions of squares. The teacher reminded them of a jigsaw puzzle and asked them to look for pieces, which could be joined to form a square. Learners were shown this on a dotted grid, where pieces were cut out and tessellated. It was only then that learners understood what was expected of them. After a long struggle, learners managed to identify the pieces on the *Geoboard* that could be tessellated to form squares.

The teacher introduced the second strategy where learners had to deconstruct the shapes into other shapes such as squares and triangles. Learners discovered that even though they had deconstructed their shapes differently, using different colours of elastic bands, they still arrived at the same number of squares as an area for a particular shape. Learners who used the formulae for the trapezium and parallelogram were surprised that they all got the same answer. Learners learnt that there was no one way of doing things.

Learners were then shown how to use Pick's theorem to find the area of two-dimensional shapes and were excited to discover another strategy for finding area. This gave learners a variety of strategies to choose from, rather than relying solely on one strategy. Learners enjoyed using Pick's theorem, because it gave them the same answer as when they used the formulae and when they counted the squares. Whenever they were asked to find area, they used Pick's theorem. Learners began to realise that they could find the area of any shape, irrespective of what it looked like; they admitted that prior to this lesson, they had only been able to calculate the area of a square, a rectangle or a triangle, and only by using the formulae, thus, their knowledge had been broadened.

To consolidate the lesson, learners were given a variety of activities. They made their own shapes on the *Geoboard* and then found the shapes' areas, using the strategies they had learnt. From the learners' responses, I observed that they no longer confused area with perimeter. As learners shared ideas in their groups, I could see that there was co-operative learning taking place.

Lesson 2

This lesson was based on investigating the relationship between the area and perimeter of original shapes and their images. Learners transformed shapes through dilation and then compared their areas and perimeters. The shapes that learners transformed were made on the *Geoboards*. They also found the scale factors that had been used to enlarge given shapes and then compared their areas and perimeters. The lesson took about 2¼ hours.

The teacher introduced her lesson by assessing learners' prior knowledge on area and perimeter of geometric figures, which they had already been taught in the first two lessons. She first checked whether learners could plot points on the Cartesian plane, thereafter she used the *Geoboard* to represent the first quadrant of the Cartesian plane. Learners had no problems plotting the points. The points were joined by rubber bands to form shapes. Learners, in their groups, found the areas of all the shapes they had made on the *Geoboard*, which they did without any signs of difficulty.

Learners then transformed the shapes they had made and compared the areas and perimeters of the original shapes to those of their images. Since learners were already familiar with transformations, they could easily transform the shapes. Learners did not encounter problems with finding the areas of the original shapes and their images; they simply counted the number of squares on the shapes' surfaces. Learners experienced problems with perimeter, since some shapes, like the trapezium, had diagonal sides and this was handled later in the lesson.

I liked the idea of linking what had been done earlier to the new concept. Learners could see the connection between the two concepts. The teacher asked learners about the relationship between the area and perimeter of the original shape and its image. Learners said, "*both shapes have the same area and perimeter*". The teacher further asked, "W*hy has there been no change in the area and perimeter of the original shape and its image*?" (TBL2) Although it took time for learners to respond, one learner said, *"the shape and its size have not changed*". I liked the learners' involvement in the lesson and engagement by the teacher. They were encouraged to talk and share ideas.

To develop the lesson, the teacher asked learners to make shapes on their *Geoboard*s, which they enlarged using given scale factors. Transformation through enlargement was not a challenge, especially where the scale factor was a whole number. As I moved around the groups, I discovered that some learners started counting from 0 and referred to 0 as 1. This was rectified by other learners by demonstrating to the whole class how they were supposed to count. Learners knew that they had to multiply each dimension by the given scale factor to get the dimensions of the image. The challenge came when the scale factor was a fraction. It appeared the teacher herself had a challenge with that. Instead of multiplying by the scale factor, she divided each side by the reciprocal of the scale factor. Although she got the dimensions of the image right, she discovered that when she used the same dimensions to get the scale factor, that did not give her the right scale factor. I intervened by showing her how to reduce a shape and that gave us the right scale factor. I stressed to both the teacher and the learners that the scale factor should be read as the ratio of the dimensions of the image to the dimensions of the original shape. After a long discussion, during which she used the formula for the scale factor and substituted the dimensions of the two shapes, the teacher realised that her interpretation had been wrong.

Learners then compared the areas and perimeters of the original shapes with those of their images. When asked about the relationship between the original shape and its image, learners said the sizes of the shapes were different and the areas and perimeters were also different. They could not state in what way they were different. One of the learners' responses was, "*the original shape's area is twice that of the image*". This showed that learners were confused, because when the teacher asked them for the area of each shape, they realised their response was wrong.

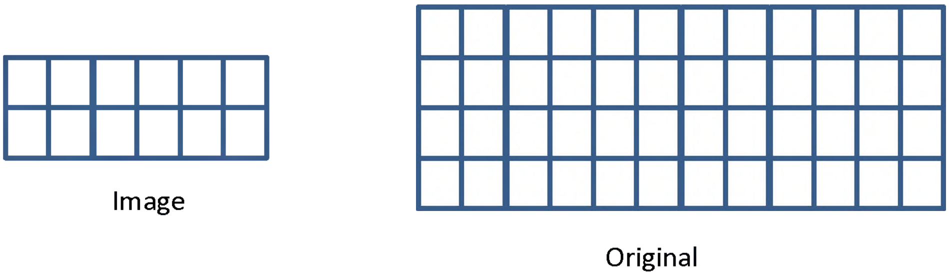

Figure 4.6.2 Misconception on the relationship between the area of the original shape and the area of its image

I intervened by asking learners that "*if you were to tile the surface of the original shape, how many of the tiles of the same size as the image would you need?*" (TBL2) Learners struggled to conceptualise this, but after some explanation, some learners understood my question and said I would need 4 tiles. I then asked the learners the fraction that the image was of the original shape. After some deliberations, one learner told me that it was a quarter of the original shape. I asked the learner to demonstrate what he meant to the rest of the class, who then grasped the concept. Co-operative learning was helpful, because learners understood better when something was explained by their classmate.

To consolidate the lesson, learners were given a number of group activities on enlargement. They were then asked to investigate the relationship between the areas of the original shape and its image. I moved around to check how the groups tackled the activities; I observed that in most cases they had understood, but where not, called upon the teacher for clarification.

4.6.3 Teacher C

Lesson 1

The teacher's progress was slow, compared to the other two participants. Learners took time to understand. This was due to the fact that the class also had learners with learning difficulties.

This was a consolidation lesson, where learners were given a variety of activities on area and were asked to find areas of the shapes they made on the *Geoboard*, using the different strategies they had learnt. To introduce the lesson, the teacher recapped by asking learners to count the squares on the surfaces of the shapes they had made on the *Geoboards*. The aim was to assess if learners still remembered that the counting of squares on the surface referred to area and the distance around referred to perimeter. Indeed, learners could differentiate between the two concepts. Checking on learners' prior knowledge is vital, because it informs someone's intervention.

Learners could identify the shapes they had made, but did not know their properties. For example, they referred to the trapezium as "*a shape with two equal sides*". Others said, "*it has opposite sides that are equal*". Learners did not know the difference between a rectangle and a trapezium. Some of the squares on the shapes' surfaces were not whole, as shown in Figure 4.6.3a, and learners struggled to find the area. Some learners counted them as full squares, giving the answer as 12 square units. Others counted only full squares and left out those that did not form squares, giving the answer as 8 square units. The teacher rectified this by asking learners to define a square. She also reminded them that the surface could not be only partly covered. The learners realised that their counting of the squares was incorrect. They did not know which parts to tessellate to come up with squares. Through the teacher's guidance, learners were able to identify the parts that would form a square. This showed that learners sometimes respond to questions without using reasoning.

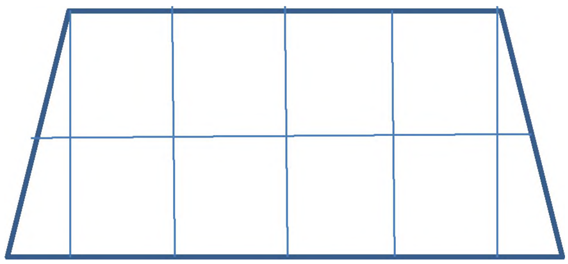

Figure 4.6.3a Calculating area by counting squares in a trapezium

Learners were asked to calculate the area by using the formula and then compare their answers to those calculated earlier. Learners knew the area formula for a square, rectangle and triangle, but did not know the formula for the area of a trapezium. They had not progressed from the Intermediate phase to the Senior phase level. The teacher had to show them the formula and then asked them to identify the parallel sides and the heights of the trapezia. Learners could identify parallel sides and heights because they had done this previously. Learners used the strategies learnt earlier, which included deconstruction and Pick's theorem. Learners found that the answer was the same as when they counted the squares. That motivated them to do further activities.

To consolidate the lesson, learners were given areas of different rectangles and asked to make such rectangles on the *Geoboard*s and determine the dimensions. It took learners time to understand the question; they wondered how they would get dimensions. One group managed to make a rectangle with an area of 6 square units, using 1 and 6 as the dimensions. This helped another group to make a rectangle using 3 and 2 as the dimensions. Learners learn better from each other, so their teacher asked those who understood to explain to the rest of the class why they decided on the dimensions they used. When finding the perimeter of their rectangles, they discovered that their perimeters were different. Learners were surprised to see that the perimeters were different, even though they had the same area. From the activities they were given, learners realised that rectangles may have the same area, but different perimeters. I liked these activities, because they made learners think critically. Learners were also actively involved in the lesson.

Lesson 2

The lesson was about two hours long; it was based on finding the area of each enlarged shape and comparing that to the area of its image. The aim was to show learners that the concepts of area and perimeter could be integrated with other concepts within mathematics. It was hoped that this would help learners see connections in mathematics. Learners enlarged and reduced shapes that they made on the *Geoboard*. They then found the relationship in both the areas and perimeters of the original shapes and their images. As a way of reminding learners about dilations (enlargement and reduction), the teacher showed them a picture of a bee that had been reduced. She then asked them what they noticed in the picture. The learners' response was that, "*it is still the same bee, but different in size*". To introduce the lesson, the teacher gave learners grid papers. They drew squares of their own sizes and reduced them using a given scale factor.

I observed from the example the teacher did on the board that she had misconceptions about enlargement. When she enlarged a 6 × 2 rectangle, she extended each side by 2 units to produce an 8 × 4 rectangle. Her learners, naturally enough, copied this. I had to intervene by demonstrating to the class how enlargement is done. By practising with a number of given activities, learners could confidently enlarge the shapes they had made. From this, I picked up the importance of ongoing teacher development, as well as the sharing of ideas, to help teachers identify and rectify their misconceptions.

Learners were then required to find the relationship between the area of each shape and its image, which they struggled to do. With a 4 × 2 rectangle, which was enlarged by a scale factor of 2 to give an 8 × 4 rectangle as in Figure 4.6.3b, some learners said, "*the area of the image is three times the area of the original shape*". Others said," the area of the image is twice the area of the original shape". This again showed that learners responded without thinking.

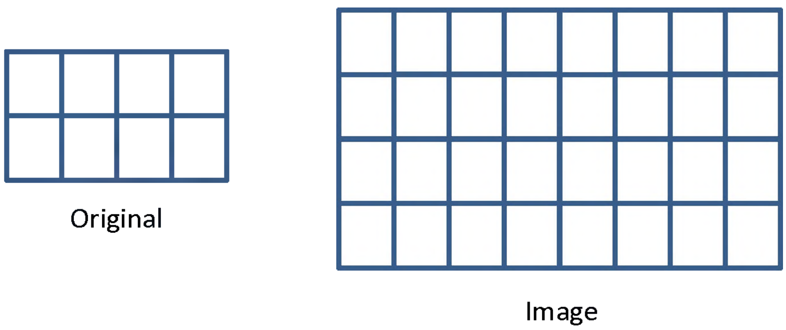

Figure 4.6.3b Finding the relationship between the area of the image and the area of the original shape

Learners were asked to count the squares in both shapes. A number of questions were asked, such as, "*what should happen to the squares in the original shape to give the squares in the image?*" (TCL2), and "*how many of the rectangles of the same size as the original shape could cover the surface of the image?*" It was not easy for learners to understand this, but after some explanation they said, "*to get the area of the image, the area of the original shape should be multiplied by 4.*" Those learners who still could not understand were helped by others, which meant that they learnt from each other. The amount of time that learners took to see the relationship could mean that they were not used to this investigative type of questioning.

I then asked the learners the fraction that the area of the original shape was of the area of the image. By so doing I wanted to check if learners could connect what they said about fractions. They said it was a quarter, which made me think that they knew the fraction concept as part of a whole. Although it took learners time to see the relationship, they ultimately saw that the perimeter of the image was twice that of the original shape. Learners were able to see the connection between the scale factor they used and the dimensions of the image. This meant that learners' reasoning and investigative skills had been developed.

Learners made shapes on the *Geoboards* and then reduced them using the given scale factor. They still remembered that each side of the original shape should be multiplied by the scale factor and thus could easily find the dimensions of the image. A challenge was experienced with the trapezium, where only one side of the parallel sides was multiplied by the scale factor. Learners saw their mistake and rectified it. After a number of questions, learners were able to see the relationship between the dimensions of the image and those of the original shape. Learners continued establishing the relationship between the area and perimeter of the image and those of the original shape. Learners managed to work on their own to find the relationship, although they took more time than anticipated. This meant that learners need more practice on such activities. Learners showed a high level of competency; they knew what to do with squares that were not full squares.

It appeared learners found the exercises challenging and interesting. They were asked to reflect on what they had learnt, and replied, "*we are happy with doing enlargement with area and perimeter, it's something we have never done. The strategies we used have helped us. We have never done the area of other polygons, it's only the square and rectangle that we did.*" This showed how much learners had gained from the lessons.

4.6.4 Synthesis of all the lessons

In all three schools, some learners had an idea of area and perimeter, but could not correctly define *area*, in particular. Some learners simply gave examples such as, "*if a rectangle has a length of 6cm and a breadth of 2cm, then its area will be 12 cm^2*". Others referred to area as "*a capacity of a shape*" or as "*the amount of space inside the shape*". Learners did not understand why area is calculated in square units. Some said, "*area is length × breadth*" while others said, "*the area of a square is side × side*". They referred to perimeter as the "*distance around a shape*" or "*outer boundary of a shape*". When asked to show their understanding of the two concepts using the shapes they had made on the *Geoboards*, they could not. It appeared learners did not learn the concepts with understanding.

Figure 4.6.4a was what some learners made on the *Geoboard*. They referred to the area as 3cm × 2cm, but could not explain why.

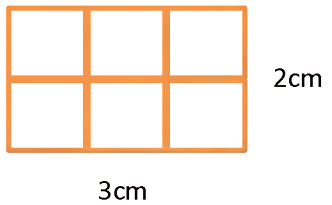

Figure 4.6.4a Finding area, but could not explain own solution

Some learners said perimeter was the squares on the edges, so they gave the perimeter of the shape shown in Figure 4.6.4b below as 16cm. This kind of misconception came up at all the schools and learners were adamant that they were right.

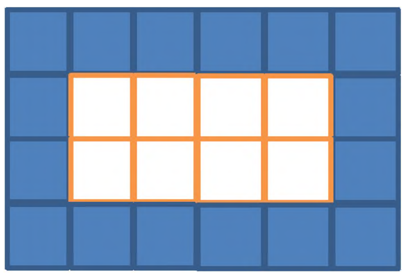

Figure 4.6.4b Misconception on finding perimeter

From this, I gathered that learners did not know area and perimeter. They did not know how the various formulae for areas of two-dimensional shapes were derived. They could not relate the squares on the surface to the shape's dimensions. I picked up that some learners did not see any difference between 108cm and 108cm^2. The confusion that learners had could be attributed to the fact that teachers went straight into the formulae, without first helping learners understand what each concept meant. This led to the activity where learners had to investigate the area of a square, rectangle and triangle. Learners used the *Geoboard* to investigate the areas of the latter shapes and in each shape, they counted the squares on its surface and related that to the shape's dimensions. This helped learners see how the formulae for the area of a rectangle, square and triangle were derived.

Learners should be given time to play with shapes in order to understand why the formulae work. Before delving into abstract mathematics, learners must be allowed to work with manipulatives as a way of enhancing their understanding of a particular concept.

During the intervention programme I noticed that teachers did teach for understanding, which led to retention of information. This was observed throughout the lessons. In their reflections learners said, "*the Geoboard helped us understand the two concepts better*". Learners could relate to what they had learnt previously. The activities that teachers designed broadened learners' knowledge of area and perimeter as well as other concepts within mathematics. Initially learners could not connect what they did to other topics, but by the end of the lessons they were able to make connections. The manipulation of the *Geoboard* brought clarity to the misconceptions learners had. The *Geoboard,* as a manipulative, gave learners an opportunity to reflect on their experiences, as stated by Seefeldt and Wasik (2006). Learners were able to construct their own knowledge on how to find the area and perimeter.

Learners did not know that a rectangle with, for example, an area of 24 square units, could have different perimeters. This aroused their interest and excitement, because they thought that they could make only one rectangle with such an area. All learners agreed that this was something new that they had not learned before. In all the schools, learners worked in groups. I observed that learners helped each other, and learnt from each other. The active involvement of learners within the groups showed that the groups were not just formed for purposes of grouping learners, but for learners to share ideas and learn from each other and this lessened the burden on the teachers. I liked the idea of teachers moving around the groups trying to assess learners' understanding and helping where necessary. I observed that learners were more investigative; they could construct their own knowledge. Seefeldt and Wasik (2006) argue that the use of mathematical manipulatives helps learners construct their own understanding. This meant that learners' investigative skills had been sharpened, because they constructed their own knowledge. Van de Walle (2004) states that it is very important that learners become actively involved in the lesson, because if their minds are not actively thinking, no learning can take place. He further states that to construct and understand a new idea, active thinking about the idea is needed.

In all the schools, learners had a challenge finding the area of a triangle, especially where some of the squares were not full squares as shown in Figure 4.6.4c.

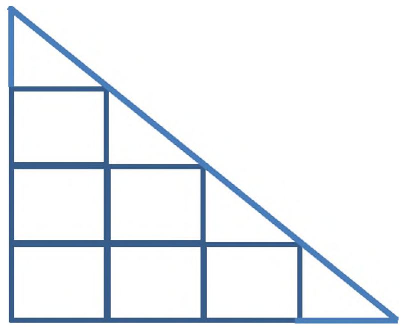

Figure 4.6.4c Errors identified while finding area by counting squares

Some learners said the area was 10 square units, while others said 6 square units. The same thing was observed with the grade 6 benchmark tests that RUMEP administers annually. To address this, learners were referred back to the definition of a square. They were asked to think of what could be done to the other parts to make full squares. This was quite difficult for learners to understand. The teachers and I moved from one group to the next trying to explain this. A square grid was also used to bring more clarity. After a number of questions, learners were able to identify the parts that could tessellate to form a square. Learners thought that the only way one could find the area of a triangle was to use the formula. Reliance on formulae inhibits learners' critical thinking, as was observed in the latter exercise.

Learners had a challenge when they were asked to make types of triangles other than the right-angled triangle on the *Geoboard,* as reflected in Figure 4.6.4d. They struggled to find the parts that could be tessellated to form squares.

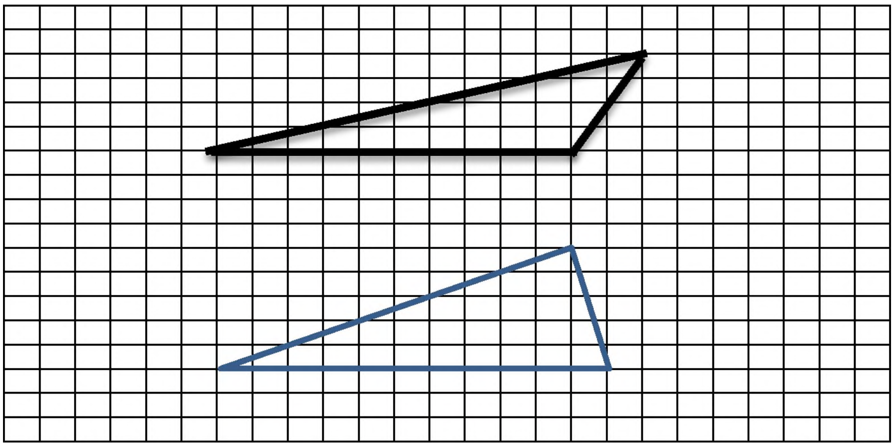

Figure 4.6.4d Problems with identifying the height of a triangle

The teachers and I helped learners to identify the various parts that could form squares. They checked the answer they got for the area by using the formula for the area of a triangle and indeed they were correct, although it took them time to identify the height of the triangle. From this interaction with the learners, I realised that the geometry of straight lines was another learning barrier for learners. In one of the workshops I conducted for the cluster teachers, one of the teachers said, “I do not do geometry with my learners, because I do not know it”. Many other teachers at the workshop attested to this.

The use of a variety of strategies to find area of two-dimensional shapes excited learners at all the schools. One learner said, “*we are happy that we do not have to use the formulae to find area*” (FGLI). The strategies included the counting of squares, deconstruction of a shape and Pick’s theorem. What excited learners about these strategies was the fact that they could be applied to any shape. There was more meaning attached to what learners did than when they used formulae, so effective learning took place. All learners enjoyed Pick’s theorem, because in almost every activity involving finding the area, this was their method of choice. This showed how important it was to expose learners to different methods.

As a form of integration, activities on similarity where area and perimeter were involved, were given to the learners. Figure 4.6.4e is an example of what learners were given, with shape 1 having an area of $6cm^2$ and the area of shape 2 being required to find.

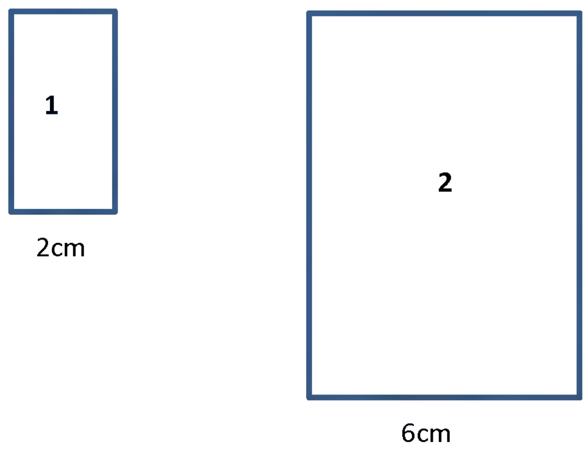

Figure 4.6.4e Using similarity to find area and perimeter of the two shapes

Learners had no idea what was expected of them. They did not know how to find area when given only one dimension. They did not see any connection in the dimensions of the two shapes and the given area. Lack of creative, critical and logical thinking on the part of the learners became clear in this activity. The teacher had to recap on similarity, but it became clear that learners had not done the topic earlier. I learnt from the teacher that the challenge was not as a result of forgetting, but that they had not been taught. They had scant knowledge of what was meant by similar figures. It meant that curriculum coverage was a challenge for teachers.

I observed that although many learners were in grade 9, their mathematical proficiency in area and perimeter was still at the grade 6 or 7 level. It appeared to me that the teachers did not appreciate sufficiently that their learners' progress should keep up as the curriculum progressed from one grade to the next. I also observed that teachers did not connect their topics; this could be due to poor planning. This resulted in some topics prescribed for the grade not being taught when teachers ran out of time. Planning was a major challenge for the teachers. I observed this at the cluster schools during classroom support visits as well as with students at RUMEP. Teachers did not know how to plan their work and as such I found that there was no progression in what they taught. If teachers planned their work, they would know the topics to connect. Planning helps teachers know in advance the kind of manipulatives they would need for a particular topic and also determines the relevance of such manipulatives in the lesson to be taught. Lack of planning leads to poor designing of activities that are intended to help learners with understanding. Poor planning also makes it difficult for teachers to reflect on their teaching and learners' learning. Participants had challenges planning their lessons; they did not know where to start and I had to assist them.

The questions teachers asked learners were often not thought-provoking. I had to intervene in order to be sure that learners understood. The cognitive levels, as prescribed in the CAPS when one assesses, were not taken into consideration (South Africa, DoE, 2011). It could be that teachers did not fully understand the cognitive levels. In one of the clusters, teachers wanted a workshop on cognitive levels, saying they did not know what they entailed. The assessment tasks in the form of classwork, assignments, tests and examinations that teachers set for their learners attested to this.

Conversion from one unit of measurement to the other was also a challenge. Learners were given the area of a rectangular plot made on the *Geoboard* as $600m^2$, and were asked to convert it to millimetres. Learners are taught conversions from the Intermediate phase. I thus assumed that all learners would answer this question correctly, but to my surprise only 51% of the learners managed to do the conversion. At all the schools, some learners simply multiplied the given area by width of 15m to get 9 000m, which they referred to as the length of the plot. This was clear evidence that learners had no conceptual understanding of what they did. They could not connect their answers to what they were given. The benchmark tests that I administer annually at the Collegial Clusters also revealed that learners struggle with conversions. To address the challenge of conversions, teachers asked those learners who showed an understanding, to help other learners. This was a way of promoting co-operative learning among learners.

Learners were asked to make regular pentagons and hexagons on their *Geoboards*. They simply made these shapes without taking into account the fact that they had to be regular, meaning they did not know what regular shapes were. To address this, learners were given a worksheet, where they measured the sides and the angles of the shapes that were drawn. Learners categorised the shapes according to their sides and angles, grouping those with equal sides and equal angles. Some shapes had both sides and angles equal, while others had unequal sides and unequal angles. The terms *regular* and *irregular* were discussed and investigated; thereafter learners were able to identify regular shapes on the *Geoboard*. The activity that learners were given on regularity of shapes was the third highest in terms of learner performance. The explanation that learners were given improved their performance, which otherwise would have been 0%.

The other challenge learners had was enlargement, which was integrated with area and perimeter. On their *Geoboards* learners made images of the shapes they were given. Some learners divided the given dimension (2) by the scale factor of 2 and got 1, which they referred to as the length of each side of the image. Others added the scale factor to 2, which was the dimension in the original shape and got 4. The learners explained that to them, enlargement meant extending each side by the given scale factor, i.e. 2 units. I asked them what would happen if the scale factor was 3, they said, "*you would add 3 to the given dimension of the original shape and that would give the dimension of each side in the image"*. Clearly the learners had misconceptions about enlargement. One of the three teachers had the same misconception as these learners. Prior to this, I had conducted a workshop for all the cluster schools, during which it emerged that several teachers found enlargements to be a challenge. I decided I would workshop this topic as there was obviously a need for professional development of teachers in such topics. Some cluster teachers once said, "*we don't know transformation because we were not taught*". Although I did address the misconceptions with the teachers concerned and with the cluster schools, more intervention was needed, as other teachers had the same misconceptions.

At all three schools, learners did not understand the question on ratio, where they had to find the ratio of the area and perimeter of the original shape to the area and perimeter of its image. The teachers and I explained the concept, using examples such as, "*if I am 30 years old and Lizo is 15 years old, how is Lizo's age in relation to mine?*" or "*Kuhle has R25 and Sethu has R75, how much does Kuhle have in relation to what Sethu has?"*. Ratio is supposed to be taught from grade 6 as prescribed by CAPS. The fact that all learners at all the participating schools did not know it, could mean that it was taught in a manner which was difficult for learners to understand.

Lastly, I observed that learners generally have a challenge with geometry, meaning that more intervention is needed on the topics of space and shape and measurement. Teachers spend more time on numbers at the expense of geometry (RUMEP's Annual Report, 2013). I also observed that many of the teachers' assessment tasks were on numbers. The analysis of ANA results in 2013 also revealed that learners perform poorly in Geometry.

I also noticed that the teachers' participation in this intervention was quite onerous. As a result of their participation they often had to make other arrangements to catch up the time spent on this project, demonstrating commitment and dedication to their work. The participants were very keen to share their experiences of using the *Geoboard* with other teachers within their clusters, even before this study came to an end.

4.7 ANALYSIS OF THE SEMI-STRUCTURED INTERVIEWS

The interviews that were conducted with teachers were semi-structured. Ten questions were pre-prepared for the interviews, as well as follow-up questions. The interviews were recorded and transcribed. In this section, I present questions that were asked during the interviews as well as the teachers' responses. Since the study did not focus on learning, I only present a brief overview of learners' responses during their interviews. This is then followed by a general discussion on the interviews.

Similarities and differences were picked up from the teachers' responses to the interview questions regarding their experiences on the use of the *Geoboard* as well as the role it played in the teaching and learning of area and perimeter.

4.7.1 Question 1 (RQ1)

Do you normally use manipulatives, i.e. concrete materials to teach mathematics in your class and when do you use them?

All the teachers said they used manipulatives when they taught certain topics in mathematics. They further said that they used concrete materials to teach the properties of 3-D objects. Teacher B said, "*I use concrete materials when I teach volume, fractions and graphs*". Teacher C said, "*I use manipulatives to teach the total surface area of objects. I use manipulatives when I want to involve learners in my lessons*".

4.7.2 Question 2 (RQ2)

How do you find teaching mathematics using manipulatives?

All the teachers said manipulatives led to better understanding of the concepts taught.

Teacher A said, "*I find manipulatives helpful, because learners can actually see what is being talked about and manipulatives make learners perform better.*"

Teacher C said, "*There is a great difference in learners' understanding when manipulatives are used than when they are not used*". She further said, "*manipulatives make learners actively involved in the lesson.*" She commented that concrete materials made the lesson practical and learners had an opportunity to touch the objects.

It was clear that manipulatives improved understanding of concepts and encouraged active involvement of learners. .

4.7.3 Question 3 (RQ3)

Have you ever used a *Geoboard* to teach area and perimeter?

All the teachers said they had never come across a *Geoboard* and had therefore never used it in their teaching.

Teacher A said, "*I simply heard about it from a teacher at a workshop. I was told it is making maths easy for learners.*" She said her curiosity was aroused and she was very keen to see and use it.

I discovered that the grade Rs at school B had *Geoboards*, but Teacher B did not know about them. This could mean that there was no co-operation between Foundation phase teachers and other teachers within the school. Despite teachers having more than 10 years' experience, they had not seen nor used a *Geoboard*, yet it is simple to construct.

4.7.4 Question 4 (RQ4)

How do you feel now that you have used a *Geoboard* to teach area and perimeter of two-dimensional shapes?

Teachers C and B both said the *Geoboard* made it easy for their learners to calculate area and perimeter with understanding.

Teacher C went on to say, "*the Geoboard helped me develop confidence in teaching area and perimeter*". She further said, "*learners did not have to memorise the formulae*", referring to the trapezium and other shapes. "*The practicality involved when using the Geoboard helped learners retain information, because there was meaningful learning*", she said.

Teacher A said, "*the Geoboard made the teaching and learning of mathematics interesting and learners could see what they talked about. Learners enjoyed forming shapes on the Geoboard*".

From these responses, one can conclude that the use of the *Geoboard* did not only help learners, it also helped the teachers. "*Some of the things that I was not sure of or did not know, have been clarified and made easy to understand*", said Teacher A.

4.7.5 Question 5 (RQ5)

How do you feel about the other strategies that you learnt for calculating area and perimeter?

All teachers agreed that they, along with the learners, had enjoyed the new strategies for finding the area and perimeter of two-dimensional shapes. Teachers' responses proved that learning is an ongoing process, irrespective of one's teaching experience or age.

4.7.6 Question 6 (RQ6)

Do you feel that the use of the *Geoboard* made the understanding of the two concepts of area and perimeter, clearer to both you and the learners?

All the teachers said the use of the *Geoboard* cleared the confusion that learners had between area and perimeter, as proven by the activities they had done. Teacher B said, "*the Geoboard enabled learners to see the difference between area and perimeter, so learners knew what to do when asked for area or perimeter*".

Teacher C said, "*When comparing the learners, looking at their examination marks after the intervention, those who were not part of the project performed more poorly in area and perimeter of two-dimensional shapes than those who participated in the study*".

Teacher A said, "*the Geoboard helped learners see the connection between halving and reduction and enlargement and doubling, when the scale factor is ½ and 2 respectively. They saw that a scale factor of 2 did not mean the area of the original shape should be doubled, nor halved when the scale factor is 1/2* ".

Teacher B added, "*the Geoboard was very useful, it made it easy for learners to calculate area and perimeter of shapes and learners enjoyed forming shapes on the Geoboard*".

All the teachers acknowledged that there was a shift in learner performance in area and perimeter, as evident in the common paper that learners wrote, which according to them proved better understanding of the concepts in question. Teachers said that the discussions learners had in the groups also helped them to construct their own knowledge, meaning they had learnt with understanding.

4.7.7 Question 7 (RQ7)

Would you recommend the use of a *Geoboard* to other teachers within your school or cluster or district?

From the experiences that teachers had with the *Geoboard* they all said they would encourage other teachers to use the *Geoboard*. Teacher C said, "*I wanted to share my experiences with other teachers in the 1 + 4 programme, but my colleague told me that I should not because this was a research*." She said she was waiting for me to grant her permission. This was supported by the other two teachers. They said the confidence they gained made them want to share the acquired information with colleagues.

Teacher A further said, "*I have already started telling other teachers about my experiences of using the Geoboard. I told them how the Geoboard aroused my learners' interest*".

It appeared that the use of the *Geoboard* helped learners understand area and perimeter better. The fact that all teachers wanted to share their experiences of using the *Geoboard* with other teachers, proved that they found the *Geoboard* helpful and useful in the teaching and learning of mathematics.

4.7.8 Question 8 (RQ8)

If you were to teach area and perimeter of two-dimensional shapes again, where do you think you would need to improve?

Teacher A said, "*I would need to check on the time needed to teach the topic using the Geoboard, because I took longer than normal, but learners understood. I don't regret, because I see the results of the time taken.*"

Teacher C acknowledged that the use of concrete materials made learning more meaningful. She said, "*I would use concrete objects, that is, the Geoboard itself.*" She further said, "*I would take more time to teach the topic, because I saw that two or three lessons are not enough to build understanding*". Learners were actively involved, because the lessons were practical. Referring to one of the learners, Teacher C said, "*the use of the Geoboard helped even the most inactive learners to participate in the lesson*". She went on to say, "*the Geoboard made my learners to be hands-on*".

Teachers appreciated the integration of area and perimeter into other topics within mathematics. Teacher B said, "*I would need to improve on the integration of area and perimeter with enlargement and reduction, using the Geoboard*".

Teachers' responses showed that they were keen to practise and improve their teaching and learning of mathematics.

4.7.9 Question 9 (RQ9)

Has there been a shift in learner performance as a result of using the *Geoboard*?

All teachers said there was improvement in learner performance in the concepts of area and perimeter.

Teacher A and Teacher C further said their learners had struggled to find the area of a trapezium and parallelogram, but the *Geoboard* had helped them reach the correct answers. They said, "*previously, learners relied on formulae, which they just memorised*". In other words, learners would forget the formulae, because they learnt without understanding.

Teacher C stated further that the *Geoboard* made the two concepts clear and understandable and that became evident in the activities that learners did. She said, "*learners understood better after using the Geoboard, than before when there was no Geoboard.*"

Teacher B said, "*the way the topic was handled made it appear new both to me and my learners*". She said it brought more meaning to both her and the learners.

4.7.10 Is there anything else that you would like to say? (RQ10)

When asked for further comments on their experiences of using the *Geoboard*, teachers said the following:

Teacher A said, "*the use of the Geoboard is great, and I think I got what I wanted long ago, but I didn't know where to get it from*." Teacher A was an example of a person who was keen to learn and change when required to do so. Her experience in teaching mathematics did not make her think she knew everything or that she was too old to learn something new. She said that the use of concrete objects made learners learn with enjoyment, and that in her opinion concrete materials should be used. According to Teacher A, the fear of mathematics as a monster was removed; instead learners took the lessons as a game which they thoroughly enjoyed and that is how teaching should be.

Teacher B said, "*using the Geoboard was very useful and fruitful to me*." She also enjoyed the connection of area and perimeter with other concepts in mathematics. In order to avoid the treatment of topics in isolation, teachers should be encouraged to link their topics. It appeared teachers no longer wanted to rely on formulae, but encouraged the use of other strategies that learners could choose from. Learners did not have to rely on one strategy, which was the use of formulae in this case, which they may find difficult to understand. She said the project equipped her with knowledge and skills of how best she could plan her lessons and teach them. Lesson planning plays a significant role in effective teaching and learning. She said, "*sometimes we think we know and yet we don't know*".

From the teachers' responses, it appeared teachers had gained much from my intervention. The intervention equipped them with the necessary skills to teach area and perimeter of two-dimensional shapes. The intervention not only enriched them with knowledge and enhanced their understanding of the two concepts, but also boosted their confidence.

4.8 ANALYSIS OF THE FINDINGS IN THE INTERVIEWS WITH LEARNERS

Although my initial intention was to only focus on teachers, I was also interested to find out the experiences of the learners using a *Geoboard*. I was particularly interested to see whether their experiences aligned with those of teachers. Two learners from each school were interviewed, so in all six learners were interviewed. I present here a brief discussion of what emerged from these interviews. The interviews were transcribed, and the transcripts are attached as appendix 8.

None of the learners had any experience of using a *Geoboard;* this was the first time they had even seen one. Asked about their experiences of using a *Geoboard*, learners stated:

- *The Geoboard made us understand area and perimeter better.*
- *With the use of the Geoboard, the lesson became more practical.*
- *The different strategies, especially Pick's theorem, enabled us to calculate areas of a trapezium, parallelogram and other shapes easily. We did not have to rely on the formulae.*
- *There is a lot that we learnt from the project*
- *The use of the Geoboard has developed confidence in us in as far as the understanding of area and perimeter of two-dimensional shapes is concerned.*

- *Using the Geoboard, we were able to see the connection in various concepts within mathematics.*
- *The Geoboard is a useful tool to learn mathematics with meaning.*

Learners' responses to the interview questions indeed showed alignment with those of their teachers. It came out clearly that learners' understanding of area and perimeter of two-dimensional shapes had improved. This was evident in the post-intervention assessment task that was administered at the end of the study. Some had already been asked by their teachers to help those learners who were not part of the study, which meant that their confidence was also boosted. Learners' active involvement in class, as confirmed by both learners and teachers, contributed to better understanding.

4.9 CONCLUSION

In conclusion, I discovered that the *Geoboard*, as a manipulative, led to better understanding of area and perimeter of two-dimensional shapes. The participant teachers' and learners' confidence in the two concepts was boosted. Learners' active involvement and co-operative learning that took place in the groups enabled learners to construct their own knowledge. The assessment of prior knowledge, lesson planning and progression in lessons should be taken into account. These are contributory factors to the success of a lesson. This emerged when teachers reflected on their teaching.

In the next chapter, I present the conclusion of my research study. I also highlight the significance, assumptions and limitations of this study. Recommendations on how this study could be taken further, to help teachers teach area and perimeter meaningfully with the use of a *Geoboard*, are also made. Lastly, I present my own personal reflections on the research study.

CHAPTER 5

CONCLUSION

5.1 INTRODUCTION

This chapter concludes my research. It gives a brief summary of my findings during this study as well as during my interaction with the participants. I also highlight the success of this study and the limitations identified in the research study. Furthermore, I discuss the significance of the study to the field of mathematics education. In conclusion, recommendations and suggestions on the use of manipulatives, with special reference to the *Geoboard,* are made. Lastly, my own personal reflections on this research study are included.

5.2 BRIEF SUMMARY OF FINDINGS

5.2.1 Findings from the baseline assessment task (Phase 1)

In Phase 1, I found that learners lacked content knowledge of area and perimeter of two-dimensional shapes, as assessed in Research Questions 1 to 4 (RQ1 to RQ4). The results showed that learners were at a lower level of understanding as far as their content knowledge was concerned. Research Questions 5 to 15 revealed that learners were not used to any other form of learning, except the one that requires mere knowledge or routine procedure. This was proved by the fact that learners could not perform activities that demanded creative, critical reasoning and problem-solving skills. For example, some learners managed to define area, but failed to show their understanding by means of a drawing or diagram, as required in RQ3 and RQ4. When learners were given the area and one dimension of a shape and asked to determine the other dimension, they simply multiplied the given values, which meant they did not read with understanding. Although their answer was greater than the area they were given, they did not see anything wrong with their answer. There was no link formed between the sides and the area they were given.

5.2.2 Findings from the workshop (Phase 2)

During Phase 2, a workshop was conducted for the participants at their respective schools and a learning programme was designed. Teachers' active involvement showed that they were keen to learn and ready to implement the plan. Teachers were unaware of the prior knowledge that learners should have before embarking on area and perimeter. They were excited to learn there were many mathematics topics to which they could connect area and perimeter of geometric shapes. Teachers struggled to do some of the activities that demanded critical thinking. I identified some misconceptions, one of which was enlargement of shapes. One of the teachers extended each side of the original shape by 2 units which was the scale factor. My interaction with the three teachers made me realise that there was a need for professional development of teachers, especially in content knowledge. Teachers appreciated the use of a variety of strategies to find area and perimeter. "*I have always used formulae*", one teacher said. Initially teachers thought that a maximum of three lessons would be enough to cover area and perimeter. They were amazed at the number of lessons that had been designed.

5.2.3 Findings from the presentations (Phase 3)

Phase 3 was an implementation phase where teachers presented their lessons to their respective learners. During the two lessons that each teacher presented, I observed that learners' content knowledge on area perimeter needed more attention. For example, when asked to define area, some learners said, "*it's length × breadth*". The few learners who knew area and perimeter could not explain themselves, which suggested that they had learnt without understanding. Teaching for understanding led to retention of information and this was observed throughout the lessons. Learners could relate to what they did. The investigative approach that teachers used helped learners to construct their own knowledge. For example, the investigation of the relationship between the area and perimeter of the original shapes and their images was evident here.

Recapping on prior knowledge proved to be very effective, because I discovered that some learners had forgotten what had been covered earlier. Through recapping, teachers were able to identify learners' content knowledge gaps and misconceptions. Lessons took longer than anticipated, but teachers were happy, because meaningful learning had taken place. One teacher said, "*I don't complain about the fact that the lessons took long, because learners and I gained a lot*".

I observed that learners enjoyed the use of various strategies to calculate area, especially Pick's theorem. Some of the learner I interviewed said the use of the *Geoboard* helped them, because they did not have to memorise the formulae. This showed how important it is for teachers to expose learners to as many strategies as possible. I also observed that in the various groups learners helped each other, and their active involvement showed that the groups were not just formed for purposes of grouping learners, but for learners to share ideas and learn from each other. Van de Walle (2004) states that it is very important that learners become actively involved in the lesson, because if the minds are not actively thinking then no learning can take place. He further says that to construct and understand a new idea, active thinking about the idea is needed.

5.2.4 Findings from the post-intervention assessment task (Phase 4)

During this phase a post-intervention assessment task was administered to the same learners who had written the baseline assessment task. The aim was to assess the possible improvement in learner performance. The post-intervention assessment task, compared to the baseline assessment task, showed improvement in learner performance at all three schools. In all the questions, learners gained an average of 40% and above. Learners struggled to answer questions that demanded creative reasoning. This meant that when planning learners' activities, teachers should also include questions that provoke learners' critical and creative thinking.

5.2.5 Findings from the interviews with the participants (Phase 5)

In this phase, teachers were interviewed to get their experiences of using the *Geoboard* to teach area and perimeter of two-dimensional shapes. When teachers were interviewed, they said their colleagues had complained about being excluded from the study and this made the three teachers feel privileged to have been selected to participate in this study. The confidence they developed in the two concepts made them want to share what they had learnt with their colleagues. The fact that teachers wanted to share their experiences of using a *Geoboard* with colleagues, was enough evidence of effective learning. In them I saw people who were not selfish; they did not want to keep the information to themselves. Teacher A said, "*the project helped me improve on my practice and become a more effective and better teacher*".

Teachers saw the powerful role that a *Geoboard*, as a manipulative, played in the teaching and learning of area and perimeter. They would have liked to be shown how manipulatives could be used in other areas of mathematics. Teacher C said, "*I wish that projects of this nature could be conducted with other topics in mathematics*". I learnt that the lessons that teachers planned for this study, had improved their attitude towards planning. They saw the importance of connecting topics within mathematics. They asked if they could be helped plan other lessons in mathematics. The study allowed the participants an opportunity to reflect on their planning as well as their teaching.

I observed that the participants were impressed with the active involvement of their learners during the lesson and they attributed this to the use of manipulatives. Teacher B said, "*the use of a Geoboard made it easy for my learners to understand area and perimeter*". Teachers felt that there was active thinking on the learners' part. Teacher C, referring to me, said, "*it's good you brought the Geoboard, because people who always keep quiet in class, are now active*". Although the participants used concrete materials when teaching some mathematical topics, they said they had never used a *Geoboard* before, because they did not know it. The participants were excited about the use of a *Geoboard* and promised to encourage their colleagues to join the cluster. Teacher A said, "*peer learning is more powerful than only depending on own ideas*".

5.3 SIGNIFICANCE OF THE STUDY

The research I did before embarking on this study revealed that this research study had never been conducted in the Eastern Cape, where I am based. A similar case study on Surface Area and Volume investigated the role of physical manipulatives in the teaching and learning of measurement in grade 8 in the Queenstown area (Chiphambo, 2011).

When participants were interviewed on their experiences of using a *Geoboard*, they said they had never seen nor used a *Geoboard*. This immediately confirmed that many other teachers could be in the same situation, which warranted the study being extended to a larger sample.

The study of area and perimeter of two-dimensional shapes starts in the Intermediate phase (grades 4-6). The early introduction of area and perimeter prepares learners for the Total Surface Area of solids that is done in grades 8 and 9. The use of a *Geoboard* to learn area and perimeter proved to be effective, as indicated by learners and teachers during the interviews. The use of a *Geoboard* also developed learners' investigative and critical thinking skills, which are emphasised in the curriculum for the understanding of mathematics. The use of a *Geoboard* helped clear the confusion that learners had about area and perimeter. CAPS emphasises co-operative learning and learner involvement, an opportunity that a *Geoboard* created for the learners. Through the use of manipulatives, learners constructed their own knowledge, which is a requirement for effective learning. Teachers saw the importance of assessing learners' prior knowledge, because it informed their intervention.

5.4 ASSUMPTIONS AND LIMITATIONS

5.4.1 Assumptions

The use of manipulatives to teach mathematics for effective learning is emphasised by Basic Education. I therefore assumed teachers were familiar with concrete materials, including a *Geoboard*. The topic on area and perimeter of two-dimensional shapes is prescribed in the curriculum for the Intermediate and Senior phase learners, which suggests that learners should be well versed with the topic by the time they reach grade 7. I therefore assumed that learners knew what the two concepts entailed. The baseline assessment task results revealed that learners had a huge content gap in the topics of area and perimeter.

I had also assumed teachers were competent to teach the topic, but the workshop I conducted in phase 2 proved that teachers' content knowledge on this topic needed attention. When we drew up the learning programme, we had to start from scratch, as if the topic had never been done before. As indicated earlier in the thesis, the participants came from some of the best performing cluster schools, which made me think that they would not struggle with the activities that were designed for the workshop. I learnt later that my assumptions were wrong.

Due to the participants' commitment and dedication, I assumed that I would work with them until the termination of the project. Teacher deployment and the rationalisation process by the Department of Education did not threaten my study. I thought it would not be easy for principals to release such teachers, especially looking at the quality of mathematics results they produced.

I observed from my classroom support visits that the principals of all three schools were committed to anything that would bring improvement to the teaching and learning of mathematics. I therefore thought they would easily accept my request to conduct my study at their school, because they would see it as something that would benefit their schools.

5.4.2 Limitations

Due to the size of the study one is bound to experience some constraints and limitations, which amongst others is the generalisation of the study. There are 23 districts in the Eastern Cape, but the study was conducted in only two of these. Only three schools participated in the study and these included one school from one district and two schools from the second district.

The distance between Grahamstown, where I work, and the participants' schools, limited my visits to the schools, and increased the cost of each visit. Sometimes the classroom visits would be cancelled at the eleventh hour due to Departmental activities and teachers' personal commitments. My work schedule also prohibited me from visiting the schools as often as I would have liked, especially when participating teachers were awaiting my visit. The project was limited to the use of the *Geoboard* to teach area and perimeter of two-dimensional shapes, although there are other topics within mathematics where a *Geoboard* could be used, including e total surface area of solids and transformations. This suggests that the participants had limited time to work with the *Geoboard* for purposes of this study.

According to CAPS, each topic in mathematics is allocated timeframes and periods within which it should be taught. The participants were therefore under pressure to do their presentations within a specified period. This meant that they had to plan their schedules to accommodate both their day-to-day teaching and the teaching of the lessons of the study. In order to meet the challenges, teachers had to organise extra classes.

5.5 RECOMMENDATIONS

Since the study was limited to just three cluster schools, I would recommend that more schools be included in the study. Participants should be allowed ample time to manipulate or work with the *Geoboard* to ensure that learning takes place.

If possible, the participants should be where the researcher is or the two should not be far apart from each other. The closer they are, the greater the opportunities for them to interact with each other. This would also cut down on costs incurred.

Time-management during the research is very important; participants should be allowed reasonable time in which to complete the study. In order to avoid working under pressure, the researcher should also adhere to deadlines.

Teachers should be encouraged to use manipulatives for more meaningful learning. Relevant and appropriate use of manipulatives as well as the right choice of manipulatives is important, and teachers need to be made aware of this.

The content gap in the knowledge of both the learners and the three participants made me wonder about the number of other teachers who may be in the same situation. I would therefore recommend that more research, on a wider scale, be conducted on the extent of this problem among teachers. This would help the Department of Education, as well as all other stakeholders that are involved in professional development of teachers, to become aware of the areas of concern that need attention.

I have seen that most teachers teach without any form of consolidation; they think that giving learners one or two activities is enough to make learners understand the concepts. Both teachers and learners saw from the study that consolidation of lessons played an important role in effective learning. I would therefore recommend that teachers should consolidate their lessons, because more practice brings better understanding.

The identification of learners' misconceptions and errors also contributes to better understanding, and depends to a large extent on the types of questions that teachers set for their learners. I would therefore recommend that teachers apply all cognitive levels when assessing their learners. Problem-solving questions, for example, help teachers assess their learners' reasoning skills.

Lastly, the study helped teachers reflect on their own teaching, I would therefore recommend that teachers should reflect at the end of their lessons. Reflection informs teachers about their learners' progress, as well as the areas they need to improve on.

5.6 PERSONAL REFLECTIONS

I have conducted a number of teacher workshops on area and perimeter, but the workshop I did in phase 2 of the study, made me rethink the teaching and learning of mathematics. This study confirmed why learner performance in grade 9, as revealed by RUMEP annual benchmark tests and ANA results, is so low. It strengthened my passion for the professional development of mathematics teachers. Through this study, I learnt that I should not assume that teachers have the necessary knowledge, but should first conduct research first in order to be able to help them.

The study also helped me reflect on my personal interaction with the cluster teachers. I think some of the strategies I use to develop teachers need to be reviewed. A form of baseline assessment task for teachers, on an annual basis, is necessary, because this would inform me of areas of concern that would need intervention. Teachers get deployed and promoted every year and they get moved from one school or phase or grade to the next due to rationalisation by the Department of Education. Professional development of teachers should be continuous, and not be a once-off thing. Due to a shortage of teachers, some teachers had to teach mathematics, even though they had never specialised in mathematics; hence we have teachers with a wide knowledge content gap. This confirms that professional development of teachers must be ongoing.

Some cluster teachers confirmed that they do not teach what they do not know. They said they would rather spend more time on what they know best, than waste time trying to make learners understand what they themselves do not understand. They claimed that they found it difficult to teach topics that they themselves were not taught. This puts learners at a disadvantage, because there has to be progression in what is being taught and the mathematics curriculum is designed such that it builds on prior knowledge.

In the participants, I saw teachers who were keen to learn and change their attitude. They wanted to know more in order to improve their teaching and learning of mathematics, especially the topic on area and perimeter of two-dimensional shapes. They did not only want the information for themselves, but also for other teachers within their clusters and the district at large. The study showed that there were teachers who were still committed to their teaching. Even though these teachers always produced good results, they did not regard themselves as experts in their field, but saw the need for professional development. They understood that for one to be competent, one should be willing to learn and change for the betterment of others.

In the interviews, teachers agreed that the study had broadened their knowledge. I freely admit I too, learned from the research study as well as from the participants. They taught me that one has to be patient and should be committed to an idea until its completion. Despite their busy and tight schedules, they remained committed to the project right up to the end. This gave me courage to carry on with this study even though at times I was faced with family challenges.

I learned that I should be willing to help others achieve or realise their dreams. The three teachers wanted me to achieve my goals for this study and did not want to disappoint me by pulling out of the study, even though it put much pressure on them.

The demands at work as well as my workload, have made it impossible for me to finish this study in good time. This study took longer to finish than I had anticipated. I could not sacrifice my work time for my studies and this delayed the progress of the study. My time-management skills as far as this study is concerned, were quite poor, because I could not meet the deadlines. This resulted in me working under tremendous pressure and I had to take leave to do the writing-up. It would be ideal for people to be granted sabbatical leave to do the writing-up.

Lastly, I believe that professional development is very important if we are to see improvement in teaching. Learning is an ongoing process, meaning that there is no time when one can say one has learnt enough.

My creative and critical thinking skills were put to the test. I had to think seriously of how best the *Geoboard* could be used to arouse teachers' interest and curiosity. The integration of area and perimeter with other topics within mathematics aroused participants' interest, which in turn helped learners see connections between different mathematics topics.

This study taught me that in order to achieve and realise my vision, I personally should be willing to change. I should be the change that I want to see in others. I also learnt that I am the only person who can change me. I can only influence others by my behaviour which is reflected not in the things I say, but in the things I do, and the manner in which I conduct myself. Change therefore starts and ends with me.

Making a difference in someone's life by what I do is what kept me going during this research and motivated me to carry on, even though it was not easy at times.

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APPENDIX 1A

RUMEP

RHODES UNIVERSITY
Where leaders learn

General information of my research project

I, Mkhwane Fezeka Felicia, am working for the Rhodes Mathematics Education Project (RUMEP), as a Collegial Cluster Coordinator. RUMEP is an in - service programme that aims at helping teachers improve on their teaching of mathematics. The Collegial Clusters are communities of committed and dedicated teachers who work on their professional development in order to improve the teaching and learning of mathematics.

I am currently enrolled for MEd in Mathematics Education at Rhodes University. For my research topic, I wish to investigate the experiences of selected Grade 9 teachers of a Geoboard intervention programme. The focus of the study will be on the roles that the use of Geoboards as a medium of instruction can play in the teaching and learning of area and perimeter of geometric figures.

The participants will come from three clusters that I am working in. I would like that one Grade 9 teacher from each cluster will take part in the study.

The study is designed such that it will take place in five phases which are as follows:

Phase 1

A baseline assessment will be administered to the learners of the three participating classes before the intervention takes place. The assessment will be one hour long and consist of 10 questions. This aims at assessing learners' conceptual understanding of area and perimeter of geometric figures.

Phase 2

A three hour workshop will be conducted, where the three participating teachers will engage in Geoboard activities. Each of the teachers will make a Geoboard and participate in designing a learning programme for their Grade 9 classes, which will focus on area and perimeter of shapes. The learning programme will take place twice a week over a period of three weeks.

Phase 3

During this phase each participating teacher will roll out the planned intervention programme in their individual classes with their learners. During this phase, I will do classroom support visits, where I will observe teachers while they teach what they planned and prepared at the workshop. There will also be video-recording of two lessons per teacher in order to capture how they used the Geoboard as a teaching medium.

Phase 4

A post intervention assessment will be conducted with the learners and it will be similar to the baseline assessment. The post intervention assessment aims at exploring possible conceptual shifts that have taken place as a result of the intervention.

Phase 5

A semi structured interview will be conducted with each participating teacher. The purpose of the semi-structured interviews with teachers is to reflect on the use of the Geoboard during the intervention and also to explore their experiences with using a Geoboard as a manipulative in the teaching and learning of area and perimeter of geometric shapes.

The teachers' participation in the intervention programme is voluntary. They can withdraw from the research project at any time they wish. Their identities and that of the schools will not be revealed.

Fezeka Mkhwane

Signature:

Date: 26 January 2015

APPENDIX 1B – CONSENT FORM FOR THE DEPARTMENT OF EDUCACTION

Province of the
EASTERN CAPE
DEPARTMENT OF EDUCATION
Private Bag X 1203 * Dutywa * 5000 * REPUBLIC OF SOUTH AFRICA

ENQUIRIES: Mr A. M DWANGU TEL. NO. 047 489 2247 FAX. NO. 047 489 1028
DATE: 05 February 2015

TO : MS FEZEKA FELICIA MKHWANE

FROM : THE DISTRICT DIRECTOR

SUBJECT : PERMISSION TO CONDUCT RESEARCH- F.F. MKWANE

DATE : 4 FEBRUARY 2015

Kindly be advised that Ms F.F. Mkhwane has been granted permission to conduct a research in your school in pursuance of his studies towards the Education Eastern Cape Province through Rhodes University.

She is enrolled for degree of MED in Mathematics Education.

Your anticipated co-operation with her is appreciated in advance.

Yours truly,

A.M. Dwangu
District Director

DEPARTMENT OF EDUCATION
EASTERN CAPE PROVINCE
2015 -02- 04
DISTRICT DIRECTOR
PRIVATE BAG X1203
DUTYWA 5000

Province of the
EASTERN CAPE
DEPARTMENT OF EDUCATION
Private Bag X 1203 * Dutywa * 5000 * REPUBLIC OF SOUTH AFRICA

ENQUIRIES: Mr A. M DWANGU TEL. NO. 047 489 2247 FAX. NO. 047 489 1028
Date: 4 February 2015

Consent form for the Department of Education

I, Mr A.M. Dwangu the District Director Education Dutywa ,understand the content of the research project and willing to grant permission to teachers and learners from the identified school to participate in the study on the condition that their identities are in no way revealed.

Yours truly

DISTRICT DIRECTOR
A.M. DWANGU

DEPARTMENT OF EDUCATION
EASTERN CAPE PROVINCE
2015 -02- 04
DISTRICT DIRECTOR
PRIVATE BAG X1203
DUTYWA 5000

RUMEP

RHODES UNIVERSITY
Where leaders learn

Consent form for the Department of Education- Eastern Cape Province

I,..N.A. MAGIBILE - TINDLENI......................., the Director of the Department of Education-Eastern Cape Province, understand the content of the research project and am willing to grant permission to teachers and learners from the identified school to participate in the study on the condition that their identities are in no way revealed.

Signature:..NAMagibile - Tindleni..........

Director:..Date:.........................

DEPARTMENT OF EDUCATION
2015
STERKSPRUIT..............................

APPENDIX 1C – CONSENT FORM FOR THE PRINCIPALS

RUMEP

RHODES UNIVERSITY
Where leaders learn

Consent from the principal of the school

I, PAMBILI MEI, the principal of

ESILINDINI F.S.S (name of school) understand the content of the

research project and am willing to grant FEZEKA MKHWANE (name of

teacher) and her/his learners permission to participate in the study on the condition that the

identities of the teacher, the learners and the school will in no way be revealed.

Signature:..

Principal: MEI P. Date: 11/02/2015

DEPARTMENT OF EDUCATION
ESILINDINI F.S.S.
P.O. Box 245, Sterkspruit, 9762
11 FEB 2015
Principal: ....

RUMEP

RHODES UNIVERSITY
Where leaders learn

Consent from the principal of the school

I,.....BENSON THOZAMILE VANGA..... the principal of

STERKSPRUIT COMMUNITY...(name of school) understand the content of the

research project and am willing to grant ...JOYCE N. LETSOSO.........(name of

teacher) and her/his learners permission to participate in the study on the condition that the

identities of the teacher, the learners and the school will in no way be revealed.

Eastern Cape Dept. of Education
STERKSPRUIT COMMUNITY SCHOOL
EMIS NO: 200600798
Signature:.....-02- 2015........................
Box 455 • Sterkspruit • 9762
Tel: 051 611 0546 / Fax: 051 611 0344
Principal: B. T. VANGA

Principal:.................................Date: 11/02/2015...........

RUMEP

RHODES UNIVERSITY
Where leaders learn

Consent from the principal of the school

I,......G. T. ....QUBEKA......................., the principal of

...VULITHUBA J. S. S.....(name of school) understand the content of the

research project and am willing to grant ......E. S. BUNWANA..........(name of

teacher) and her/his learners permission to participate in the study on the condition that the

identities of the teacher, the learners and the school will in no way be revealed.

Signature:...

Principal:...G. T. QUBEKA...........Date:..04 : 02 : 2015

DEPARTMENT OF EDUCATION
VULITHUBA J.S.S.
04 FEB 2015
P O BOX 213, DUTYWA 5000
PRINCIPAL

APPENDIX 1D – CONSENT FORM FOR THE PARTICIPATING TEACHERS

RUMEP

RHODES UNIVERSITY
Where leaders learn

Participant consent form

Research project title: An investigation of teacher experiences of a Geoboard intervention programme in Area and Perimeter in selected grade 9 classes.

I have read the contents of the information leaflet for the study and understand the details of the study and its objectives explained to me.

I am participating in the study out of my own volition and have not been coerced to do so.

I understand that I can withdraw from the study and decline to participate at any time.

All my questions regarding the study or participation therein have been answered to my satisfaction.

I agree to provide information to the researcher on conditions that my participation will be treated with confidentiality and anonymity.

I understand that my identity and that of my school will in no way be revealed.

I consent that the findings of this research to be used for other research papers.

Participant's name: SIBOTO Y.V Participant's signature:...............................

Date: 8 11-02-2015 Contact Details: 0718860525 / 0715153426

Researcher's name: F. Mkhwane Researcher's Signature:...............................

DEPARTMENT OF EDUCATION
ESILINDINI F.S.S.
P.O. Box 245, Sterkspruit, 9762
11 FEB 2015
Principal: ....

RUMEP

RHODES UNIVERSITY
Where leaders learn

Participant con ent form

Research project title: An investigation of teacher experiences of a Geoboard intervention programme in Area and Perimeter in selected grade 9 classes.

I have read the contents of the information leaflet for the study and understand the details of the study and its objectives explained to me.

I am participating in the study out of my own volition and have not been coerced to do so.

I understand that I can withdraw from the study and decline to participate at any time.

All my questions regarding the study or participation therein have been answered to my satisfaction.

I agree to provide information to the researcher on conditions that my participation will be treated with confidentiality and anonymity.

I understand that my identity and that of my school will in no way be revealed.

I consent that the findings of this research to be used for other research papers.

Participant's name: [illegible] Participant's signature:..................................

Date: [illegible] Contact Details: [illegible]

Researcher's name: F. M[illegible] Researcher's Signature:..................................

RUMEP

RHODES UNIVERSITY
Where leaders learn

Participant consent form

Research project title: An investigation of teacher experiences of a Geoboard intervention programme in Area and Perimeter in selected grade 9 classes.

I have read the contents of the information leaflet for the study and understand the details of the study and its objectives explained to me.

I am participating in the study out of my own volition and have not been coerced to do so.

I understand that I can withdraw from the study and decline to participate at any time.

All my questions regarding the study or participation therein have been answered to my satisfaction.

I agree to provide information to the researcher on conditions that my participation will be treated with confidentiality and anonymity.

I understand that my identity and that of my school will in no way be revealed.

I consent that the findings of this research to be used for other research papers.

Participant's name: BUNWANA.E.S Participant's signature:..............................

Date: 04/02/15 Contact Details: 083 3732 365..............

Researcher's name: Fezeka Mkhwane Researcher's Signature:..............................

APPENDIX 2 - BASELINE ASSESSMENT TASK

RHODES UNIVERSITY MATHEMATICS EDUCATION PROJECT

RUMEP

education
Department: Education
REPUBLIC OF SOUTH AFRICA

RHODES UNIVERSITY
Where leaders learn

Baseline Assessment

2015

Grade 9

Learner's Name: ………………………………………

Name of School: ……………………………………….

Name of teacher………………………………………

Name of cluster………………………………………

Instructions

1. *Circle the correct answer from those given where necessary*
2. *You are not allowed to use a calculator.*
3. *Do your working on the paper provided and attach it to your answer sheet.*
4. *Use an HB pencil.*
5. *Time allowed to answer the questions is 1 hour*

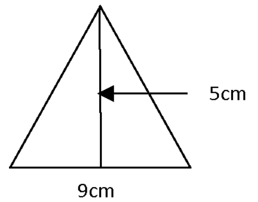
1. In your own words explain what you understand by the area of a shape?
2. In your own words explain what you understand by the perimeter of a shape?
3. Using a diagram show what you understand by area of a shape.
4. Using a diagram show what you understand by the perimeter of a shape.
5. The area of a rectangle with a length of 12cm and a breadth of 9cm is:

A: 42cm B: 216cm^2 C: 108cm D: 108cm^2

6. A square with an area of 196 square units has its sides equal to:

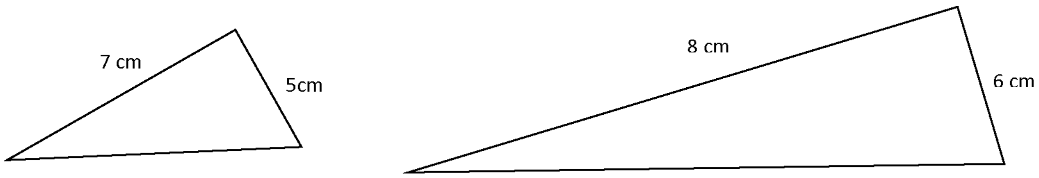
A: 49 units B: 14 units C: 14 square units D: 98units

7. The area of the triangle alongside is:



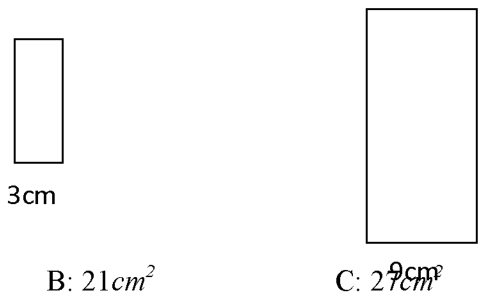
A: 22cm^2 B: 45cm^2 C: 22,5cm^2 D: 22,1cm^2

8. The figures below are similar. Perimeter of Fig. B is 24cm. What is the perimeter of Fig. A?



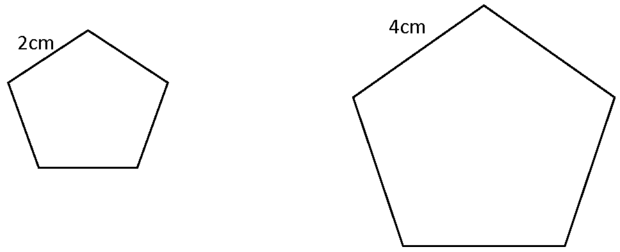
A: 21cm B: 15cm C: 24cm D: None of these

9. The two figures are similar. The area for Figure 2 is 189cm^2. What is the area for Figure 1?



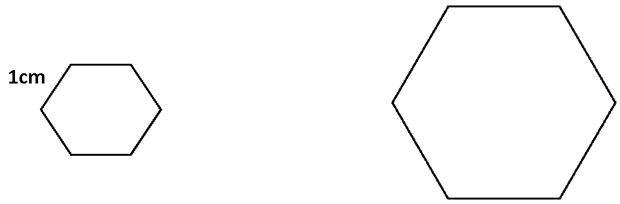
A: 18cm^2 B: 21cm^2 C: 27cm^2 D: 20cm^2

10. These pentagons are similar and they are both regular. The perimeter of Figure 1 is 10cm. What is the perimeter of Fig 2?



A: 20cm B: 20cm^2 C: 12cm D: None of these

11. The two shapes are regular. If Figure 1 has been enlarged by a scale factor of 4, what is each side in Figure 2 equal to?



A: 0,25cm B: 4cm C: 5cm D: 3cm

12. What is the ratio of the perimeter of Figure 1 to the perimeter of Figure 2 above?

A: 4: 1 B: 24: 6 C: 6 : 24 D: 1: 6

13. A circular shape has a diameter of 14cm. What is its circumference (perimeter)?

A: 44cm B: 44cm^2 C: 616cm D: 616cm^2

14. The square of a rectangular plot is 600m^2. If its width is 15m, what is its length?

A: 285m 40m^2 C: 40m D: 9 000m

15. What is the length of the above shape in cm?

A: 6 000cm B: 60cm C: 0,600cm D: 60 000cm

TOTAL = (2 × 10) = 20 marks

APPENDIX 3 - POST-INTERVENTION ASSESSMENT TASK

RHODES UNIVERSITY MATHEMATICS EDUCATION PROJECT

RUMEP

education
Department: Education
REPUBLIC OF SOUTH AFRICA

RHODES UNIVERSITY
Where leaders learn

Post-Intervention Assessment Task

2015

Grade 9

Learner's Name: ……………………………………………

Name of School: ……………………………………….

Name of teacher:………………………………………….

Name of cluster:………………………………………..

Instructions

1. *Circle the correct answer from those given where necessary*
2. *You are not allowed to use a calculator.*
3. *Do your working on the paper provided and attach it to your answer sheet.*
4. *Use an HB pencil.*
5. *Time allowed to answer the questions is 1 hour*

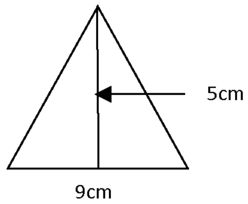
1. In your own words explain what you understand by the area of a shape?
2. In your own words explain what you understand by the perimeter of a shape?
3. Using a diagram show what you understand by area of a shape.
4. Using a diagram show what you understand by the perimeter of a shape.
5. The area of a rectangle with a length of 12cm and a breadth of 9cm is:

A: $42cm$ B: $216cm^2$ C: $108cm$ D: $108cm^2$

6. A square with an area of 196 square units has its sides equal to:

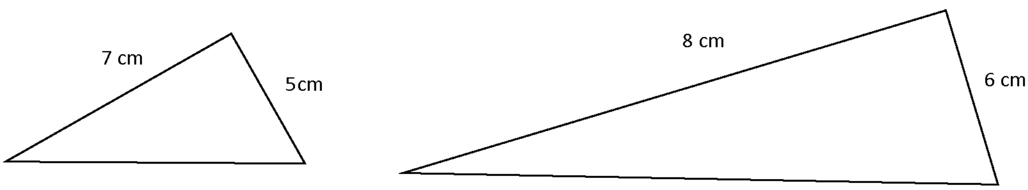
A: 49 units B: 14 units C: 14 square units D: 98units

7. The area of the triangle alongside is:



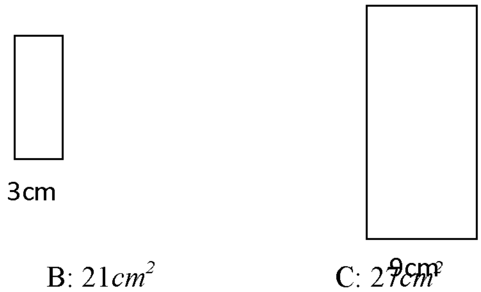
A: $22cm^2$ B: $45cm^2$ C: $22,5cm^2$ D: $22,1cm^2$

8. The figures below are similar. Perimeter of Fig. B is 24cm. What is the perimeter of Fig. A?



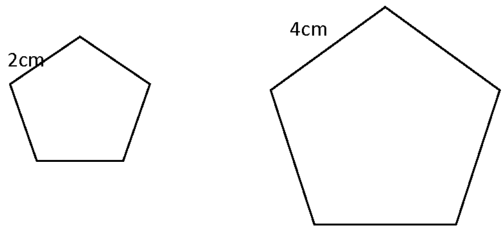
A: $21cm$ B: $15cm$ C: $24cm$ D: None of these

9. The two figures are similar. The area for Figure 2 is 189cm^2. What is the area for Figure 1?



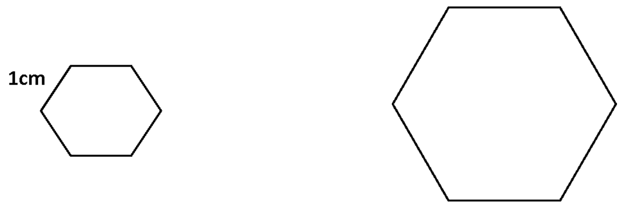
A: $18cm^2$ B: $21cm^2$ C: $27cm^2$ D: $20cm^2$

10. These pentagons are similar and they are both regular. The perimeter of Figure 1 is 10cm. What is the perimeter of Fig 2?



A: $20cm$ B: $20cm^2$ C: $12cm$ D: None of these

11. The two shapes are regular. If Figure 1 has been enlarged by a scale factor of 4, what is each side in Figure 2 equal to?



A: $0{,}25cm$ B: $4cm$ C: $5cm$ D: $3cm$

12. What is the ratio of the perimeter of Figure 1 to the perimeter of Figure 2 above?

A: 4: 1 B: 24: 6 C: 6 : 24 D: 1: 6

13. A circular shape has a diameter of 14cm. What is its circumference (perimeter)?

A: $44cm$ B: $44cm^2$ C: $616cm$ D: $616cm^2$

14. The square of a rectangular plot is $600m^2$. If its width is 15m, what is its length?

A: $285m$ $40m^2$ C: $40m$ D: $9\ 000m$

15. What is the length of the above shape in cm?

A: $6\ 000cm$ B: $60cm$ C: $0{,}600cm$ D: $60\ 000cm$

TOTAL = (2 × 10) = 20 marks

APPENDIX 4 - LEARNING PROGRAMME

NAME OF TRAINER: Fezeka Mkhwane

TITLE OF THE PROGRAMME: Investigating the area and perimeter of two-dimensional shapes, using a Geoboard in Grade 9.

NAMES OF PARTICIPANTS: Teacher A at Sterkspruit District

Teacher B at Dutywa District

Teacher C at Sterkspruit District

DURATION: 3hrs

CONTENT AREA: Measurement

FOCUS: Area and perimeter of two-dimensional shapes

OBJECTIVES OF THE LEARNING PROGRAMME:

- ❖ To assess teachers' prior knowledge on area and perimeter of two-dimensional shapes.
- ❖ To develop teachers' teaching skills and knowledge in area and perimeter of two-dimensional shapes, using a *Geoboard* as a manipulative.
- ❖ To help teachers see the link between area and perimeter of two-dimensional shapes and other topics within mathematics, for example, translations
- ❖ Help teachers develop lessons for the intervention programme.

DESIRED OUTCOMES

At the end of the workshop, teachers should be able to:

- ➢ Compare polygons, based on their sides and angles
- ➢ Investigate the area and perimeter of polygons
- ➢ Calculate the area and perimeter of polygons using different strategies:
  - ✓ Appropriate formulae
  - ✓ Counting squares on the surface
  - ✓ The Pick's theorem
  - ✓ Decomposition
- ➢ Solve problems involving:
  - ❖ area and perimeter
  - ❖ lengths
- ➢ Perform translations of polygons, which include:
  - Enlargement
  - Reduction
- ➢ Investigate relationship between shapes and their images in terms of their dimensions, areas and perimeters.

CONTENT:

Geometry of two –dimensional shapes

- Revision on polygons and definitions thereof. This is done by looking at the sides and angles.
- Briefly looking at similarities and differences between quadrilaterals. Classifying them according to rectangles and parallelograms.
- Making given and own polygons on the *Geoboard*. The aim is to check whether a shape can be linked to its name.
- Differentiating between convex and concave polygons, then making them on the *Geoboard*.

Area and Perimeter of polygons

- Investigating the area and perimeter of polygons, with more emphasis on the area of a triangle and rectangle, parallelogram and trapezium.
- Making latter shapes on the *Geoboard* and calculating their areas using the appropriate formulae. Making sure that participants are able to determine the height of the triangles they made.
- Making rectangles on the *Geoboard* and dotty grids when given area and or perimeter. The aim here is to assess participants' understanding of area and perimeter and whether they can apply their knowledge.

  For example:

  (i) Finding the dimensions of a rectangular plot with an area of $60m^2$. The aim is to allow teachers investigate the number of rectangles that can be made on the *Geoboard* with the given area.

  (ii) Using a *Geoboard* to make a rectangle with an area of $36cm^2$ and a perimeter of 26cm.

  (iii) If the perimeter of a square is 32cm, what are its dimensions?

  (iv) If the area of a rectangle is $20cm^2$ and its length is 5cm, what is its width?
- Introduction to a variety of strategies to calculate area of polygons and these include:
  - The counting of squares
  - The Pick's theorem
  - Decomposition of shapes.

Participants are required to make various polygons on the *Geoboard* and then find their areas using the latter strategies. These include both concave and convex polygons. They then check their solutions against when formulae are used to see whether the solutions would be the same.

- Investigating the effect of doubling dimensions of a polygon on the area and its perimeter. The aim is for participants to investigate what happens to the area and perimeter when dimensions are doubled.

  For example:

  A rectangle has an area of $24cm^2$ and a perimeter of 20cm. If its dimensions are doubled, what is the new area and perimeter?

INTEGRATION WITH TRANSLATION IN CONTENT AREA 3 (SPACE AND SHAPE)

The aim is for participants to see the connection between translations and area and perimeter of two-dimensional shapes. This should help participants realise the importance of linking topics and not treating them in isolation.

CONTENT

Transformations: Enlargement and Reduction

- Participants make different shapes on the *Geoboard* and then enlarge them using a given scale factor. They determine the area and perimeter of both the original shape and its image. They then investigate the relationship between the two shapes in terms of their dimensions, areas and perimeters.
- Participants use the *Geoboard* to make a variety of two-dimensional shapes. They use a given scale factor to reduce the shapes they made. They then investigate the area and perimeter of the original shape in relation to that of the image. They find the area by using any strategy of their choice.
- Investigating the formula for calculating the scale factor. Participants are given a shape and its image being made on a *Geoboard.* They find the ratio of the dimensions of the image to those of the original shape. A comparison of the area and perimeter of the image to the original shape is made.

CONSOLIDATION

Participants do a number of activities using a *Geoboard.* This exercise aimed at ensuring that participants were confident to roll out the programmed to their learners.

EVALUATION

At the end of the workshop participants reflected on the workshop.

RESOURCES

Geoboards, dotty grids, maths sets, rulers, pencils

APPENDIX 5 – LESSON OBSERVATION TOOL

RHODES UNIVERSITY MATHEMATICS EDUCATION PROJECT

Lesson Observation Tool

Name of School and Grade: ---

Name of Teacher: --

Date and Time of Observation: --

Topic: ---

A: Excellent (80% - 100%)

B: Good (61% - 79%)

C: Satisfies minimum requirements (50% -60%)

D: Needs Support and clarity (Below 50%)

1. ***General and Classroom Environment***

Items	**A**	**B**	**C**	**D**	**Comments**
Maths Posters, Print, Pictures on the walls					
Learners in groups or well organized					
General order and discipline					

2. ***Teaching and Learning***

Items	**A**	**B**	**C**	**D**	**Comments**
Is there proper planning?					
Are the objectives/aims clear?					
Are suitable facilitation methods used?					
Are Assessment criteria aligned to CAPS?					
Are resources used enhancing learning?					
Is the subject content appropriate to the Grade level?					
Does the educator demonstrate adequate content knowledge?					
Is learning taking place?					

3. Communication

Items	A	B	C	D	Comments
Balance of teacher-talk and learner-talk.					
Does the teacher ask probing questions?					
Does the teacher give learners feedback?					
Do learners ask the teacher questions?					
Do learners interact with each other					

4. Learners' Books

Items	A	B	C	D	Comments
Is there a reasonable amount of work done?					
Are there different forms of assessment?					

5. General Comments and Recommendations to the teacher:

Signature of teacher: ---------------------- **Signature of observer-------------------**