Exploring the effectiveness of parent engagement in the teaching of Foundation Phase Geometry.

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Abstract

Learners need mathematics to fulfil academic and vocational dreams, to learn to think in a particular manner and to survive in a world where so many mathematics skills are prevalent. Learners show improvement when they understand the mathematics they are doing, and it is not merely seen as a set of rules. When you connect the dots meaningfully for the learners using diagrams, technology, physical objects, and everyday examples, they start to really understand and problem solve. However, in my experience, the one area where many learners were not showing significant improvement and seem to lack understanding, was geometry. This sparked a sincere interest in studying the cause of the geometry struggle and means of addressing it. The more I looked into it, the more research was pointing to the fact that geometry understanding has to start at a foundation level. You cannot expect learners to engage in complex geometric proofs involving difficult deductive reasoning when they do not know and understand the basics leading up to this. Thus, this master's thesis explores the teaching of foundation phase geometry and how intervention can happen at the grass roots in order to see long term benefits. One of the essential ingredients in developing correct concept formation at foundation phase, is having access to hands on activities through adult-guided play. The reality in South Africa, is that the ratio of learners to teachers is too high to allow this to happen in a meaningful way in the classroom. Too little time is assigned to geometry in the foundation phase curriculum as more important numeracy concepts and learning to read and write, are prioritized. However, lockdown brought to the foreground, the important role that parents can play in improving the education of children. Although not all parents were effective teachers, surprisingly, many very effective in assisting in the educational process of their child when asked to do so. This study therefore looks at parents' input as an interventive means of assisting in the process of teaching foundation phase geometry. Although we all know the ideal solution is a highly qualified teacher in a small classroom with all the necessary resources, this is only a reality for about 3% of the South African population. This study is seeking intervention for the other 97% who do not have the privilege of the ideal.

This study was a case study using qualitative methodology. Video analysis of one-on-one time with parents and their children was used to analyse the effectiveness of parent involvement. Teacher interviews were used to assess how space and shape is currently being taught and parent

questionnaires were used to gather data on how parents felt about being involved in helping their child with space and shape learning.

This study showed that through simple communication with parents, regardless of what socio-economic background they came from, effective activities can be designed to bring about meaningful scaffolding in geometry learning. Although video-analysis revealed very positive findings, parents felt that many other parents would not help their own children due to circumstantial constraints.

DECLARATION I, Siobhan Hopkins declare that:

(i) The research reported in this thesis, except where otherwise indicated is my original work.

(ii) This thesis has not been submitted for any degree or examination at any other university.

(iii) This thesis does not contain other persons' data, pictures, graphs, or other information, unless specifically acknowledged as being sourced from other persons.

(iv) This thesis does not contain other persons' writing, unless specifically acknowledged as being sourced from other researchers. Where other written sources have been quoted, then:

a. *a) Their words have been re-written but the general information (gathered from them has been acknowledged.

b. *b) Where their exact words have been used, their writing has been placed within quotation marks, and referenced.

(v) The work described in this thesis was carried out in the School of Education, University of KwaZulu-Natal from 2020 to 2021 under the supervision of Prof V. Mudaly

(vi) The ethical clearance No. HSSREC/00001800/2020 was granted prior to undertaking the fieldwork.

Signed: ______[redacted]______ Date: 20 September 2021

As the candidate's Supervisor I, Prof Vimolan Mudaly agree to the submission of this thesis.

Signed: ________________________ Date: _____________________

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Dedication

I dedicate this masters' thesis to my late parents, Judy and Patrick McKeon. Thank you for persevering through all the hard times and being the example for me to follow. Mom, you taught me that you are never too old to learn, and I will continue to do so until the day I die, as you did too.

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Chapter 1

Background and Introduction

1.1 Background to the problem

"When will I ever use this?" is a question which almost every mathematics teacher has to defend on a regular basis. Yet we live in a world where mathematics is the language which pervades the solutions to so many of the problems we face, including global warming, over-population, starvation, traffic congestion, crime, corruption, terrorism, and war, (de Villiers, 2016). Not only this, but our daily lives constantly rely on the vast field of mathematics, for example, to predict weather, make digital music, predict business success, or even to predict how long a pandemic will last. The technological growth has been so significant that education systems have had to undergo continuous readjustments to keep up with both the change in the demand from the job market as well as the difference in the nature of the type of learners we are educating. With an increase in technology, there has been a greater demand on in? the types of jobs requiring a mathematical mind.

Although a lot of emphasis is placed on matriculants entering tertiary institutions and the job market, the development of a good mathematical mind begins at a much earlier age. Sound mathematical abilities in younger children are a strong predictor of later mathematics achievement (Aunio & Räsänen, 2016; Aunola et al., 2004; Claessens, Duncan, Engel., 2009; Claessens & Engel, 2013; Jordan et al., 2009 and Watts et al., 2014). Unless sufficient attention is given to the foundation of the mathematical mind, the scaffolding thereon will continue to be problematic.

Since 1994, the process of designing a curriculum in South Africa to address the issues of inequality whilst serving as a tool to drive economic growth in a technologically advancing world, was certainly a challenge. With a strongly politically driven curriculum and a nation where mathematics had only been taught properly to a small percentage of the population, it is not surprising that South Africa performed poorly on the world mathematics scales such as TIMSS.

However, even since 1994, for all the political will and rhetoric, little has been done to improve mathematics education and indicators are that socio-economic inequality has worsened (Graven, 2013). Mohammed (2020, Februry 11, p. 1) states that “South Africa has one of the most unequal school systems in the world. Children in the top 200 schools achieve more distinctions in mathematics than children in the next 6,600 schools combined. The playing field must be levelled.”

South Africa was ranked second last out of 57 countries in mathematics ability according to the TIMSS ranking in 2015 for both grade 4 and grade 8. Roodt (2018) found South Africa’s education system to be generally problematic, ranking 138 out of the 140 countries that took part. Mathematics in particular, saw South Africa ranked last. According to Roodt (2018), South Africa as a member of the Southern and Eastern African Consortium for Monitoring and Educational Quality (SACMEQ) was ranked 8^{th} out of the 16 countries in 2013 re-phrase. The concerning issue, however, was the significant decline in the scores of the teachers since the 2007 SACMEQ, where they first took part (Roodt, 2018). This may have contributed to the fact that the enrolment into government schools rose by only 6% between 2000 and 2016, whereas the enrolment into private schools rose by 130% as faith in the government education system declined. This disparity shows that South Africa’s education system is in a crisis and that there is a need for intervention, especially in low socio-economic regions and particularly in mathematics (Graven, 2013).

Binti et al, (as cited in Mamali, 2015 p. 2) stated that there are many facets to mathematics, but it has been shown that the one area of particular concern is geometry. For secondary school learners in particular, geometry is presenting several challenges. As a mathematics teacher in South Africa, this is evident from first-hand experience and corroboration with other educators. Diagnostic analyses of matric examination papers (Department of Basic Education, 2018) have also shown that geometry poses a problem to matric learners. South Africa is not the only country experiencing difficulty in geometry. Studies have been done in Nigeria (Adolphus, 2011; Fabiyi, 2017) Malaysia (Harun, 2011), Lesotho (Evbuomwan, D, 2013), Zambia (Chisenga & Mulenga, 2019) and even first world countries like England and America are confirming this trend. TIMSS results showed these latter two countries being outperformed by Asian countries like Japan, Korea and Singapore in 2007, 2011 and 2015 (Bokhove et al., 2019). Geometry was so problematic in South Africa, that for a period, it was removed from the syllabus and made optional. Many learners fail to develop an adequate understanding of geometrical concepts, and to demonstrate reasoning and problem-solving skills (Khoo and Clements, 2001).

According to Battista et al. (2017), the positive correlation between spatial ability and mathematical ability has been well-documented. In fact, Mix and Cheng (2012 p. 206) state that "The relation between spatial ability and mathematics is so well established that it no longer makes sense to ask whether they are related." Yet in KwaZulu-Natal; South Africa, space and shape development is awarded as little as 11% of the grade 1 mathematics syllabus time in CAPS and yet geometry constitutes as much as 30% of the total marks in the grade 12 final examination, (DoBE, 2011). Despite its importance, research shows that this area of mathematics is often disregarded or given minimal attention in the early years of schooling (Clements & Sarama, 2011).

Geometry is fundamental to the learners for it helps them to fully understand other topics of mathematics, that is, if properly taught from the foundational level of schooling. Geometry is also the area in early childhood development which lends itself to visual, tactile, enjoyable and meaningful play and is therefore the gateway to making mathematics a positive experience. Many learners have problems understanding mathematics as it does not connect to the visual thinking modality, (Rich & Brendefur, 2018).

Researchers such as Adolphus (2011) have shown that although poor performance in geometry in African countries can be due to a complex combination of socio-political factors, there is evidence to support the fact that learners and teachers have strongly felt that the lack of foundational knowledge and understanding in spatial development has been a significant contributor (Adolphus 2011; Luneta 2014; Mamali 2015; Van der Sandt, 2007).

1.2 Theoretical Frameworks

This study will focus on two key theoretical frameworks, namely van Hiele's development of spatial ability and Clement's and Sarama's Learning Trajectories.

According to van Hiele, spatial ability develops in levels (Abdullah & Zakaria, 2013). Levels are not so much age specific as simply progressive, where it is impossible to master a higher level, unless previous levels of competencies have been reached in lower levels. The detail of Van Hiele's levels will be discussed in more depth in the Review of Literature, but fundamentally the levels include level 0 (visualization), level 1 (analysis), level 2 (abstraction), level 3 (deduction) and level 4 (rigor) (Abdullah & Zakaria, 2013). Van Hiele's work is critical to this research study as it underpins the purpose of focusing on early geometric development. Gujarati, (cited in Alex & Mammen, 2016, p. 2226) emphasized the fact that albeit in the classroom or elsewhere, it is the quality and nature of the learning experience that enables learners to advance from one level to another of Van Hiele's model.

In South Africa, researchers have investigated the critical levels of early childhood development and spatial ability in particular, (McLachlan, 2018). There seems to be an underlying trend which shows that teachers in the foundation and intermediate phases, are not mathematics specialists and are failing to reach the appropriate van Hiele levels themselves. They are therefore not equipped to move learners through the necessary developmental levels (Bowie, Venkat and Askew, 2019). In 2017, some 5139 teachers were found to be under qualified or unqualified, 57% of whom were from Kwa- Zulu Natal (Savides, 2017). This is compounded by the fact that many schools are over-crowded and under-resourced. So where spatial development relies heavily on learners being able to interact with material, teachers and classrooms are not equipped with the resources to allow this to happen. Teachers therefore tend to stick to traditional methods of rote learning and drilling, to teach geometry. According to Boaler (2015) this can be ineffective and can cause high stress levels to learners. The effect is that by the time South African learners are expected to achieve at a much higher level in grades 10-12, they are ill-equipped to handle the standard of questioning and thinking that is expected of them. Therefore, for South Africans to move forward, it is critical that our attention is focused on early childhood development. A study done in the UK has shown that the most important aspect of improving geometry is using good models of pedagogy, supported by carefully designed activities and resources (The Royal Society, 2001).

Building on Van Hiele's levels and the importance of good models of pedagogy, are the learning trajectories designed by Clements & Sarama. These learning trajectories are based on the premise that children follow a natural developmental path of progress when learning. There are well-researched activities that are effective at guiding children through a natural path of learning. Learning trajectories therefore have three parts to them, namely a learning goal, a developmental path, and a set of activities appropriate to each level of thinking (Clements & Sarama, 2020).

It is therefore fair to say that development and learning are different concepts, but closely linked through the theoretical frameworks of Van Hiele and the learning trajectories. Spatial ability is developed at levels, but these levels are attained through the meaningful learning experiences of learners when given the opportunity to be involved in appropriate activities following a sequential pattern.

In South Africa, in many cases we remain rooted with a fundamental problem. It is that foundation phase teachers are not mathematics specialists and often prefer to focus on other areas and secondly, class sizes and resources cannot accommodate the activities appropriated in the learning trajectories. First world countries such as England, Australia and America have identified parents as a valuable resource to assist in the developmental process of learning geometry in early childhood (Monson, 2010; Muir, 2012).

Đurišić and Bunijevac (2017) confirm anecdotal evidence when stating that there is widespread agreement that learners perform best where there is a strong partnership between parents and the school. Despite the consistent evidence of the benefits of parent involvement, mathematics has been of particular interest, with some conflicting views. Important consideration needs to be given to the attitudes and abilities of parents in mathematics. Firstly, parents' abilities can play a significant role in the education of their children. TIMSS has shown that South African learners whose parents had some post-school education did 11% better than learners whose parents only had a secondary school education, and 17% better than those whose parents only had a primary school education (Roodt, 2018). Parents who have a tertiary education, are more likely to understand the benefits of a good education and are therefore not only better equipped to assist their child, but also more likely to drive the attitude of appreciating a sound education.

Secondly, the attitude of the parents is also significant in their involvement. With regard to how parents help their child, it is important to consider how parents themselves were taught mathematics. Muir (2012) believes that parents hold on strongly to their attitudes, beliefs and methods of being taught mathematics (viz drilling and rote-learning). Some learners believe in the more hands-on, constructivist approach, but their enjoyment and attitudes toward mathematics can be influenced by their parents. So, for example, according to Marshall and Swan, 2010 (as cited in Muir, 2012, p. 3), activities involving games and manipulatives may be perceived as a waste of time by parents. Unless parents are informed of the rationale behind the activities, a negative attitude towards the activities may prevail. This has the potential to cause conflict in parental mathematics instruction.

Jay et al (2018) refers to two very different approaches in parent involvement. The first being parent centred, where parents initiate mathematics learning through every-day, household situations offering context-rich opportunities. School-centred involvement is where parents receive directives from schools to assist with curriculum content. Parent-centred involvement tends to have a much higher success rate according to Jay et al. (2018). Having said that, Muir (2012) ran a very successful two-year school-centred project at Pleasant Hills District High School in Tasmania from 2008 to 2010, where "home-bags" were sent home weekly, with instructions, materials and feedback questionnaires from the school.

Tom Harbour launched his British-based website called Learning with Parents (Harbour, 2020). He distinguishes between parental involvement (where parents are involved in the child's school) and parent engagement which is where parents are involved in their children's learning through frequent and positive interaction with them. It is the latter that he focuses on. In 2020, with the onset of the Covid-19 pandemic, parents all over the world were unexpectedly thrust into a situation where they were forced into parent engagement. This was unchartered waters for many parents and in many ways a positive catalyst into a fundamental solution to educational inequalities in many countries. Harbour (2020) states that parent engagement has a greater impact on children's learning than the quality of the school, provided this potential is unleashed effectively. Tilly Browne (cited in Harbour, 2020) who is a head teacher at Reach Academy, England, engaged in the process of fostering parent engagement. For her, the key to success was to make it easy, so the buy-in was high. Regular contact with parents through WhatsApp groups with encouragement of daily goals and reminders of tasks, went a long way in assisting parents. The strategy where experts design the material, videos explain how to execute the activities and text messages are used for parents to give feedback, is seen to be effective and used by the Learning with Parents site (Harbour, 2020).

On 16 July 2003, in the launch of Mindset Network, Nelson Mandela delivered a speech with his famous quote, "Education is the most powerful weapon which you can use to change the world." For so many South Africans education is the way forward. Though many do not have the resources to go out and receive an education, technology means that an education can now come to them. With the availability of smart phones and very reasonable data bundles, it is well within the reach of a large portion of the population, to access ways in which to improve their lives for themselves and their children. O' Dea (2020, p. 1) revealed that currently 3,5 billion people are using smart phones worldwide. In South Africa 55,8 million people have smart phones (Turner, 2020, p. 1). This is 41,6% of the population. It is well documented that video learning is at least as effective as classroom learning, if not more so (Bergwall, 2015; Tisdell, 2016).

This study therefore looks at intervention strategies in teaching foundation phase learners using simple, inexpensive resources that allow learners to actively engage in spatial development activities, with the assistance of their parents. Although this study is focusing on a very specific aspect of early childhood development, there certainly is scope to expand this concept to a broader educational context in South Africa. Harbour (2020) plans on reaching 17 000 primary schools and 8 million parents in the next few years, using parent engagement. Graven (2013) alluded to the fact that inequalities in mathematics education are still significant in South Africa, but that small scale intervention studies are playing an important role in contributing to our understanding of the complexity of factors at play. As qualitative intervention strategies aim to delve deeply into specific areas of study, many of the underlying issues are understood and worked on. Collectively, these intervention studies help to build a global understanding with the ultimate aim of providing a better education for our nations. The COVID-19 pandemic has the potential to unleash a completely different way of either bridging or widening the gap in educational inequalities. It is my hope that through websites such as Learning with parents and Learning trajectories which provide expert information both freely and accessibly, that we can find solutions to bridge the gap.

This study will look at how effective, simple audio presentations or illustrated instructions can be used to educate parents in helping their child develop critical milestones in space and shape learning.

1.3 Location of the Study

This study was primarily conducted in Howick in the Midlands of KwaZulu-Natal, South Africa. Howick is a community with a mixture of economic classes. There are approximately 30 primary schools and 6 secondary schools in the area. All schools in Howick are government run and learners are from a variety of backgrounds. These traverse across social, cultural and political environments. Some of the schools are extremely rural and under-resourced, while others are well resourced and have fee-paying parents contributing to the well-being of the school. As this study sought to study geometric development of foundation phase learners in South Africa, the location does not need to be restricted to any particular area, as long as it remains within South Africa. Every effort was made to include participants from different income brackets.

1.4 Objectives of the study

1) To explore how learners in the foundation phase are normally taught space and shape in schools.
2) To explore the effectiveness of parent engagement in the teaching of foundation phase space and shape.
3) The explore the views of those parents assisting in learning of space and shape.

1.5 Research questions

1) How are learners in the foundation phase normally taught space and shape in schools?
2) How effective is parent engagement in the teaching of foundation phase geometry?
3) What are parents' views about assisting in the learning of space and shape?

1.6 Research Methods/ Approach to study

The research method adopted in this study is qualitative research. It is a basic interpretive study, adopting interventionist strategies. As such, it aimed to bring well-researched global knowledge to a local setting and to bridge the gap between academic knowledge and meaningful practice (Stylianides & Stylianides, 2017).

The research design is qualitative research using interview data, audio-visual data and text data. In order to see how space and shape is being taught, a group of teachers were interviewed. Due to the circumstances during lockdown, interviews were conducted either telephonically or via zoom. The study used a descriptive, interpretive method in order to gain a rich understanding from the interview process (Basit, 2010). Teachers are able to describe, analyse and interpret current classroom practices and show what they use, how they use it and why they chose those methods. The interviews were semi-structured where initially, specific questions are answered and later, time was given for additional comments.

In order to assess how participants developed from intervention, two methods were adopted. Firstly, children were given basic pre- and post-assessment tasks. These tests as well as the activities, were administered at home, by the parents. In order to gain the richness of the experience, parents were asked to use a cell phone or video camera to record the activities meant only to be shared with the researcher as confidentiality and privacy of the participant is ensured. Every effort was made to conceal the identity of the child in the videos. The video analysis added a rich interpretation of the process, as it showed how the participants learnt, and the effectiveness of including parents in the learning process.

McMillan and Schumacher (2014) describe qualitative research as an analysis of people's' individual and collective social actions, beliefs, thoughts and perceptions that is primarily concerned with understanding social phenomena from the perspectives of participants. It is the researcher who is the main source of data collection. It is concerned with answering the questions of 'how? why?' and 'in what way?' In understanding how a learner develops spatial ability, there are too many factors effecting to process to simply imply cause and effect. In this study, the researcher attempts to describe, analyze and interpret the current situation. She examines whether carefully planned intervention strategies impact on the participants' ability to promote geometric development. The aim is not only to move closer to effective practice, but also to deepen our understanding of the problems causing poor spatial development. Due to the nature of education during lockdown, the parents of participants played a key role in administration and collection of data which was then analyzed and interpreted by the researcher, through video analysis.

The activities were sent to parents via email/WhatsApp and included a set of specific instructions (written or audio-recorded) on how to conduct the activity, a word document with printables which allowed parents to make the necessary material, (or ready-made packs where necessary) and a questionnaire for the parents to answer afterwards. The tasks were split up into five days, where a specific concept and resource was used each day. Two to four different activities were included for that day. Parents were asked to keep (limit?) a session to about half an hour so as not to hinder results due to learners' lack of concentration. The activities were all home-based and involved interaction between the participant, the parent and other family members.

The third question in this research looks at parental-engagement and how parents feel about being involved in the learning of their child. This question was answered by means of a questionnaire which parents answered via online or via email. Some of the questions were close-ended and others, open-ended. In a country where there is such inequality in education, this research was attempting to close the gap and not make it bigger. Therefore, it was essential in knowing how accessible this was to parents and whether, for example, their own educational background affected their ability to help their child. Also, of significant importance, was the aim of making mathematics a positive and fun experience for both the parent and the child, therefore using space and shape development as a tool, to remove some of the negative attitudes towards mathematics. The feedback from the questionnaires determined whether these goals were achieved.

1.7 Recruitment Strategy

The sample group in this study was three-fold. Firstly, in order to understand how geometry was being taught in foundation phase, the teachers needed to be participants. The parents formed the second group and were responsible for administering the process. Learners who were given the intervention program formed the third sample group.

This research was conducted under very specific circumstances. In 2020, when the Covid-19 pandemic forced an extensive period of lockdown, restricted contact was allowed among people. Therefore, the sampling methods used for all three groups was non-probability sampling and in particular, convenience sampling. According to Taherdoost (2016), convenience sampling is commonly used as it has the advantage of being both cost effective and timesaving, however it can lead to sample-bias. As this is a real-life study based on a small sample group of about 10 participants, it aims to gain an in-depth examination of the real-life phenomenon of parent engagement and not make inferences in relation to the wider population (Yin, 2003). It is therefore appropriate for this study.

The process involved gathering the contact details of as many of the local grade R teachers in the area as possible. The researcher compiled a list of all the schools teaching foundation phase in the area and obtained details of at least one teacher from each school. Teachers involved could recommend other teachers and therefore snowball sampling was possible.

In order to select samples from families, a message via a class WhatsApp group was sent to the schools of the teachers already contacted. Every member of the grade was informed of the process and invited to be part of the research. Those who were willing to participate were sent a reply and a signed consent form. The learners involved in the process were selected based on the fact that their parents agreed to take part.

1.8 Significance of this Study

Up until this point, we have established that mathematics is a critical skill needed in today's society. Geometry is a part of mathematics where both teachers and learners do not perform well, particularly in South Africa. Geometry and spatial development are too important to ignore. They need more attention in the former years and South African needs wide-spread solutions.

The significance of this study is therefore to ultimately contribute to a deeper understanding of how we can revolutionize the teaching of foundation phase mathematics. It aims to use parents as an essential resource to provide the necessary opportunity to scaffold geometric development and reach the appropriate van Hiele levels, through well researched learning trajectories. As learners are afforded the opportunity to reach the lower van Hiele levels they will then be better equipped to move onto the higher levels required of them in high school.

Chapter 2:

Literature Review

2.1 Description and significance of geometry

According to Heilbron (2020, p.1), geometry is " the branch of mathematics concerned with the shape of individual objects, spatial relationships among various objects, and the properties of surrounding space." Plane shapes are formed by straight lines joining two points on a plane surface and solids are formed by surfaces on a plane (Adolphus, 2011). Plane geometry includes flat shapes such as lines, circles and triangles whereas solid geometry includes 3-dimensional shapes such as spheres and cubes. It is plane geometry that this research is mainly referring to, although many other forms of geometry exist.

Although Euclid (365-300BC) is seen as the father of geometry, similar studies arose in many ancient cultures independently (Russel, 2018). The popular theorists Pierre and his wife Dina Van Hiele based their theory of geometry development on Euclidean Geometry in the 1950's (Vojkuvkova, 2012). However, geometry has evolved significantly to include concepts such as analytical geometry, transformational, and vector approaches (Dindyal, 2007) and according to Heilbron (2020), also encompasses projective geometry, differential geometry, non-Euclidean geometries, and topology.

Geometry is an essential part of the school curriculum globally from grade R to grade 12 (Alex & Mammen, 2016). In many countries, including South Africa, schools use a spiralling curriculum where topics such as geometry are progressively built on every year (DoBE, 2011). In the South African curriculum, the study of Euclidean geometry starts with the introduction to basic two-dimensional and then three-dimensional shapes in the foundation phase. It also introduces spatial ability by laying the foundation of vocabulary such as under, over, above, and below, as early as grade R. Later, learners move on to learn about properties and relationships of shapes and solids. In high school, learners progress from the learning of properties and characteristics of shapes to basic calculations related to properties and then finally to higher order proofs and deductive reasoning. Higher levels of geometry also involve moving from purely Euclidean, to co-ordinate geometry, more complex measurement concepts and linking into other areas such as trigonometry and calculus (DoBE, 2011). Jones (2002) suggests that the study of these geometric concepts helps the learners to develop the skills of visualization, critical thinking, intuition, perspective, problem-solving, conjecturing, deductive reasoning, and logical argument. It is perhaps the complexity of level of thinking required and not only the content that makes geometry so difficult, but also so useful. Progression in geometry involves moving from more concrete to more abstract concepts where analysis and reasoning become fundamental (Russel, 2018).

Understanding geometry is an important mathematical skill since the world in which we live is 'inherently geometric' (Clements & Battista, 1992, p. 420). It is one of the essential building blocks in mathematics which connects to many other areas (Hatfield, Edwards, Bitter, & Morrow, 2000). For example, trigonometry (right angle triangles), functions (gradients), differential calculus (instantaneous gradient), integral calculus (area under a graph) are all fundamentally linked to important geometric concepts (Usiskin, 1980).

Geometry is key in certain career fields such as engineering, geology, astronomy, architecture, robotics, sports science, and art. It is also essential in everyday living applications such as finding directions, household DIY constructions, parking your car and organization of living space (van de Walle, 2001). Geometry is therefore not only essential in its practical content which relates to many career paths, but also in the complexity of cognitive development it enhances.

Longitudinal studies were conducted by Shea, Lubinski and Benbow, (2006) to uncover the best methods of identifying and developing talent for Science, Technology, Engineering and Mathematics (STEM). Five hundred and sixty-three talented participants were tracked over 20 years. Those that saw Mathematics or Science as their best subject by age 13, and who went on to STEM careers showed a high level of spatial ability, closely linked to geometry. In fact, spatial ability allowed for greater incremental validity than SAT mathematical or SAT verbal scores. Other such studies revealed by Wai, Lubinski, and Benbow (2009) reveal with a high level of consistency) that spatial ability has a high influence on STEM domains. It is therefore essential that geometry is taught effectively.

2.2 What should be taught in Geometry in foundation phase

The teaching of geometry begins with basic knowledge of space and shapes. Spatial thinking, according to Copley, (2010) refers to different positions of shapes and being able to imagine and use language of the movement of objects. This includes for example backwards, forwards, left and right, up and down. Shape refers to both two-dimensional and three-dimensional shapes and their form. Familiarity with shape, structure, location, transformations and development of spatial reasoning enable children to understand not only their spatial world, but also other mathematics topics. (Copley, 2000, p105)

In a child's cognitive development, shape is a fundamental construct (Clements et al, 2018). Children group similarities of ideas to form artifact categories of concept images. These concept images stabilize at about the age of 6 years. It is therefore important that children between the ages of 3 to 6 years, are exposed to good foundational knowledge of plane figures such as triangles, rectangles, circles and squares as well as three dimensional shapes and spatial competencies (Clements et al, 2018). Using books, toys, mobiles, blocks, phone apps and television programs, children can be exposed to the concrete manipulation required for effective concept image formation. Shapes are one of the first mathematical concepts that children are exposed to. Children are naturally curious and interested in shapes and spatial ideas (Brown 2009:474). Playing with and manipulating various toys and games contributes to the concept images children form of space and shape. However, play in itself, is not enough. With the careful facilitation by an adult, children are given the opportunity to form the foundation of space and shape understanding (Weisberg et al, 2016).

Clements et al (2018) stress the importance of analysing how children identify figures by using carefully selected subcategories. These include both examples and non-examples of shapes. Four categories are used, for example, in the assessment of triangles and rectangles. In the members category, there are exemplars and variants. These are illustrated in figure 1 below. Exemplars show typical shapes that children are most commonly exposed to while variants show shapes that are definitionally correct, but are atypical in puzzles, blocks and games that children are exposed to. Children may incorrectly reject certain triangles based on skewness (apex not in midline of triangle), aspect ratio (too "skinny") or orientation (up-side down). It is skewness that affects children the most in their interpretation (Clements, 2018).

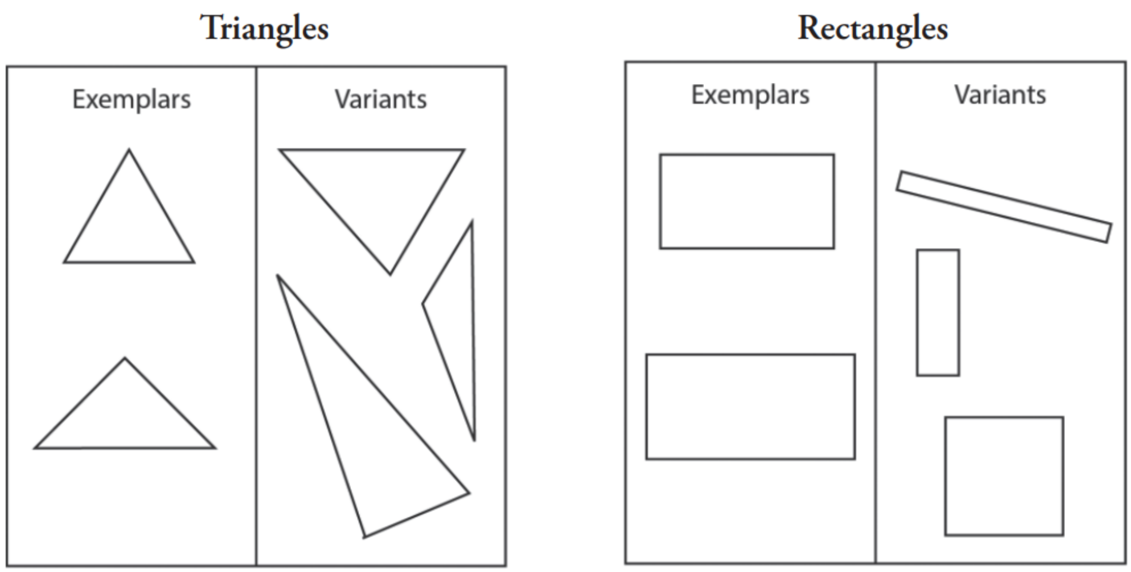

Figure 1: Examples of members of classes of triangles and rectangles (Clements, 2018, p. 10)

In the non-members' category there are palpable distractions and difficult distractors as shown in figure 2. Palpable distractors show obvious shapes that do not fit into the category and are usually clearly identified. Difficult distractors are similar to the classified shape, but tend to have one property, such as a side without a straight edge, that makes it a non-member as illustrated in figure 2.

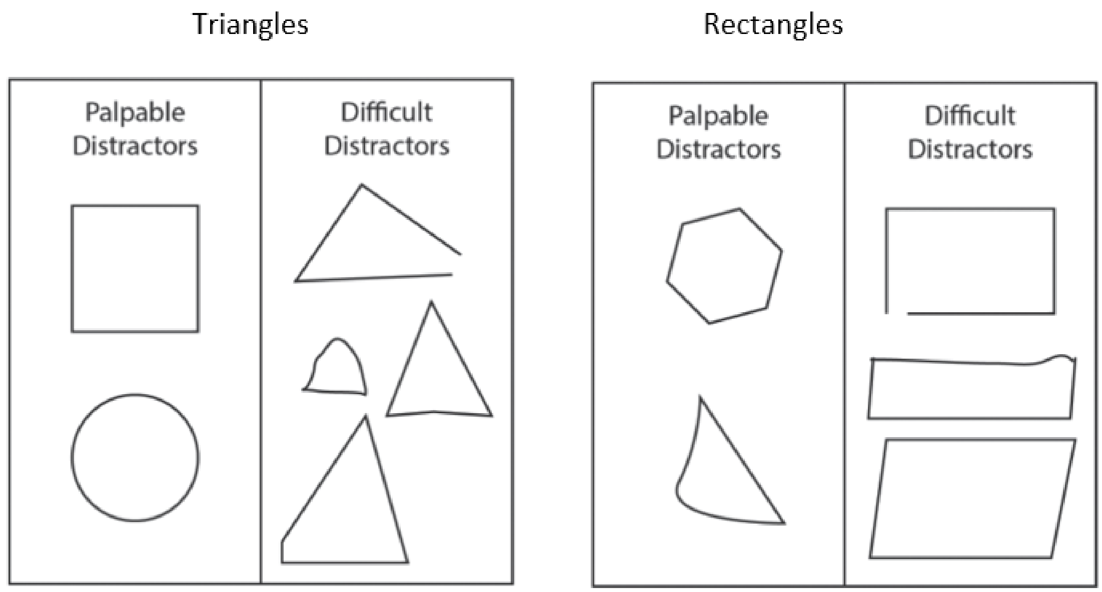

Figure 2: Examples of non-members of classes of triangles and rectangles (Clements, 2018, p. 11)

Vinner and Hershkowitz (cited in Clement et al., 2018, p. 10) stress that without good quality exposure to foundational shape knowledge, children can form (sometimes incorrect or misrepresented) rigid visual prototypes which stick with them throughout their lives. A typical example of this would be the triangle which is always shown as an equilateral triangle with a flat base (Δ). Children who see a triangle with a point at the base (∇), might think that this is not a triangle as it deviates from their rigid, ingrained concept image. This concept of a shape being different when it has a different orientation is known as invariance. According to Feikes et al. (2018), it cannot simply be taught to a child. You cannot just tell the child that they are the same shape and expect them to understand. Learning comes through continued and repetitive manipulation of concrete objects through sensory motor activities such as tangrams, pentominoes and block or shape play. Therefore, an important aspect of how geometry is taught, is paying attention to forming correct concept images by exposing children to a variety of concrete, manipulatable shapes, repetitively. The assistance of a competent adult in playful activities creates meaningful concept images.

Copley (2010) reiterates this by using an example of squares and rectangles which are often taught as two discrete shapes. Children need to be taught that a square is a subset of a rectangle and that rectangles don't have to have two long sides and two short sides but can have equal sides. Concepts that can be built on at a later stage are that of a square being also a quadrilateral, parallelogram, and rhombus, which young children wouldn't understand. The point is that teachers should not "dumb down'' concepts to the point of being wrong by saying for example "that is not a rectangle, it is a square". In addition to this, teachers may start introducing specifics related to sides and angles. Angles are referred to as "points", "tips" or "corners". Teachers may start emphasizing the difference between corners being a right angle and a tip being a non-right angle. The definition of sides of a circle also creates discrepancies among educators. If a "side" is defined as having a straight edge, then a circle has no sides, only arcs, which are curved edges. However, if a side is seen as the outer edge of a shape, then a circle has one curved side. Therefore, discrepancies need to be made for example, between a side (consisting of straight lines) and an arc (consisting of curved lines).

Emphasis has been placed on triangles and rectangles in the examples given above as these two shapes seem to cause the most confusion. All shapes, however, need to be carefully unpacked and attention given to both members and non-members, so children form strong and accurate concept images, without misconceptions, of all fundamental shapes.

2.3 Goals of Geometry Learning

In understanding how geometry is taught, it is important to firstly conceptualize the general goals of geometry, secondly, the goals for foundation phase and lastly, the goals for foundation phase in South Africa in particular.

The general goals of teaching geometry have been established for many decades. Different sources define geometry goals differently, but there are commonalities. According to Suydam (1985), these are to develop logical thinking abilities; develop spatial intuitions about the real world; impart the knowledge needed to study more mathematics and teach the reading and interpretation of mathematical arguments. The National Council of Teachers of Mathematics (2020) in the United States, includes in its aims, that all grades analyze characteristics and properties of two- and three-dimensional geometric shapes and develop mathematical arguments about geometric relationships. The understanding of two- and three-dimensional shapes is foundational knowledge which is necessary not only for other mathematical concepts to be built on, but also in certain professions. It also aims to specify locations and describe spatial relationships using coordinate geometry and other representational systems. This is a very practical aspect of geometry and is used in everyday life. The third goal is to apply transformations and use symmetry to analyse mathematical situations and lastly to use visualization, spatial reasoning, and geometric modelling to solve problems. This holistically ties into the broader mathematical goals as problem solving is essential in its application throughout life.

For the sake of this study, we will look more specifically at what the objectives are for foundation phase learners in geometry, in South Africa. Specifically, the content focus on foundation phase geometry is to improve understanding and appreciation of the pattern, precision, achievement, and beauty in natural and cultural forms (DoBE, 2011, p10). It focuses on the properties, relationships orientations, positions and transformations of two-dimensional shapes and three-dimensional objects. This ties in closely to the international goals of geometry learning.

In the foundation phase, learners focus on three-dimensional (3-D) objects, two dimensional (2-D) shapes, positions, and directions (DoBE, 2011). Learners explore properties of 3-D objects and 2-D shapes by sorting, classifying, describing, and naming them. One can see that for this goal to be reached, learners need access to resources as part of the exploration process. Not only that, but Clements and Sarama (2018) allude to the fact that the exploration of properties in part, is simply working with and manipulating shapes and objects through play. It is not, however, a natural process to associate this free play with the fundamental link to actual properties and for this, adult-assisted play is essential.

Ginsburg et al (2006) have found that children in pre-primary schools find the mathematical process of development both enjoyable and exciting. Mathematics learning is natural and pre-primary school learners are innately drawn to mathematical problems and situations, according to Lee and Ginsburg (2009). Many mathematical ideas are constructed through mathematically rich environments, regardless of culture. However, this is not where it ends. Teachers need to build on this crude foundation with intentional pedagogical mathematics, which allows children to understand mathematics in deep, formal, and conventional ways (Ginsburg & Seo, 1999). A colleague of mine described how as a child his parents often gave him crayons and paper. As he learned to draw houses, furniture, cars etc., he was innately learning how to construct parallel lines, draw circles, make walls perpendicular to floors, etc. Later, however, it took a teacher to mathematize what he had already naturally been doing. This example not only supports Ginsburg and Seo's (1999) ideas, but is strongly emphasized in the more recent work of Clements and Sarama's (2018) learning trajectories.

The foundation phase curriculum also encourages learners to draw shapes and build with objects. Learners should recognize and describe shapes and objects in their environment that resemble mathematical objects and shapes (DoBE, 2011). Learners are also expected to describe the position of objects, themselves, and others, using the appropriate vocabulary, follow and give directions. The concept of language in mathematics is not to be underplayed. It is often the lack of understanding of terminology, such as points of intersections, conjectures, transversals, etc. which leaves learners lost in understanding. In South Africa this is particularly problematic as many learners are not taught in their mother tongue. Although this is worth a study on its own, it is certainly worth considering in geometry learning in South Africa and will be discussed in greater depth when addressing the failures of geometry teaching.

The National Curriculum Statement (2011) suggests that classroom mathematics time should be split into three parts, namely whole class activities, small group activities and independent work (DoBE, 2011). The significance of the way in which content is delivered cannot be over-emphasized. Grade R mathematics learning should be based on integration and play-based learning (DoBE, 2011). The teacher is seen as the mediator to facilitate incidental learning opportunities that arise during free play as well as teacher-guided activities that focus on mathematical concepts such as space and shape (DoBE, 2011).

The NCS also suggests that learners with barriers to mathematics learning be given more time on activity-based learning, as moving to abstract concepts too quickly could lead to frustration and regression. Mathematicians such as Baptista (2017), Clements and Sarama (2018) are advocates of the learning trajectories approach, discussed in the theoretical framework. The art of a skilful grade R mathematics teacher is being able to identify where the individual learner is at and being able to provide appropriate activities and learning opportunities which will allow the learner to progress to the next goal. Most learners progress in the same way so teachers should be able to follow a developmental pathway with all their learners at large. However, small groups can allow for both fast and slow learners to progress at the appropriate pace. (Clements & Sarama, 2018)

The NCS also stipulates that all activities should promote the holistic development of the child. These activities aim to move learners through the three stages of development, namely the kinaesthetic stage, the concrete stage and the paper and pencil representation. The manner in which geometry learning is delivered is discussed in 'methods of teaching geometry,' below.

2.4 Methods of Teaching Geometry

In studying how geometry is taught, we consider a brief neurological understanding of the brain when learning mathematics. We also look at different types of teaching of geometry in foundation phase, namely free play, guided play, and pedagogical teaching. We draw on the successes of Singaporean mathematics which developed the concrete, pictorial and abstract model (Hui et al, 2017).

Theories on the processes of how learners learn, is constantly evolving as more and more research is being done in various fields. Stanford University has been corroborating with neuroscience labs to discover ways in which our brains work mathematically. The brain uses five networks which we engage in mathematics thinking (Boaler et al., 2016). Two of these networks are visual, one being dorsal, one being ventral. These neuro-scientific brain operations are extremely complex to explain and understand and require a thesis within themselves. However, for the sake of this study, what we take from them, is that with all mathematics learning, it is essential to develop concepts visually to make meaningful connections between networks and therefore deepen understanding (Boaler et al, 2016).

Other researchers such as Feikes et al (2018), believe that children learn through repetitive manipulation of their physical world as well as reflection thereof. Children need to construct, tear down, change, draw and importantly, then reflect on the world around them. For spatial development in particular, learners need to start to understand the vocabulary and terminology in a meaningful and progressive way (Feikes et al, 2018). Words such as near and far, bigger, smaller, in, on and under, are learnt initially as learners "play" and make sense of words connected with actions. These common terminology words are often re-enforced in the home and with games played with friends. Children make sense of spatial shapes and ideas by forming a concept image, as mentioned earlier. This mix of mental images with no specific formal definitions attached, created by looking at examples and non-examples, needs to be deliberately emphasized. It is important that teachers are intentional in their interaction with learners in early mathematical development to give them the opportunity to be exposed to both examples and non-examples (Cross et al, 2009).

It is common knowledge that effective teaching in mathematics, involves meeting the learner where they are and then helping them to build on what they know, but this is really much easier said than done (Clements & Sarama, 2009). A child who has the advantage of a good foundational knowledge, a skilled teacher, sufficient access to resources and the support of a loving family, is bound to succeed.

Much research (Clements & Sarama, 2019; Van der Walle, 2001; Rosli & Lin, 2018; Hembold, 2017) has been done on types of learning in the foundation phase. We understand that the teaching of geometry is a process of formalizing children's innate ability to engage with the mathematics around them. In the search to improve didactic instructional methods, Fisher et al (2013) studied children of the age of 4 to 5-year-old. It was revealed that with children learning the basic structures of four shapes, that of the three methods, namely, guided play, free play, or didactic instruction, it was guided play that showed the most improved shape knowledge compared to the other methods. That is not to say that there is no merit in free play or didactic instruction. Freud was a strong advocate of free play and valued the psychological benefits it had in helping a child gain control over situations which helped them later in life (Rosli and Lin 2018). Gray (2011) showed evidence that with the decline of free play, comes increased mental health disorders in children and adolescents. Free play allows children to become better decision makers, problem solvers, better rule-followers and to learn better self-control according to Gray (2011). Free play also helps to regulate emotions, make friends, and experience joy. It certainly has its place in education although as a stand-alone, cannot always bridge the fundamental gaps needed to grasp key concepts. So, children should be allowed to play freely with blocks and shapes, but the support of an adult is necessary when constructing their knowledge of space and shapes to a more advanced level of understanding.

Didactic instruction methods such as the drill method have been very strongly criticized, yet also highly valued. In 2018, Barbara Oakley wrote an article emphasizing the important role that old-school drilling can play in math learning. Petre (2014 p. 1) showed that on mathematics tests done with 562 nine- and ten-year olds, Chinese learners performed a significant 20 – 30% higher than their English counterparts. When investigating what was happening in the classroom, videos revealed that in the Chinese classrooms 72% of the time was spent in whole-class interactions compared with only 24% in England. This seems to contradict the evidence which promotes guided- play, however, age, culture and nature of the child are to be considered. Two studies done on dentistry learners (Sharma & Kumar, 2018) and chemistry learners (Shallcross &

Harrison, 2006) showed that university learners actually prefer chalk and talk methods of teaching to other more modern methods as they tend not to be over-complicated. They also create natural breaks and go at an appropriate pace. Thus, didactic methods are appropriate for more mature learners who are at an advanced stage of constructing their understanding. At a younger age, children are not able to construct meaningful understanding on abstract concepts and therefore need a more hands on, playful approach.

Although all methods of study have their place, in geometry learning in the early childhood development phase, it is guided play that has been shown to be most effective (Hembold, 2014; Fisher et al, 2013). Guided play maintains the joyful child-directed aspects of free play but adds an additional focus on learning goals through light, adult scaffolding (Weisberg et al, 2016). The adult scaffolds the child's learning by providing the correct opportunities and activities to guide them where free play may not necessarily have taken them.

Clements and Sarama (2009) support this argument and show for example that children would not necessarily learn the definitional properties of a triangle when playing with the shapes by themselves. Hembold (2014) substantiated this international evidence and conducted similar research in South Africa. Her research study showed conclusively that teacher-directed play as opposed to free-play or worksheet based curriculum activities, yielded better results in mathematics progression from grade R to grade one across the urban, rural and township areas she worked in. I agree with both Clements and Sarama, and Hembold views, not only in that a teacher-guided task will yield better depth of progress, but that if a child is left to their own devices, they may not expose themselves to the variety of activities that are required to create the ambit of progress they require. Chalk and talk, however, which is still commonly practiced in South African, falls short in that children are not given the opportunity to manipulate objects and therefore are limitted in forming foundational concept images or developing invariance.

Guided play works because it encompasses the enhanced discovery approach which increases a child's knowledge through immediate and effective adult feedback. The concept of guided play stems back to the work of Lev Vygotsky in his concept of the Zone of Proximal Development, (Woolfolk, 2010). Vygotsky believed that all human activity occurs within a social and cultural context, and that guided play creates the ideal opportunity for a child to construct knowledge and learn through interacting with a person who could skilfully advance their thinking to a higher level at the opportune moment (Woolfolk, 2010). Guided play helps to discover causal relationships through informal experimentation. For example, a child playing with blocks will learn that if the block is placed in a specific orientation, it will topple over, but if he changes the orientation, it stays upright. While playing, the adult might include the language and some guidance about the block and ask questions which help the child engage in longer periods of play without being frustrated (Hirsh-Pasek et al, 2017).

Hassinger-Das et al (2017, p. 193) illustrate the difference in the various methods of instruction in shape learning as follows:

Direct instructions: Teacher asks children to sit quietly at their tables while she shows them images of shapes. While they listen, she tells them the definition of a triangle, presents images of triangles on a Smart Board, and shows a video about triangles.

Free play: Children in a playroom filled with toys choose to play with blocks of varying shapes and sizes. They decide to use the blocks to build a castle and pretend to be kings and queens.

Guided play: Teacher asks children to break into small groups. She hands each group ten shapes. The children begin to play with the pieces. The teacher joins in with a puppet friend who says she was sent by the king and queen to bring back the secret of what makes a triangle 'real'. The teacher/puppet asks children how they can tell which pieces are 'real' triangles. She helps them discover the common features among triangles that define them. The children play with the shapes and continue to discuss whether they are 'real' triangles or not. The teacher scaffolds the discussion to help them learn that all the triangles are 'real', they are just of different types

Adult-scaffolded play experiences might be particularly important because they help children develop what scientists call *proactive control*: neural mechanisms in the brain's prefrontal cortex that use clues from the environment to help the brain figure out what might happen next (Weisberg et al. 2014). Guided play might support the development of proactive control by fostering a *mise en place*—a term derived from the culinary world meaning "everything in its place "suggested by the famed psychology professor Jerome Bruner (2013).

The three different methods of teaching foundational space and shape have been discussed and adult guided play was conclusively seen to be the most effective method (Hembold, 2014). Singapore has featured in the top three countries in the world in mathematics ability according to the TIMMS scale for a while now, and their mathematical education system has been under scrutiny in order to discover the secret of their success. Leong et al (2015) describes the basic concept of Singaporean mathematics, that is, learning by doing. The basic precepts are that, firstly, learners are taught fewer concepts but, in more depth, to gain a richer and fuller understanding of the concepts. Secondly, concepts are taught using a 3-step process, namely, concrete, pictorial and abstract, otherwise known as the CPA Model. (Hui et al, 2017). This is a model based on Jerome Bruner's proposition of enactive, iconic, and symbolic representations of cognitive growth which was adopted into the Singaporean mathematics curriculum (Chang et al, 2017). The concrete stage involves the use of physical objects which learners touch, play with, and manipulate, such as paper clips, dice, blocks. This is followed by drawing pictorial representations of their manipulatives which in the NCS is known as the paper and pencil stage. Learners remain in this stage until they reach the final stage where they can solve problems abstractly.

A caution in bringing in this 3-phase approach without proper teacher-training is that the use of stimulants is not always constructive. According to McNeil and Jarvin (2007), manipulatives that are too rich in perceptual detail or ones that may be too familiar to learners in a non-school context, may serve more as distractors than as useful resources. This is often the case with the introduction of iPads into teaching environments. Although the development of exceptional learning tools has been evident, too often learners associate the iPad with mindless entertainment or even switch out to other applications during class times. Many schools have chosen to remove devices such as these from classrooms with younger children as they often did more harm than good, in spite of their learning potential (McNeil & Jarvin, 2007; Greenfield, 2015).

It can therefore be seen that setting meaningful goals, adopting effective teaching methods, and paying attention to how space and shape is being taught, has been well researched and many experts and research projects have alluded to how effective geometry learning can happen. Environments with qualified teachers, abundant access to knowledge, training and resources, and classrooms which allow for the necessary adult supervised play, lead to the effective teaching of space and shape. South Africa and many other less developed countries usually do not have these ideal environments. The complexity of the failure to produce such ideal learning environments cannot be ignored. Some of the most prominent issues will be discussed in more detail.

2.5 How and why the teaching of geometry has failed

Clements and Sarama (1990) reported that geometry, at high school level, is one of the learners' weakest areas in mathematics in the United States. This, however, is not unique to the United States. Copley (2000) claims that although geometry is one of the first aspects of mathematics taught in the United States classrooms, geometry it has received little focus in the curriculum. Much learning of geometric concepts by U.S. learners has been by rote; they frequently do not recognize components, properties, and relationships between properties (Clements & Battista, 1992b). It is therefore not surprising that geometry is also the one mathematical domain least understood by teachers of young children in many countries, (Clements et al, 2018). According to Genz (2006), evidence from a variety of sources makes it clear that learners at junior school level are not learning geometry concepts appropriately in order to prepare them for success in their high school geometry courses (Alex & Mammen 2018).

The University of Pretoria has done extensive research on how to improve mathematics results of grade 12 learners (Horak & Fricke, 2015). Research funds were getting exhausted, and improvements were minor. The focus was on offering many hours of support at a grade 12 level and re-emphasizing current work. With donors tiring of the low success rate, the university was required to rethink their approach (Horak & Fricke, 2015). It became evident, after studying many intervention strategies, that the problems in South Africa, are of a systemic nature. TIMMS results have shown that South Africa has continually performed poorly in mathematics and science. Graven (2016) described the South African education system as being two different systems. One is a functional system for the wealthy, where our results are similar to those of international standards and, another dysfunctional system where poverty prevails and poor performance in mathematics and science is understandably the norm. According to the in-depth analysis of TIMSS (2002) results, key issues in South Africa were teacher-related aspects, the language of tuition, and learner-specific socio-economic situations. These are discussed below in more detail

2.5.1 Teacher-related issues

It is clear that the impact the teacher has on learners is significant. This value is highlighted in the early years of education as the learners usually only have one teacher, as opposed to different teachers for different subjects in high school. Researchers such as Makofane and Maile (2019) and Adolphus (2011) addressed concerns regarding teachers that included a lack of formal qualifications, lack of proper lesson preparation, teachers' low expectations of learners, teachers' pedagogical beliefs and the need for teachers to teach topics from previous grades.

The teaching of mathematics in foundation phase requires the careful attention, involvement, and skilled development of the educator. However, attention is often drawn away from mathematics and given to the more exciting and visible language and literacy programs (Lee & Ginsburg, 2009). Typically, teachers of pre-school children have had little course work or training in teaching mathematics (Ginsburg, Hyson & Woods, 2014).

Mamali (2015), attributes poor teacher performance to the fact that learners capable of being good mathematics teachers are choosing professions which have considerably better remuneration, thus leaving sub-standard mathematicians in the classroom. Due to the shortage of mathematics teachers, appointments are made for teachers with little or no suitable qualification. Even in the case of effective, well-trained teachers, the poor physical conditions and lack of resources in many of the disadvantaged schools, means that good teachers will favour independent schools which are well-resourced with comfortable working conditions. This perpetuates the cycle of the large socio-economic gap in South Africa. Roodt (2018; p. 3) quantifies this gap by saying, based on TIMMS (2015) results, independent schools performed "13% better than those in fee-paying public schools and nearly 40% better than those in non-fee state schools. Learners at fee-paying state schools also had scores nearly 25% better than those attending schools with no fees." Alex and Mammen (2018) commented on the fact that the South African education system has an ongoing struggle with under-preparedness of educators largely due to persistent curriculum changes since 1994. It takes a great deal of time to prepare lessons and resources for a given curriculum. When the curriculum is frequently changing, as has been the case in South Africa since 1994, teachers are diverting their energy on familiarizing themselves with new curriculum content material rather than using valuable time enhance their skills.

Van der Sandt (2007) looked specifically at geometry education of pre-service and in-service teachers in South Africa. Her research concluded that pre-service training is not adequately preparing teachers to understand the level of geometry required of them to teach at a level that is necessary. Her research confirms other prior research where Mayberry (1983) showed Van Hiele levels achieved by elementary school teachers to be; 13% (level 0), 20% (level 1), 19% (level 2), 24% (level 3) 25% (level 4) and 0% (level 5). Thus, teachers entering the teaching profession are not adequately prepared with content knowledge regarding geometry.

In South Africa, similar studies have investigated the critical levels of early childhood development and children's spatial ability in particular, (McLachlan, 2018). There seems to be an underlying trend which shows that teachers in the foundation and intermediate phases, are not mathematics specialists and are failing to reach the appropriate van Hiele levels themselves. They are therefore not equipped to move learners through the necessary developmental levels (Bowie, Venkat & Askew, 2019). In 2017, some 5139 teachers were found to be under or unqualified, 57% of whom were from Kwa- Zulu Natal (Savides, 2017, p.1).

2.5.2 Language of tuition

According to the 2007 DoBE Annual School Survey, 7% of all South African learners are English speaking, yet 65,3% of learners are taught in English. In 2010, after 16 years of democracy, still 94% of learners were being taught in either English or Afrikaans when only 17,2% spoke those languages at home (Graven, 2016, p. 9). It is therefore clear that a vast percentage of learners are not taught in their mother tongue. Research has shown that learners being taught in their native tongue, out-perform those taught in a non-native tongue (Robertson et al, 2020). This is especially true in the early years of schooling (Robertson and Graven 2015). The fact that geometry uses complex concepts and vocabulary, means that language of tuition cannot be ignored as it is a major contributing factor to the failure in geometry learning. English is often chosen as the language of instruction as it is believed that good English is beneficial in providing access to power, both socially and economically (Graven, 2016). So although language issue prevail across all areas of education, in and many topics covered in mathematics, it is of particular concern in geometry as it is an area rich in specific vocabulary such as conjectures, axioms, proofs, and corollaries for example. Failure to understand words such as these, can hinder progress in geometry.

2.5.3 Socio-economic issues

Mathematical studies by Klein et al (2008) across countries, namely the US, China, and Japan, have shown that a gap in mathematical knowledge due to differences in socio-economic status (SES) was prevalent in all three countries. South Africa is no different. Not only are these SES-gaps clearly defined, but also broad and stem across a wide spectrum of mathematical concepts, namely numbers, arithmetic, space and shape, patterns, and measurement. They also seem to prevail over an extensive time. Children with SES- related gaps in pre-school, tend to show persistent and more pronounced problems over time. One of the compounding factors is the belief system of parents; those from economically disadvantaged families believe that it is the school's responsibility to impart mathematical skills and knowledge, whereas middle class families believe in the importance of the role parents play and therefore try to assist in mathematical learning in the home. Secondly, the limited knowledge and skills of some teachers in economically disadvantaged schools, also contributes to the problem. All of this points to the fact that there is a real need to develop intervention studies which aim at dealing with ways in which SES-related gaps can be narrowed, (Klein., et al 2008).

Mohangi et al (2016) researched some of the realities facing South African rural schools (of low socio-economic status) in terms of three major themes, namely pedagogical challenges, resources provisioning, and management and support. It is apparent from their research that schools faced many challenges in making grade R education effective. This included poverty, transport challenges, language issues, limited professional training, poor school attendance, diverse learner backgrounds, lack of infrastructure (for sanitation, water, electricity, and ICT (information and communication technology). Rural schools make up 62% of South African schools, according to Surty (2011), (cited in Mohangi, 2016), and a large portion of these schools are not able to reach the ambitious National Curriculum Statement objectives due to the above-mentioned complications. It is impossible to merely see the problems of geometry learning without considering the socio-political background which directly affects every aspect of the learning process.

Although South Africa certainly have a number of socio-political factors to consider, there have been improvements. Grade R enrolment improved from 15% in 1999 (DoBE, 2009) to 72,6% in 2011 according to the 2011 census (statssa, n.d). This is indeed a positive change as Grade R is an important foundational year which 85% of South Africans were not exposed to at all.

Help "from the top" has also improved significantly as the White Paper 5 has served as a guide to improve early childhood development. The 2012 diagnostic review saw early childhood development as a priority. Intervention strategies included increase in the provision of infrastructure, learner support material, standardization of teacher training and staff remuneration. Since 2008/9 the government expenditure on grade R trebled, the number of rearly childhood development (ECD) increased and of the recorded 836 000 children in ECD centres in 2012, 58% were subsidised (Atmore et al., 2012, p. 121). This intervention is not sufficient to allow the goals set out by the former Minister of Education to be met, which was to have every compulsory attendance to grade R by 2010 (Janse Van Rensburg, 2015). Learners in schools of low socio-economic status continue to struggle and Mohangi et al.'s (2006) research show that what is happening on the ground is indeed very different to what policies intend.

2.5.4 Lack of resources

A study conducted in the UK has shown that the most important aspect of improving geometry learning, is using good models of pedagogy, supported by carefully designed activities and resources (The Royal Society, 2001). According to Adolphus (2011), in geometry, which forms the fundamental underpinning of engineering and technological development, the need for physical resources is paramount. The physical tools such as models, games, concrete shapes, and blocks will help learners to grasp the idea of geometry which otherwise seems to be disconnected and abstract. Learners use resources of a physical nature to grasp concepts and acquire a deeper understanding thereof. Many schools lack certain facilities and equipment, forcing teachers to use antiquated teaching methods, like drawing and writing on a chalk board. This offers little support to scaffolding learners' understanding of geometric concepts. According to Boaler (2015) this can be ineffective and can cause high stress levels as teachers progress to more complicated concepts with little or no understanding from learners. Botha et al (2005) are strong advocates for the use of real, concrete materials and activities in early mathematics teaching, in South Africa. The work of Jean Piaget has shown that even children up to the age of 11, still require learning stimulants as their logical abstract thought is not yet fully developed (Hembold, 2014). Piaget's advocation of concrete stimuli in what he calls the pre-operational child, is supported by both Vygotsky and Feuerstein (Botha et al, 2005). Thus, environments where learners do not have access to stimulating resources, could hinder their developmental progress, as is so often seen in under-resourced South African classrooms.

2.5.5 Class size

Spaul (2016), reveals that the post-provisioning norms for class sizes in South Africa in 2002 (Government Gazette 24077) indicate that the ideal maximum class size for grades R – 4, is 35. However, statistics from the Annual Survey of Schools (ASS) data for 2013 show that in KwaZulu-Natal, for example, 16% of grade 1-3 learners are in classes of 41 to 45 learners, 14% are in classes of 46 to 50 learners and 27%, in class sizes larger than 51 (Spaul, 2016 p. 3). These class sizes are certainly not conducive to fulfilling the NCS objectives of allowing small-group activities and independent play, no matter how skilled the educators are. Learners that in essence must have individual time with an adult on a regular basis to be able to form foundational concept images, will not be afforded this opportunity in classes that are this large. In contrast to this, The World Bank (2020 p. 1) recorded the world average ratio of teacher to pupil for pre-primary schools, to be 1: 17,451 in 2018. The most recent World Bank results for South Africa was a ratio of 1: 29,644 for pre-primary schools, in 2014. Although there was significant improvement from 2002, it is still a long way off world standards.

2.5.6. Curriculum issues

Earlier, the Singaporean mathematics approach of concrete, pictorial and abstract?? was discussed. The foundation of this approach is that there is less content knowledge taught in more depth. I think that a short fall of the South African education system that many teachers are struggling with, is that we are seeking to bring in effective methods without reducing content knowledge in the curriculum. This has left teachers exhausted and frustrated as they are unable to get learners to understand at the level required, due to the high content demand and rigid curriculum, forcing them to move on in order to finish the syllabus. Learners are forced to move on before they have been given substantial time and means to grasp concepts properly and are left with gaps in their understanding. With the spiral approach to teaching, in the years that follow, the gaps tend to get bigger.

Although in the ancient Greek times, geometry constituted the whole of mathematics, now, in high schools, it tends to be side-lined for arithmetic and algebra (Sinclair et al., 2015). In primary schools, this is exacerbated by the fact that learners have one teacher expected to teach various subjects. Geometry learning is not only competing against other areas in mathematics, but also with all other components of foundation phase learning, including reading and writing skills.

Fuys et al., (1988 p. 84) stated very bluntly that 'current curricular emphases have produced "geometry deprived" learners.' Still today, one of the most problematic areas in high school mathematics, is geometry. So much so that in South Africa, "The Revised National Curriculum Statement came into effect in the Further Education and Training Band (FET) in 2006, where Euclidean geometry was excluded from the compulsory mathematics curriculum component" (Alex & Mammen, 2018, p1). This exclusion of geometry from the syllabus was largely due to the fact that too many teachers were incapable of teaching it. It also however resulted in a band of teachers who had no experience in learning it, let alone teaching it, and therefore the problem perpetuated long after it was returned to the syllabus.

The curriculum also wrestles against other stakeholders such as the culture of examinations, the textbook industry with their own agenda, the demands of mathematics departments of universities and teachers wanting to stick to methods which worked for them (Bruce et al, 2016). Graven highlights the matters of curriculum issues in an article dealing with how systemic intervention gets in the way of localized mathematics reforms (Graven, 2016). Her report on a specific case study highlights the extent to which this problem prevails. A teacher was interviewed in February 2015 where she was asked how she managed the tension of revisiting work from earlier grades and keeping up with the grade 4-7 departmental schemes of work. In essence, the teacher alluded to the fact that although she felt the need to spend time on grade 2 work because that's where her grade 2 learners were at, her subject advisor told her that it was wrong to do so and that she should stick to the curriculum. She felt obliged to hide the recovery work from district officials. She felt that moving on to the work she was supposed to be doing was only frustrating the learner and herself because she could not foster the progression required (Graven, 2016 p 9-10).

There is a clearly existing tension between stakeholders who ultimately aim for the same thing, to improve the education levels in our country. However, conflicts between systemic objectives and ground level teacher practice are clearly evident. Similar systemic conflicts exist with mathematics teachers through all grades. Not only are they overwhelmed by the sheer volume of the curriculum, but also by volume of time needed to complete the demands of administrative tasks that the system places on them.

It is clear that South Africa's NCS has been well-researched and is ambitious in aligning our learners with international standards. However, the question remains, 'Are these ambitious aims realistic in all South African contexts?' The results often speak for themselves.

2.6 Parent engagement as a potential solution

The depth and complexity of educational issues contributing to poor mathematics results in South Africa, is evident from the research described. However, as much as there are many problems, there are many solutions. Intervention studies aim to address problems and try new ways of moving closer to solutions. A large body of evidence has shown that learners who come from supportive homes tend to do better. However, causal correlations between parent involvement and academic success, are not obvious, despite the large number of studies on parental involvement. This section will attempt to address; the different types of parent involvement, what motivates parents to get involved, what research has shown about parent involvement in foundation phase learners in particular and more specifically, related to mathematics. Very little research has been done globally on using parents in the process of geometry learning and even less so in South Africa.

There are many families in South Africa that are desperate to break the cycle of poverty created in the apartheid era and to understand the resounding wisdom of former president Nelson Mandela who said that "Education is the most powerful weapon which you can use to change the world." At a national level in South Africa, the government has failed to bring enough good schooling into the areas that need it the most. The Covid-19 pandemic did however bring to the fore, the ability of parents to help their own children with nothing more than a cell phone needed to access teachers, other parents and the internet. Johnson (2021) revealed that in 2021, 36.13 billion South Africans (approximately 60% of the population), were active internet users. Although the benefits of face-to-face classroom environments have been strongly advocated for (Tran, 2016), there is also evidence to support the fact that blended learning is at least as effective as classroom learning, if not more so (Bergwall, 2015; Tisdell, 2016; Vallee et al., 2020).

One has to look no further than the home-schooling statistics to advocate for the success of parent involvement. Across the world, the growth in home-schooling numbers has been significant, especially over the last few years with it becoming more widely accepted, with the quality of online resources improving and with the results speaking for themselves. Ray (2021) showed that in the United States alone, home-schooled learners increased in number from 2,3 million in 2016 to 2,5 million in 2019 and then to 5 million in 2021. The reasons that parents are choosing home-schooling is varied, but the sudden rise in the phenomenon, has been as a direct result of the Covid-19 pandemic. Many families that never considered it as an option, were forced into using it. According to MacDonald (2020), although parents had voiced dissatisfaction in the schooling system and had considered home-schooling, they lacked the catalyst to give it a try until now. Many learners will return to schools once the pandemic is over, but parents have grown in confidence in their ability to assist schooling their children. Many will consider remaining with the home-schooling system, or at least feel more confident in parent engagement once children return to school.

What we have seen so far, is that if parents want to help, if they feel capable of helping and if they have effective means to help, parent involvement can have a positive effect on a child's education. It is therefore necessary to look at; exactly what parent involvement is, which types are most effective in helping foundation phase pupils learn geometry, the complexities of motivating parents and the factors limiting parent involvement.

2.6.1 Defining Parent Involvement

Parent involvement is a very broad term used to describe any form of parent interaction with their child's education (Grolnick & Slowiaczek, 1994). Dr. Joyce Epstein has been an expert in the field for many years and came up with a model of parent involvement focusing on six different types of parent involvement. It includes parenting which involves helping families establish a home environment conducive to learner success. This for example, would be ensuring that the child has three balanced meals a day and a good desk to work at. The second type, involves communication, where effective school-to-home and home-to-school communication channels are created. Here, parents would go to parents' evenings, read newsletters and write messages in their children's homework books, for instance. The third type relates to volunteering, which involves the recruitment and organization of help and support from parents. A parent might provide catering services at sports matches or help out at a school gala, for example. The fourth segment is devoted to learning at home. It involves the provision of information and ideas so that families can help with homework and other curriculum-related activities. If dad was good at mathematics, he might, for example, help his son with his algebra homework. Fifth, is decision making component, which includes parent input in school decisions through groups such as governing bodies. Lastly, is the collaboration with the community. This involves the integrating of resources and services of surrounding community members, which have the potential to strengthen school programs, family practices and academic learning. In this instance, a parent may help to compile a directory of businesses that various parents are involved in, so the school could recruit parents to do various jobs within the school (Epstein et al., 2002).

It is clear from Epstein's model that parent involvement takes on a wide diversity of roles. It is, in fact, such a broad topic that it has led to a lot of inconsistencies in the definition thereof. Even with discrepancies in definitions, research has concluded that there is significant evidence to support the strong correlation between parent involvement and learner success (Jeynes, 2005; Hoover-Dempsey & Sandler, 2005, Epstein, 1989, 1991,1994;). Hoover-Dempsey and Sandler (2005) define more specific indicators of success. They point to positive successes in lower drop-out rates, higher on-time high school graduation rates and higher rates of participation in advanced courses. They also link parent involvement to the learner's sense of "I can do this", I know how to do this" and "I want to do this."

The positive correlation between parent involvement and academic success has led to parental involvement becoming a priority in education systems. For example, the Improving America's Schools Act of 1994 had parental involvement as one of its main aims. It emphasized the importance of "parents' meaningful opportunities to participate in education of their children at home and at school". Also, the No Child Left Behind Act of 2001 had parent involvement as one of its six aims (Harris & Robinson, 2016). The Parental Involvement Provisions in the Elementary and Secondary Education Act specified that schools receiving over $500 000 in funding, spend at least 1% of it on parent involvement. As more countries have prioritized parent involvement, more money has been invested into it and consequently more research, to ensure that state funds were being spent on that which can bring about meaningful change.

2.6.2 Inconsistencies in definition

In spite of many research articles pointing to the importance and positive outcome of parent involvement, there are many inconsistencies. According to Kohl et al. (2000), the inconsistencies of definition and measurement of parent involvement have been debated across various studies. Although research has shown that parental involvement has a positive effect, due to the inconsistencies of what parent involvement looks like and how its definition is manipulated to suit different studies, the effect on academic outcomes on learners, becomes blurred. This means that research on parent involvement is coming up with results showing that parent involvement positively affects the child, but it does not appear to identify exactly which form of parent involvement is the most effective, and under what circumstances. Further, when we consider one particular type of parent involvement, there seem to be inconsistencies across different age groups of learners, different socio-economic groups and the outcomes for different learning subjects.

Gorad and See (2013) were commissioned to investigate 756 reports on parent intervention between 1990 and 2012 in order to define a causal relationship more clearly between parent involvement and academic success. Out of the 756 reports, only 68 were found to be academically robust enough to be considered. They concluded that the most promising intervention happened in the age group of preparation pre-scholars through to primary school level, but that there was a need for better research as still no conclusive causal relationship could be ascertained (Gorad & See, 2012). This is, however, not surprising due to the complexity of the nature of parent involvement. Crozier (sited in Goodall and Montgomery, 2014) cautions against a ‘one size fits all’ approach, as factors such as parents’ unique nature, needs, barriers, and conceptualization of their involvement, differ significantly.

In a study done on low-income parents in the United States, evidence showed cultural differences in how parent involvement was perceived (Smrekar, & Cohen-Vogel, 2001). Parents' saw it as the school's responsibility to deal with academic education and the parents' responsibility to foster moral education and cultural beliefs, (Smrekar & Cohen-Vogel, 2001). This therefore means that it is not just the objective of the study that can alter the definition of parent involvement, but also the context of the research. A great deal of parent involvement research is based on middle class, western education systems and their belief structure has determined what parent involvement should look like (Bower 2011). In the South African context, the extremely wide variety of language, culture and socio-economic status means that a model dealing with a stereotypical definition of parent involvement, will always have limitations and this must be taken into consideration when defining parent involvement.

2.6.3 Distinguishing between Parent Involvement and Parent Engagement in this Study

Some research distinguishes between parent involvement and parent engagement whereas others use the terms interchangeably. In this study, parent involvement will be used to refer to the broad context of the definition, encompassing all six of Epstein's types of parent involvement, whereas parent engagement will refer specifically to parents engaging with their child at home, in order to assist in learning. This is Epstein's fourth type of parent involvement. The specific context of this research is parents engaging in the space and shape learning of foundation phase learners. It therefore defines parent engagement as "the active engagement of a parent with their child outside of the school day in an activity which enhances academic performance" (Nye et al., 2006, p. 7). It is also important to understand the meaning of "parent" in a South African setting. There are so many homes where the biological mother and father are not the ones responsible for the care of their child due to complicated socio-economic factors. This means that it might be a grandparent, an older sibling, an aunt, uncle or a neighbour who may fill in the role of "parent" assisting the child with work at home. This has to be considered in the South African context in which the research was conducted.

2.6.4 Different Scopes of Parent Involvement

There are primarily three different scopes of home support, namely home-schooling, parent-initiated support, and school-initiated support (Goodal & Mongomery, 2014). When we are looking specifically at parents helping children with schoolwork at home, research shows discrepancy in its effectiveness. For learners up to the age of about thirteen, home schooling typically involves the direct engagement of parents as the teacher after which, they enroll at a specific institute for a more blended learning approach. Home schooling has advantages in that it is the parents' choice to engage in their children's education and therefore tends to involve parents who feel confident in their role as a facilitator of such education. Parents would also have specifically set enough time aside to be a part of this process.

Parent engagement that is not home-schooling is either initiated by the parent or by the school. Goodal and Montgomery (2014), see the initiation of parent engagement as a continuum, where there may be degrees to which parents initiate involvement or the school initiates the involvement. However, Jay et al. (2018) argue that in reality, they seem to be more distinctly different in school where it tends to be the school making decisions to initiate parent engagement of parents who initiate it. School-centred approaches often see parents as passive recipients of information. They are helping the teacher carry out school-defined learning activities at home. Parent-centred approaches focus more on everyday activities in family life (Jay et al., 2018). They are activities determined by the parents for the improvement of their child. Parent-initiated engagement has been shown to be more effective. It is thus important that schools look at what motivates parents to want to take the initiative to help their child.

2.6.5 Looking at why parents get involved

Hoover-Dempsey and Sandler's model (2005) of parent involvement has a different approach to Epstein's model. Where Epstein focuses on the different types of parent involvement, Hoover-Dempsey and Sandler focus more on how and why parents get involved in their child's education.

Three key factors affect parents' motivation for involvement, namely parents' motivational beliefs, parents' perceptions of invitations to involvement from others, and parents' life context (Hoover-Dempsey & Sandler, 2005). Parents' motivational beliefs are determined by their belief in what they think they should do and how capable they perceive themselves to be, in helping their child (Lui & Leighton, 2021). In the context of this study, the motivational beliefs of parents cannot be under-stated. According to Lui and Leighton (2021), parental self-efficacy stems from factors such as parents own educational experiences, relationships they had with teachers, emotional readiness to parent, their general relationship with their children, and interactions with other parents. The complexity and diversity of these factors in the South African context are significant.

Parents' perception of invitation is derived from their perception of the school's invitation, the child's invitation, and the teacher's invitation, to get involved. Hoover-Dempsey and Sandler (2005), explain invitation as referring to actions from the school, the child or the teacher that make the parent feel needed, valued, or welcome (Jay et al., 2018). The nature of the invitation during Covid-19 changed significantly. The school's and teacher's need to involve parents changed from being a choice to being a necessity. Thus, parents' motivation to become involved also increased radically.

The third motivational factor for parents is their perceived life context. This aspect I feel is particularly pertinent in the South African situation and more so in mathematics. Hoover-Dempsey and Sandler (2005) state that this includes parents' perceived knowledge and skills, their time and energy. In South Africa, factors such as ethnicity, stress and socio-economic status, strongly effect on how much parents perceive themselves as suitable facilitators to their child's education.

The year 2020, with a worldwide Covid-19 pandemic and lockdown strategies being enforced in many countries, brought a new perspective to this issue. Parents were unable to hide behind their past mathematical failures because they had no choice, but to help their children. The number of online resources created, grew extensively. Teachers all over the world needed to be creative and determined to bring the effectiveness of parent engagement into the equation.

Blended learning became the new norm. Due to the recency of the pandemic, the reported successes or failures of this approach are not yet well documented, however local findings have shown a significant improvement in parent-engagement with many successes reported (Harbour, 2020; Harper, 2021; Winthrop, 2020). Thus, there has been a shift in parents' perception in their ability to help their child.

2.6.6 Parent Involvement specific to mathematics

For a long time, parent engagement has been a challenge, especially when it comes to mathematics (Okeko, 2014). Muir (2012, p. 1) stated that "While there is widespread agreement in the literature that students' learning is maximized when strong educational partnerships between home and school exist (Groves, Mousley & Forgasz, 2006; Stephens & Steinle, 2005; Anthony & Walshaw, 2007), the nature of these partnerships, particularly in the area of mathematics education, is not extensively documented."

Parents are largely an un-tapped resource which can be harnessed to improve learner's' mathematical ability (Hyde et al., 2006). However, the confidence of the parents in their own mathematical skills, affects their ability to assist their child. Although research has shown the importance of parental involvement, it acknowledges that parental engagement is still limited (Keane, 2007; Mncube, 2009; 2010; Wherry, 2009; Makgopa & Mokhele, 2013). Jay et al (2018) suggested that research from Peters, Goldstein and Coleman (2008) evidenced that parents find it more difficult to help their children with mathematics homework than with other subjects. This is perceived as being due to parents' own attitudes towards mathematics.

Dweck (2006), cited in Boaler (2013) emphasized the importance of mathematics mindset. A limited mindset is where learners believe that one's mathematical ability is fixed and either you are born with a mathematical ability or not. Alternatively, a growth mindset can be described as a belief in the flexibility of mathematical ability. Learners will work harder because they believe that hard work produces better results (Boaler, 2013). The plasticity of the human brain has now been factually proven by neuroscience as can be seen by many people who have been in accidents and had brain damage. They have managed to teach themselves to read, write and ride bikes again, for example (Beilock, 2011). This has positive implications for learners who have been negatively labelled. As is often evidenced in eastern countries such as Japan, when learners are made to believe that achievement is simply a product of hard work and determination, and not of raw intelligence, learners' success improvement is significant. The implication of this is that not only is the parents' ability to help their child with mathematics important, but possibly even more significant, is the parents' mindset towards mathematics. The gap in mathematical ability between east and west is often discussed and is evidently clear. Stevenson et al. (1993) stated in an important observation that it is the cultural belief of Americans and their mothers that innate mathematical intelligence is fundamental to mathematical ability. However, in the Asian culture, it is the opposite. They believe hard work and effort are the essence of achievement.

Statistical and factual evidence such as that presented by Boaler (2013) can go a long way in convincing both the parents and their children that just by working hard, they can make significant progress. Children who have this concept re-enforced by both teachers and parents, are bound to develop a better mindset themselves.

Anderson (2020) reported on adult's' abilities to help their children with mathematics during lockdown. In her report, she firstly looked at adult numeracy results from the Program for International Assessment of Adult Competencies. She found that more than half of the US adult population operate at a mathematics level lower than that of an 11-year-old American child (Anderson, 2020).

Not only are adults less competent at mathematics, but this often plays out as an anxiety within adults which inadvertently gets thrust upon the child in an attitude of "I can't do mathematics". There is a strong correlation between mathematics anxiety in adults and the effect it has on their children (Maloney et al., 2015). I do however feel that the mathematics anxiety that parents feel is created by the vision of having to do calculus, algebra, and geometry in high school examinations, not playing games with their 6-year-old child. It is thus important to consider how the age of the child affects parent involvement.

2.6.7 Parent involvement specific to the age of the child

According to Desforges, 2003 (cited in Goodall & Vorhaus, 2011, p. 3):

> **"Parental involvement in the form of 'at-home good parenting' has a significant positive effect on children's achievement and adjustment even after all other factors shaping attainment have been taken out of the equation. In the primary age range the impact caused by different levels of parental involvement is much bigger than differences associated with variations in the quality of schools. The scale of the impact is evident across all social classes and all ethnic groups."**

Gross et al. (2020) re-iterated that in the early years, parents play a critical role in creating a home environment conducive to supporting brain development and learning. Parents that are involved in creating a conducive learning environment at an early age are more likely to be involved later, than those who don't.

Fehrmann et al. (1987) noted that parent involvement tends to be more stable in the elementary school years. Patall et al. (2008) found that when it came to parent involvement in homework, results were more effective at elementary school level than middle school. Anecdotal studies have shown that the demeanour of high school learners is different. They tend to be more peer-focused and independent, and less willing to work with parents. That is not to say that parent involvement is not important as children get older, merely that it needs to take on a different form (Monson, 2010). At a high school level, the line between parental involvement, which is shown to have a positive effect on learner performance, and parental control, which adversely affects learners' performance, becomes very distinct. Teenagers who do not ask for parental assistance, may see it as controlling and tend to rebel. However, young children thrive on time spent with parents. (Monson, 2010)

Muir (2012), reported on a number of intervention projects in Australia. For example, “It’s in the bag” was an intervention project aimed at children aged six to seven years (and then later extended to slightly younger and slightly older children). Bags were sent home with instructions, resources, and mathematics activities for parents to do with their children. Muir had a feedback sheet in the activity pack which allowed the parents to comment on the activity. Muir reported that positive feedback was received both from parents and teachers. Suggestions to further mathematics success, included having resource-easy activities, having a list of contents in the bag so kits are maintained and introduce new activities to do after a while to keep parents and children interested (Muir, 2012). Thus, intervention studies have shown that parent engagement in early education can be successfully achieved.

2.6.8 Parent involvement specific to the South African context

Parental involvement has been a topic of interest in many areas of the world for some time now. In the US, the “No child left behind” act came into play in 2001 (Patall et al., 2008). Key to this program effort was involving parents in the education program. The question of whether South Africa has given the same attention to parent involvement is not as clear. In the South African context, the Department of Basic Education, (1996) stipulated that parent must serve on the governing body. The extent of parent involvement was often limited to a handful who served on the governing bodies. This is Epstein’s fifth level of parent involvement. On researching whether the South African Department of Basic Education has added any further parent involvement strategies, it is indeed promising to see that there are intentions to improve. In 2016, the National Education Collaboration Trust (NECT) released a booklet with practical guidelines to help parents assist meaningfully, thus contributing to the success of their children’s education. (NECT, 2016)

Particularly relevant in the National Education Collaboration Trust document is the heterogeneous nature of South African households. It alludes to the fact that one cannot ignore the harsh South African reality that caregivers may range in age from teens to grandparents in their eighties. Education levels, health and wellness status, physical ability, religious beliefs, values, and the socio-economic status of caregivers all need to be factored into the complexity of South Africa’s situation (NECT, 2016). So, although the Department of Basic Education has acknowledged the importance of parent involvement, they also understand the complexity thereof.

It can thus be seen that the learning of geometry in foundation phase forms the backbone to the more complicated geometry that high school learners have to deal with. How geometry is taught is key to later success in geometry. Evidence has shown the failure of learners to perform in geometry is in part, due to how they are taught at primary school level. This failure cannot divorce itself from a number of complex issues. Parents are seen as part of an intervention, especially during early childhood development. The next chapter will look at how this study was designed to test the effectiveness of using parents in the learning of geometry in foundation phase.

It can thus be seen what geometry is, what some of the key objectives of geometry and how certain aspects have led to the failure of the South African education system to achieve satisfactory geometry results. The literature review also looked at some possible solutions to this problem and in the light of the recent pandemic, it looked specifically at how parental involvement can be used to bring deeper understanding to learners in geometry in particular. In the next chapter, the theoretical frameworks which underpin geometric development will be discussed.

Chapter 3:

Theoretical Frameworks

3.1 Introduction

One cannot begin to understand the learning of geometry and research thereon, without first understanding the theoretical frameworks which underpin it. There are two critical components which play out in this particular study. The first is that of the process of acquisition of geometric knowledge and the second is the background by which this acquiring of knowledge is influenced. The learning of mathematics and geometry in particular, has numerous frameworks, however, the resounding voices to consider are those of constructivism, van Hiele's theory of geometry development and the more modern learning trajectories of Clement's and Sarama (2019). All of these theorists consider the process of learning in different ways. Constructivism is a more general theory applicable to acquisition of all knowledge, not geometry in particular. Learning trajectories is more specific in that it looks at mathematics in particular and deals with early mathematical development. It isn't however specific to geometry only, but all aspects of early mathematical development. Van Hiele's theory deals with geometric development as an entity on its own.

3.2 Constructivism

3.2.1 What is constructivism

Constructivism is a very well-established theoretical framework which sees the work of Piaget, Vygotsky, Bartlett, Bruner, Rogoff, and Dewey as being key. It is rooted in the idea that meaning is constructed by the learner (O' Donnell, 2012). All of these theorists have a slightly different approach to learning, but share key principles which include the following:

People actively construct their own knowledge with new knowledge being built on the foundation of previous knowledge (Elliott et al., 2000). According to Selden and Selden (1996), we can look at a fundamental of constructivism as people constructing their own knowledge. Old knowledge is used to construct new knowledge, and this helps us to adapt to our changing environment. Constructing of knowledge, is done through mental processes including reflection.

Secondly, constructivism sees learning as an active, rather than a passive process (McLeod, 2019). That is not to say that information cannot be passively received. However, a deeper understanding requires the active process of connecting previous knowledge to new concepts in a meaningful way.

Thirdly, constructivists, like Vygotsky, see learning as a social activity. Vygotsky (1978), believed that community plays a central role in the process of "making meaning." For Vygotsky, the environment in which children grow up will influence how they think and what they think about, (McLeod, 2019). Vygotsky speaks of the Zone of Proximal development. It is seen as the gap between what children are already able to do and what children are not quite ready to accomplish by themselves (Papalia & Feldman, 2011 p. 34). It is therefore a dynamic, changing space where the interaction between the child and teacher is essential but slowly shifts from being adult dependent to the child being responsible for their own learning (Woofolk,2010).

The fourth key principle in constructivism is that all knowledge is personal. The implication of this is that a teacher can teach a lesson to 30 children, and each, based on their own set of circumstances, will interpret the content? of the lesson differently. This is almost in contradiction to the third principle, however, there is no doubt that different individuals can share common knowledge. (Macleod, 2019)

The last common principle of constructivism is that learning exists within the mind. Knowledge in the mind of the learner does not have to match any real world (Driscoll, 2000). Individuals are constantly developing their own mental model based on their life experiences. Their mental model shifts, and changes as new knowledge and experiences impact their own interpretation of reality.

Kirschner, Sweller, and Clark, (2006) have been prominent voices as critics of constructivism. In their view, constructivism involves minimally guided approaches in the classroom, and studies have shown that this is counterproductive as it leaves learners lost and frustrated. Alanza (2016) also states that constructivism places too much emphasis on group work and collaborative thinking and doesn't pay enough attention to individual thinking. It can also be problematic in so far as dominant learner's' viewpoints may control classroom interactions and quieter, less confident learners are ignored and possibly left behind. I feel that this can be especially true of large classes.

Constructivist teaching has also been argued to be expensive, requiring lots of teacher-training and resources and is therefore not always viable. Siegel (1993) critiques constructivism because it sees development as occurring in four separate stages in a fixed order. Critics such as Woolfolk (2010), believe that development is a lot more fluid, continuous and gradual.

3.2.2 Implications of constructivism on education

The implications of constructivism for the teacher in the classroom, is that teachers can assist in the process of knowledge construction by being deliberate about the tasks and learning material they use in teaching. Kelly (2012) recommends teaching styles which include brainstorming, problem-solving, case-studies, guided discovery learning, collaborative learning, and research projects as ways to enhance constructivist approaches to learning.

Previous experiences that learners have had, are key in determining what new knowledge can be learnt and teachers need to be mindful of where learners are at. Copple and Bredekamp (2009), emphasize the importance of scaffolding, where the teacher skilfully and continually moves backwards and forwards on previous knowledge, using modelling, (a skill providing hints or cues), and adapting material or activities to do so.

Learner-centred approaches as opposed to teacher-centred, are far more effective at constructing knowledge in learners. Constructivism therefore focuses more on how people learn rather than on what people learn.

3.2.3 Implications of constructivism on this study

One of the key objectives of this study is to design interventions which focus on the improvement of geometry learning. Constructivism emphasizes that knowledge is constructed on previous knowledge. It is therefore paramount that foundations of geometry learning are focused on. One of the key reasons why the topic of Space and Shape development was initiated by the researcher was due to the frustrations of teaching geometry to grade 10, 11 and 12 students. Many years of experience showed that of the sections taught, geometry showed the least progress among students. The deductive reasoning skills required at this level seem to frustrate and overwhelm students, often leading them to give up on geometry altogether. Although the researcher has had over 20 years of experience at High school teaching and only one year at primary school teaching, based of the concept of constructivism, a key issue seems as though at a high school level, teachers are trying to construct onto knowledge and skills that have not clearly been scaffolded at a primary school level. The gap in geometry requirements in the South African curriculum seem too large in terms of what is required of students in primary school as compared to high school.

Conceptually, children can be actively involved in constructing their own knowledge of space and shape. The supervising adult plays a key role in facilitating the process, by creating activities which allow children the build on previous knowledge in a meaningful way. Adult-guided play, where the child is absorbed in both the interaction with the adult, and other learners in the activity, as well as the stimulation of the activity creates an environment of engagement. This allows for the social, emotional, cognitive and physical development of the child (Milteer et al., 2012). Mathematical games with well-designed resources, allow children to engage in meaningful learning opportunities. As teachers appear unable to give learners enough time to construct meaningful concept maps for space and shape, the prospect of involving parents is favourably considered in this study. If intervention does not happen at an earlier age, students will continue to be frustrated and "stuck" in their inability to solve complex geometry problems required of them at a high school level.

3.3 The Van Hiele Theory of the Development of Geometric Thought

3.3.1 What is the Van Hiele Theory

The Van Hiele Theory is well documented for understanding the qualitatively different levels through which individuals pass, when learning a new topic in geometry. The Van Hiele levels ''explain the understanding of spatial ideas and how one thinks about them'' (Luneta, 2015, p. 11) For example, learners are expected to perform deductive reasoning in complex geometric proofs in high school, but according to Van Hiele, this cannot happen unless there is an extensive understanding of the systems of necessary relationships between geometric ideas.

Van Hiele's most recognized work is the five levels*learners undergo in geometry learning.
The first level is the **visual level.** This, according to Fuys, Geddes, Lovett and Tischler (1988) is where learners identify, name, compare and work on geometric figures such as triangles and rectangles. The second level is the **analysis/descriptive level**. Here learners describe or analyse shapes in terms of their parts and establish properties. They do not see relationships between properties and cannot distinguish which are important and necessary (Fuys et al., 1988). The third level is the **abstract level** or relational phase where learners define properties of objects in a meaningful way. They can draw logic maps and give simple definitions of objects. Pierre van Hiele wrote: "My experience as a teacher of geometry convinces me that all too often, learners have not yet achieved this level of informal deduction. Consequently, they are not successful in

their study of the kind of geometry that Euclid created, which involves formal deduction" (Vojkuvkova, 2012). The fourth phase is the **formal deductive** phase. In this phase learners can relate the properties and differentiate between necessary and sufficient conditions. They understand the role of definitions, theorems, axioms, and proofs. The final level is the **rigor level** where learners are able to use all types of proofs. They are able to comprehend the effect of bringing in or taking away an axiom from any geometric system, Euclidean or non-Euclidean (Vojkuvkova, 2012).

Aside from these levels, the Van Hiele Theory also had some distinct characteristics (Meng & Idris, 2012). They are sequential. Higher levels cannot be achieved unless lower levels have been achieved first. This has important implications for teachers. Concepts that are not completely understood on one level, cannot become clearer on the next level. Secondly, is the concept that geometric ideas understood implicitly by learners on one level, become explicitly understood at the next level (Clements & Battista, 1992). Also, there is "language" to each level which has its own symbols, specific terminology, and network of relationships. Another characteristic essential to teaching is that when a teacher teaches at a level higher than the level the learner is on, a mismatch occurs. The learner will not be able to understand the language or thought processes and may not be able learn effectively (Van Hiele, 1986). Lastly, but also very significantly, unlike Piaget's stages, van Hiele implies that the movement from one level to another is not a natural progression, but that the success of the movement depends on the use of effective resources and instruction from skilled facilitators (Crowley, 1987).

3.3.2 Implications of Van Hiele Theory on Education

Although Van Hiele's Levels have both been utilized and scrutinized, it remains one of the most useful theories to help describe ordered development and understand where learners need to be in order to do the level of mathematics we are expecting of them, in different grades in South Africa. It is useful to gain insight as to why teachers are often unsuccessful in progressing learners in secondary phase geometry. We have already seen that South African foundation phase teachers often lack the knowledge and understanding to assist learners in reaching the appropriate levels of geometric development in their early years (Roodt, 2018). As Van Hiele describes, the levels are progressive, therefore learners will struggle continually unless the gap is filled. Where curriculi are fully packed, class-sizes are inappropriately large, teachers do not have the time to allow learners to go backwards in order complete the understanding process. Intervention strategies are required in order to help learners effectively reach the Van Hiele's early levels of geometric development, so that they are suitably prepared for the more advanced deductive reasoning, required of them in high school.

3.3.3 Implications for this study

Feikes et al. (2018) explains how children learn about space and shape in early developmental stages. In the initial stages of shape developments (grades R-2), children need to name and give basic properties of shapes. If you show a child in this phase a square, s/he will be able to recognize that it is a square, but if you tilt it sideways onto one of its points, they will call it a diamond. This is called invariance. "Although van Hiele claimed that the roots of his theory are found in the theories of Piaget, progression from one level to the next is not the result of maturation or natural development. All depends on the quality of the experience that one is exposed to" (Dinydal, 2007 p. 74)

It is therefore the focus of this study to use parents as instruments in the development of early levels of van Hiele's theory. As learners are exposed to one-on-one adult-supervised play, it is expected that they will start the process of meaningfully identifying shapes, analyzing shapes and begin to identify properties through games which allow for careful and playful manipulation of space and shapes.

Constructivism focused on the importance of scaffolding knowledge on previous knowledge. Van Heile emphasizes the importance of levels of geometric development and how a higher level cannot be achieved unless a previous level has first been attained. The implications of this for geometry development in South Africa are paramount have evidentially been a concern for many years. The fact that geometry was removed from the syllabus altogether indicated that it was a major stumbling block to students. Its return to the syllabus indicated that it is simply too important to remove. However the problems have perpetuated. It is critical importance that more emphasis is placed on bridging the gap between Van Heile's descriptive level and abstract level through adult-guided play at an early stage of geometry development in order to assure that learners can progress. The reality, however, is that other aspects covered in the mathematics syllabus are also very important and curriculum designers and educators also need to give the appropriate time to other mathematical content. This limits the time that teachers have to teach geometry.

3.4 Learning trajectories

3.4.1 What are Learning trajectories

Building on Van Hiele's levels and the importance of good models of pedagogy, are the learning trajectories which have been a major project of Douglas Clements and Julie Sarama over the past few decades. As cited in Clements and Sarama, (2019, p. 3)

> **"The use of learning trajectories (LTs) in early mathematics instruction has received increasing attention from policy makers, educators, curriculum developers, and researchers (Baroody, Clements, & Sarama, in press; Clements & Sarama, 2014; 2011; Maloney, Confrey, & Nguyen, 2014; Sarama & Clements, 2009) and are generally deemed as a useful tool for guiding standards, instructional planning, and assessment (Frye, Baroody, Burchinal, Carver, Jordan, & McDowell, 2013; National Research Council, 2009)**"

Although Clements and Sarama are currently seen as the key researchers in the concept of learning trajectories, it first appeared in 1995 in Martys Simon's work, "Reconstructing

Mathematics Pedagogy from a Constructivist Perspective” (Empson, 2011). Other researchers such as Driver (1989) and Shapiro (2004) have also worked extensively on the concept, calling it learning progressions as opposed to learning trajectories. However according to Empson (2011), it was only after 2004 that learning trajectories really took off when a multitude of researchers such as Clements and Sarama, 2004; Duncan and Hmelo-Silver, 2009), wrote reports (Catley, Lehrer, & Reiser, 2005; Cocoran, Mosher, and TME, vol 8, no.3, p .575 Rogat, 2009; Daro, Mosher, & Cocoran, 2011), and books (Clements & Sarama, 2009), focusing on this work. Smith et al. (2006, p. 5-6) define learning progressions as “a sequence of successively more complex ways of thinking about an idea that might reasonably follow one another in a learner’s learning”. Although Piaget’s work implies that progression in learning is developmentally inevitable, learning trajectories tend to be more in line with Van Hiele’s work which implies that development is instruction dependent (Smith et al., 2006).

Learning trajectories are based on the premise that children follow a natural developmental path of progress when learning (Clements & Sarama, 2020). The learning trajectories approach has been well received by policy makers, educators, and researchers (Clements et al., 2019). There are three key components to learning trajectories, namely, a mathematical goal, a developmental path, and an instructional activity (Clements & Sarama, 2009). The mathematical goals are the big ideas of mathematics. According to Clements et al. (2010, p. 2), it is “clusters of concepts and skills that are mathematically central and coherent, consistent with children’s thinking, and generative of future learning.” An example of a big idea is that geometric shapes can be transformed, analyzed, described, composed, and decomposed into other shapes.

3.4.2 Implications for education

Often teachers have not been taught well themselves and they do not understand the goals of specific content. In geometry, for example, when a teacher asks a child to bring them a rectangle and the child brings them a square, the teacher may incorrectly tell the child it is wrong, rather than inform the child that a square is a special type of rectangle. It is important that educators have had an opportunity to engage in specific goals of content knowledge on the topic, to effectively achieve certain mathematical goals (Clements & Sarama, 2020).

A developmental sequence or learning paths are the levels of thinking which learners naturally pass through on their way to achieving a mathematical goal. It is a process of thinking through which a child progresses to understand a specific concept. Teachers may best learn the developmental sequence by watching videos of children in different situations and piece together how the developmental process works. It is useful to know this process so that teachers can work with a class as a whole as they progress on the natural path of learning. It is however useful for a teacher to see when a child is stuck or really advanced in the process and therefore know whether they need to go back to or go forward, to ensure that the child continues to progress. Teachers who do not join the developmental process may frustrate themselves and the learners if they try repeatedly to get a child to understand at a particular level, when in fact the child needs to move back a few steps in order to understand.

The instructional activities are designed to correlate with the specific goals and sequence of development. It is this, according to Battista (2007), that separates learning trajectories and learning progressions in that learning progressions do not include instructional activities. The instructional activities are a progression of activities designed to assist in teaching children the ideas and skills needed to achieve/reach a specific level of thinking (Clements et al., 2009).

According to Clements et al. (2020), all three of these strands have been researched in-depth and individually. Research into mathematical goals has led to comprehensive common core standards in mathematics. Studying the developmental pathway that children follow has led to improved assessment standards. Studying teaching techniques and teaching strategies has managed to improve on the curriculum guidelines.

It is therefore important for a professional teacher to know the content, know how a child grows in that content and know what kinds of activities will activate the levels of thinking required to reach the next level. Clements and Sarama (2020) however, believe that only through the weaving of these three components together with a scientific approach to learning trajectories, do we have the whole picture.

Empson (2011, p. 572) has raised some concerns related to learning trajectories. These are threefold:

1) Although learning trajectories have become very popular since 2004, the concept is not new. We need to consider other research on learning mathematics and how other concepts have been considered in trajectories.

2) Learning trajectories focus on specific domains of conceptual development. This could mean that other aspects of the curriculum which may well add value, are muscled out of the trajected pathway.

3) The skill of teaching plays a major role in learning. Learning trajectories, if too rigidly focused on, may not allow for other dynamics involved in the teaching process.

3.4.3 Implications for this study

Can these American-based trajectories be relevant in a country like South Africa? There is no doubt that the mathematical learning pathway is relevant to all children, not just American. I also believe that the research that has gone into the weaving of all three aspects, especially that including websites with free, accessible, and well-formulated instructions, can go a long way in assisting teachers who may not be experts in mathematics in particular and who may want to improve.

I do however feel that an area that may be problematic in a country like South Africa is the teacher's ability to identify the levels at which each learner is at and to adjust activities accordingly. This would be the case because class sizes are much too big, and most classes lack the necessary space, resources, and assistance to split the learners into specialized groups. Clements (2020) mentioned that most children naturally progress at more or less the same rate and that one can plan activities for the class at large. However, due to many adverse home conditions in a country like South Africa, I think the abilities of the average foundation phase class will range far more widely. There has also been enough evidence, (Luneta, 2015) to show that many South African educators lack training and experience. It requires a certain level of skill and experience to keep children working at the appropriate level. Therefore, the careful selection of activities involving few resources, but that teach key developmental milestones, can be sent home to parents to assist in the process of reaching specific goals.

Clements (2020) alludes to the fact that it takes a very skilled and trained educator to execute learning trajectories effectively. How then could it be conducted by the average parent when they do not know the learning goals, the developmental stages or how to judge the level their child is at? There is no doubt that a skilled educator is ideal. However, when a teacher works with parents, sending home short instructions and resource packs to follow up on, this can provide for a promising learning experience.

Chapter 4:

Research Design:

4.1 Introduction

In the previous chapter, the theoretical frameworks which underpin the learning of geometry and parent involvement at foundation phase were discussed. In this chapter, the research design and methodology `is discussed. It focuses on detail, on the purpose, research paradigm, the approach, the data collection techniques as well as the ethical considerations in studying foundation phase geometry learning and parental engagement in Howick, in the province of KwaZulu-Natal.

4.2 Statement of problem

The researcher's interest in this study stemmed from a personal experience in trying to improve geometry understanding as a senior mathematics teacher. It seems to be the one area that negatively impacts learners' marks in mathematics, most significantly. Research has shown that unless learners are able to master the initial stages of Van Hiele's levels of geometric development, they will be unable to master tasks requiring the type of thinking expected at higher levels. Thus, it is the foundation of geometric development that needed to be focused on. Constructivism has shown that careful scaffolding on a learner's current knowledge through adult-supervised play, is the most beneficial way for one learner to learn. Clements and Sarama (2019) have spent many years developing learning trajectories which aim to provide the necessary goals and activities to help both teachers and learners in the process of development. Due to lockdown, the role of parent engagement in learning, came to the fore as a means of intervention.

The purpose of this thesis was therefore to explore the effectiveness of parent-engagement in the teaching of Foundation Phase Geometry.

The study aimed to answer the following questions:

1) How are learners in the foundation phase normally taught space and shape in schools?
2) How effective is parental engagement in the teaching of foundation phase geometry?
3) What are parents' views about assisting in the learning of space and shape?

4.3 Research Paradigm

A paradigm, according to Rehman and Alharthi (2016, p. 1) is the researcher's way of understanding the reality of the world s/he is studying. It is a basic belief system and theoretical framework with assumptions about ontology, epistemology, methodology and methods." Paradigms are usually defined as systems of interrelated assumptions about ontology, which is the form and nature of reality; epistemology, which deals with the relationship between the knower and what can be known; and lastly the methodology, which is how the inquirer goes about finding out whatever he or she believes can be known (Terre Blanche and Durrheim, 1999, p. 36).

This study followed an interpretivist paradigm, a form of qualitative research. According to Dean (2018), interpretivism sees reality as being subjective as opposed to being objective. It sees reality as socially constructed and postulates that data cannot be collected without considering the social context. Ryan (2018) stipulates that in interpretivism, the researcher can never completely separate their own values and beliefs, during the process of research, and this affects the way in which data is collected, interpreted, and analyzed. Interpretivism focuses on descriptive data, using words to describe observations. This paradigm contrasts with positivism which dominated research in the early nineteenth century. Positivism focused on quantitative data collection and sees reality as governed by well-established laws which is not affected by human senses (Rehman & Alharthi, 2016). Due to the complexities of human nature, individuality and social interactions, positivism has been largely criticized as being ineffective in dealing with certain types of human research and out of this, qualitative research grew.

Interpretivism was chosen for this study as the interpretivist approach allows for the use of different research methods to gain an in-depth understanding of reality in a social context. Interpretivism uses a relativist ontology which according to Pham (2018) means that a single phenomenon may have multiple interpretations. This type of research means that the researcher is involved in an in-depth manner and can gain a deeper understanding of the nature and complexity of a unique context, without necessarily generalizing. That is not to say that interpretivism does not have its downfalls. It is impossible for the researcher to detach themselves from the research they are conducting, in an interpretivist investigation. Therefore, the results of the study will always be affected by the position of the researcher and how they see the world. This means that it is not as generalizable as quantitative research. Interpretivist research allows for inductive reasoning. Only once data has been collected, interviews analyzed and observations made from a careful analysis of the data, can a hypothesis be formed through the patterns that emerge (McMillan & Schumacher, 2014).

This study seeks to build a pool of understanding of the teaching of space and shape at foundation phase, the interplay between the child, the teacher, the parents, and the impact that larger cultural influences have on the learning process. This paradigm therefore allowed for interaction with the child, the parent, and the teachers in order to gain a richer understanding of the learning process. The teachers were seen as a resource to understand how space and shape learning was happening in the classrooms in Howick and compare this to what literature is saying should be happening in local and global settings. The unique set of circumstances that Covid-19 presented in 2020 and 2021, meant that the role of the parent in engaging in their child's education, was highlighted. The importance of the parents' reality in this situation has not been well-documented and the interpretivist approach enabled the researcher to engage richly with the observations of the parents in this process, and their responses from questionnaires about how they felt being part of this process. Thirdly, the interpretivist approach enabled the researcher to make in depth observations of the child and their learning process in a unique learning environment which was the home. The learning experience between the child and parent allows for the effectiveness of adult supervised play to be analysed. In most cases, parents are not experienced mathematicians. However, foundation phase mathematics and the knowledge and skills required to develop the child can easily be disseminated to parents through instructions via WhatsApp groups.

4.4 Research Design

In the research design "the researcher is concerned with why they collect certain data, what data they will collect, where and how they will collect it, and how they will analyze the data in order to answer the research question" (Hussey & Hussey, 1997, p. 114). This investigation focused on space and shape learning and the use of parents, as a way to improve foundation phase learners' learning. The research design used for this investigation was an educational case study. According to Johnson and Christensen (2014, p. 580) a case study is "a form of qualitative research that is focused on providing a detailed account of one or more cases." Fouché and De Vos (1998) emphasize that in case studies, either one subject or a group of subjects can be used, depending on the purpose of the study. Case studies show a bounded system which is being studied and identified, specifying what is and what is not within that system (Johnson & Christensen, 2014). This investigation is studying seven families and is therefore a collective case study. Within the system that is being studied, is the foundation phase learner, the parent who serves as the facilitator to learning and the home environment in which the learning is occurring. The aim of the case study is to make observations as to whether learners can receive a meaningful learning experience to deepen their understanding of space and shape in order to form a more solid foundation for further learning in geometry. Teachers were interviewed to make a comparison of how space and shape is being taught in the classrooms of the local schools and are therefore seen as peripheral to the investigation. A group of families were chosen rather than one family as more insight could be gained by looking at a variety of cases. This is because families stem from a variety of circumstances especially different socio-economic backgrounds and observations from each family adds rich insight to the research study. One case would not have provided the richness that variety this study needed.

4.5 Research Settings

The research was conducted in Howick in the Midlands area of the province KwaZulu-Natal, South Africa. The six schools that were considered were those that had learners in the foundation phase. This included both private, government and community funded schools consisting of learners from a variety of socio-economic backgrounds. Four of the schools were kindergartens which only went up to grade R, while two were primary schools which started at grade R and went up to grade 7. Three of schools were funded entirely by parents, two were partially funded by the government and one was funded by community donations.

These six different schools that the researcher managed to gain access to, were used in this study. To conduct research in the schools, principals were contacted and asked permission to investigate certain phenomena within the school. Five teachers from foundation phase were interviewed to ascertain how the learning of geometry in foundation phase was happening in the classrooms. Interviews were conducted in person following strict COVID-19 protocols and interviews were recorded and transcribed by the researcher.

The teachers of these six schools were then asked to contact parents via WhatsApp groups. A recording was made by the researcher explaining the research process and asking parents to volunteer to be part of it. The teachers were asked to ensure that the same recording was played to all the parents who had children in foundation phase. Teachers chose specifically to send the message to grade R parents. Parents were asked if they were prepared to spend half an hour with their child for about five days playing various games, doing activities, and recording it. Volunteers gave their names to the teachers who then contacted the researcher. Any parent that volunteered was given the opportunity to participate and no one was excluded from the process. In total, eight families volunteered and participated in the research, however one family's results had to be excluded due to problems while recording the data. In two of the families, older siblings, both matriculants, were asked to be the facilitators as the parents felt that they were better educated and had more time to do the activities. Families were asked to send one family member to a meeting where the process was explained to them in detail and resource packs were disseminated. Not all families were able to send a member to the meeting so individual meetings were held where necessary. The resource packs consisted of official documents to be signed, a pre and post assessment task, a set of printed instructions of each activity and various shapes and other templates needed to complete the activities. Almost all the resources were made from recyclable material such as cereal boxes. This was to ensure that the activities could be repeated by all parents from any socio-economic background and was not exclusive to schools and families that could afford expensive toys. A WhatsApp group for the family members was established where daily instructions were posted, and parents had the opportunity to make inquiries about any of the activities. The instructions were in the form of audio-recordings which required less data than video recordings. Parents were asked to complete the five activity sessions within a 2-week period, which meant that flexibility was allowed for parents with busy schedules. They could do the activities at the time of the day and the day of the week that suited them. There were five sessions requiring about half an hour every day. Each day options were given to accommodate variations in the abilities of participants, with some easier activities and some harder ones. They could choose to do all the activities or select one or two, but not exceed more than half an hour a day. Parents were asked to video record the lessons in the home using a cell phone or laptop for example. Sometimes the recording was delegated to another family member and sometimes a recording device was simply left in front of the child, to record on its own.

4.6 Pilot Study

A pilot is designed as a mock trial of the real research. Pilot studies are important to ensure the viability of the study (McMillan & Schumacher, 2014). In this research, two pilot studies were conducted. In the first case, the researcher personally worked with a grade R learner and tested the viability of the various activities. This was to ascertain whether the child understood the instructions, whether the activities were aimed at the appropriate age level and whether the time given for the activities was more or less accurate.

The second pilot study was given to a family who were asked to participate in all the activities. This aimed to see whether the instructions were clear and whether the process of recording the sessions was viable. The family was asked to give feedback to clarify any issues that may have occurred during the process.

As the researcher is not a foundation phase educator, the resources and instructions were also given to two South African foundation phase teachers and one Australian teacher, to ascertain whether the activities were aimed at the correct level and whether the children would enjoy the activities and be able to cope with the tasks required. Teachers gave feedback which assisted in refining the quality of the activities and the use of resources.

4.7 Data Collection techniques/Design of instructional material

In this research, interviews, questionnaires, pre and post assessment tasks and video-recorded observations, were used to collect data.

4.7.1 Stages of study and data tools used pertaining to research questions

Table 1: Stage of study and data tools used pertaining to research questions

Stage of study	**Data gathered**	**Pertaining to research question**	**Sub-research question**
Stage 1: Teacher Interviews	1)Information from teachers explaining how space and shape	How are learners in the foundation phase normally	Are learners receiving enough one-on-one time to scaffold understanding?

	is being taught in the classroom 2) Do teachers use parent engagement to improve mathematical learning?	taught space and shape in schools? How effective is parental engagement in the teaching of foundation phase geometry?	Are resources available **to** What are teachers views of parent engagement? How effective were parents when forced to be involved during lockdown? Would teachers involve parents if it was not lockdown?
Stage 2:	Pre-assessment task	How are learners in the foundation phase normally taught space and shape in schools	What did participants know about space and shape before the intervention?
Stage 3:	5-day intervention plan where parents work with their child to improve space and shape knowledge	How effective is parental engagement in the teaching of foundation phase geometry?	How effective is a parent at engaging in activities to improve space and shape learning? Can the parent effectively gauge the level that their child is at and successfully build on their understanding

			Is the home environment conducive to the learning process? Do parents feel comfortable teaching their child mathematics?
Stage 4:	Post assessment task	How effective is parental engagement in the teaching of foundation phase geometry?	Did the child improve after a week of intervention?
Stage 5:	Parent questionnaire	How effective is parental engagement in the teaching of foundation phase geometry? What are parents' views about assisting in the learning of space and shape?	Did the parents think the intervention went well? Did the parents think it was valuable to be involved in mathematics learning? Do parents who participated in the research feel that other parents would get involved in parent engagement and why?

			Would parents consider this as an option even if they weren't obliged to?

4.7.2 Interviews with Educators

To answer the first question of how learners are normally taught space and shape in schools, teachers were interviewed using the face-to-face (with social distancing and masks), semi-structured interview technique. Although the questions had been predetermined, there was an open-ended approach that encouraged the conversation to flow. Face-to-face interviews are an important means of gathering in-depth answers and allows the researcher to rephrase questions. It also allows interviewees to expand, thus adding richness to the data. The research topic was to explore the effectiveness of parent-engagement in teaching foundation phase geometry. This meant that the teachers were not the target population but interviewed to gain insight on how space and shape is currently being taught in the schools that participants came from.

4.7.3 Pre and post assessment tasks

The time schedule of the activities was planned so that research was done after children had been taught space and shape at school. It was done according to the Department of Basic Education CAPS document of the year plan. It was expected that all children had prior knowledge of all the concepts they were going to be taught at home. To have an idea of the child's understanding of space and shape before and after the activities, it was necessary to do a pre-assessment and post- assessment. Since children came from different schools and were in different grades, these tests were not necessarily designed to be used in comparison with other children, but to see where the individual child showed an improvement. The fact that it was Covid-19 lockdown, meant that the assessments were conducted by the parents in their homes. The children participating in the activities were young, so parents were required to read and assist where necessary. The questions in the post-test were more difficult than those of the pre-test. This was to see if children had gained additional knowledge and skills in the intervention process

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4.7.4 Five-day activities series

Each day, the parents were given between 2-4 tasks to do with their child. Some tasks were optional, depending on the ability of the child. If the child was able to advance quickly through the initial tasks, additional ones with higher levels of complexity were introduced. The parents were informed that the activity sessions would need to be recorded and were asked to consent to the process. Parents were advised to angle the cameras so as not to reveal the faces of their children. It was also made clear to them that if their child felt at all uncomfortable, they could stop at any stage.

Day 1: 2D shape recognition

This was introduced to ensure that the child had basic knowledge of fundamental 2D shapes including the square, triangle, rectangle, circle, hexagon, and pentagon. Children were given the opportunity to hold, feel and manipulate the shape in their own hands rather than just being shown a shape on the board. This helped them to get first-hand experience of the concepts, of how many sides and angles various shapes had, and that for example a triangle could be turned around and it remained a triangle. These concepts were re-enforced by placing the shapes in a pillowcase and having the child guess the shape without seeing it. Here, the child was relying on the sense of touch to gain information about the shape. This kind of activity could not easily be possible in a class with lots of children, as it would take too long. Task 3 involved the introduction of a game called “is it or is it not”, from Clements and Sarama’s (2021) learning trajectories. This game used a page showing many shapes, with purposely included common misconceptions such as shapes where corners were rounded, shapes that had different orientations and abstract ratios, shapes where a side was not straight or shapes where sides were not joined at the corners. When asked “is it or is it not a triangle?” for example, where the child got it wrong, the parent had an opportunity to explain and discuss misconceptions with the child. The instruction clarified all misconceptions so that the parents knew what the correct answers were. Although this activity was slightly harder, it provided a rich learning opportunity which could only be afforded by one-on-one adult supervision.

Day 2: Orientation words and shapes knowledge in the real world

The aim of day 2 was firstly to emphasize orientation or direction words such as under, over, around, next to, forward and backwards. It was felt that children were generally well versed in the orientation words based on their frequent use in everyday life. Therefore, a whole day was not required for this component of the study.

Task one involved a treasure hunt where children were instructed to move in certain directions to find the treasure (a bag of mixed shapes). Once the treasure had been found, the children created a shape graph. This exposed them to the concept of graphs while re-enforcing the fact that for example, as long as a shape has three sides and three angles, it is a triangle, regardless of how long the sides are or how it is orientated. Parents were asked to exclude a column for squares. Squares could be placed in the rectangle section, and this was an opportunity for parents to explain basic properties in a slightly different way. There was also a column for "other" which accommodated any irregular shape. Children looked for shapes within their homes to add to the "shape graph".

Day 3: Constructing shapes from parts

The aim of these activities was to emphasize the number of sides and angles on various shapes. Task one was and adaptation of the snakes and ladders game, where the dice had shapes on it rather than numbers and you move based on how many sides or angles are on the shape. The heads of each snake were on "non-shapes". This gave parents the opportunity to re-enforce why it was not a shape.

The activities then moved on to the construction of shapes using household items like straws, pencils, cardboard strips, spaghetti strips, etc. Depending on how advanced the child was, straws could be used to deal with symmetry. For example, the child could be asked to use a straw to make their square into 2 equal triangles. This is a useful problem-solving activity allowing the child hands-on guided play to grow their understanding of various concepts.

Spatial development is also a very important part of geometry learning. The next activity allowed the parent to use basic shapes to construct a combination of shapes in a certain orientation. This is then covered, and the child must design their own construction having been given exactly the same shapes. How many shapes were used depended on how advanced the child's spatial abilities were. The shape play extended to mirroring shape patterns and completing patterns, depending on time and ability of the child.

Day 4: 3D Shapes

Day 4 involved transitioning from 2D shapes to 3D shapes. Guided block play was emphasized. Blocks could be household items such as tin cans, toothpaste boxes, cereal boxes, toilet roll holders, etc. Various questions were suggested to engage the child during block play. Thereafter parents chose a few blocks to introduce the concept of Venn diagrams to categorize blocks according to whether they had straight sides, curved sides, or both. This was to emphasize, not only the names of various 3D objects, but also some of their properties.

To build on the concept of spatial orientation in a slightly more advanced manner, Lego blocks were provided in the resource packs to play similar orientation games as before. The parent placed two to five Lego blocks in various orientations and then covered them. The child had to memorize the orientation and copy the pattern on their own. Again, mirroring and pattern-continuation was included for the more advanced children.

Day 5: Roll and slide

The final day of the activity built on 3D concepts and the application thereof. This involved roll and slide activities. Initially, parents used the bodies of the child to show that when the child rolls, different parts of their body touch the ground, and when they were sliding, only one smooth part of their body slid across the smooth surface of the floor. Thereafter, an actual slide (in whatever form was available) was used to see which objects could roll and which could slide. These were then grouped according to Venn diagrams to reinforce the concept. Household objects were utilized so that the child had a chance to explore their environment and find other objects that could roll and slide.
In general, activities were designed to allow parents the opportunity to meaningfully engage in their child's education of space and shape learning using resource-light activities that could be accessible in any household.

4.7.5 Parent Questionnaires

The questionnaire is a straightforward means of data collection. It allows for structured answers that can be given without? time constraints, without the presence of the researcher and is relatively easy to analyze and administer (Cohen et al., 2007). The limitation of questionnaires is that it does not give the researcher time to probe deeper into questions. There is also no opportunity to ask for clarification of answers if necessary. There are different types of questionnaires, namely structured, semi-structured and unstructured. Structured questionnaires have close-ended questions and do not allow for free expression of answers, whereas unstructured questionnaires allow for a lot more freedom in responses (Cohen et al., 2007). Questionnaires in this research consisted of both open-ended and close ended questions. The close-ended questions are advantageous in that they allow short, easy, channelled answers, which may include selected answers that participants may not have thought of. They are not affected by how articulate the respondent is (Cohen et al., 2007). It does however mean that the answers are subject to the researcher's bias during formulation. (Kumar, 2005). Open-ended questions, on the other hand, allow participants to think about their response and write their carefully thought-out responses. In some ways this is better than interview questions, because they do not have a person in front of them that they need to be sensitive to. Because questions are open ended, it reduces researcher bias and allows participants to express what fore-most in their minds is. In other ways, it is disadvantageous because it is a written answer, so one loses the depth of expression one may get in interviews with tone of voice and body language for example. Also, written responses tend to be a lot more succinct than verbal responses which means participants may not be able to elaborate on answers.

In this research, questionnaires were designed to gain insight from the parents after they had completed the process of working with their child for a week or two. Due to Covid-19 restrictions, questionnaires were made available online and parents could fill in answers without needing to be in contact with the researcher at all. If there were any uncertainties in responses, the parent was contacted via WhatsApp and asked to clarify where necessary. Online questionnaires do not restrict the length of open-ended questions and excel spreadsheets made it very easy to compare answers of both open and close ended questions.

4.8 Sampling

The sample group in this study is three-fold. Firstly, to understand how geometry is being taught in foundation phase, the teachers will be participants. Next, to administer the activities and account for their feelings in the process, the parents formed the second re-structure. Then, the learners who were tested and given the intervention program formed the third sample group. As this is a real-life study based on a small sample group, it aims to gain an in-depth examination of the real-life phenomenon and not make inferences in relation to the wider population, (Yin, 2003). It is therefore appropriate for this study.

A selection of six schools were chosen in the Howick area. Due to heavy lockdown restrictions and schools being closed for extensive periods of time, access to school was limited. According to Taherdoost (2016), convenience sampling is commonly used as it has the advantage of being both cost effective and time saving, however it can lead to sample-bias. The researcher had to be able to interact with the parents on a one-to-one basis and needed to get resource packs to them. This meant that only schools in the immediate area were considered. Purposive sampling was also used as it was necessary to be deliberate in the selection of schools to ensure a range of socio-economic and cultural factors, for consideration.

Once schools had been chosen, sampling of teachers for the process of interviews was done. It was a matter of selecting the teachers that taught in the foundation phase and who were willing to give of their time to be interviewed. In order to choose teachers, the researcher had to rely on a network of personal contacts due to the fact that schools were closed and could not be contacted during lockdown. A foundation phase teacher from each of the purposely selected schools was contacted and interviewed. Convenience sampling was therefore used in this regard.

When selecting families to be part of the intervention process, it was done strictly on a volunteer basis. Because the research process involved a considerable time commitment on the part of the parents, convenience sampling was most appropriate. Since the research process involved the videoing of parents interacting with their children, both privacy issues and time constraints meant that only families who were willing to participate, could be considered. The researcher did however attempt to ensure that the participants that volunteered came from different socio-economic settings, to make it a viable study. This was done by approaching parents from schools that already included families from a variety of socio-economic backgrounds**.** It was however restricted by physical access to communities during lockdown.

Before the research procedure began, principals of the schools were contacted and asked if research could be conducted in their schools. Signed consent was received from the principals of the schools. Teachers who were interviewed, were briefed on the nature of the research and asked to sign a consent form. They were assured of anonymity in the research proceedings and given the opportunity to stop at any point they felt uncomfortable in during the proceedings. The same process was also made very clear to the parents of the families involved in the research. Parents were given consent forms and informed of the nature of the research. Parents filled in consent forms and were asked to explain the proceedings to their child. Parents talked through the process with their children and filled in child accent forms. Consent was also sought from the College Research Ethics Committee to commence the study before the research began.

This research involved small children in their homes. It is therefore of utmost importance that this very personal environment be handled with great sensitivity. However, as stated by Kaufman and Kaufman (2005) all studies, to be valid and reliable, impinge of the rights of people in some way, if they involve human participants. In 2020 and 2021, when this study took place, the worldwide pandemic meant that special consideration needed to be considered to avoid contact with participants such that the spread of the corona virus did not occur. For this reason, there was almost no physical interaction between the researcher and the participants, neither teachers nor families. Observations were made via self-filmed video recordings of the activities. Although this led to a slightly unnatural environment, since children were very aware of being filmed and may have behaved unnaturally, this was the most convenient manner of ensuring the safety of the participants. Individual resource packs were made for each family so there was no sharing of resources. Interviews also had to be conducted in an open space with a distance of greater than 1,5m between interviewer and interviewee.

4.9 Researcher Positionality

One cannot conduct research without understanding the critical role the positionality of the researcher has on the way data is collected and his/her views on various aspects of the research process. Positionality refers to "an individual's world view and the position they adopt about a research task in its social and political context" (Gary & Holmes, 2020). The world view of the individual affects both ontological and epistemological assumptions. The value and belief system of an individual is based on their political allegiance, religious faith, gender, sexual orientation, historical and geographical location, ethnicity, race, social class, and status, disabilities and so on (Sikes, 2004, Wellington, et al. 2005; Marsh, et al. 2018 cited in Gary & Holmes, 2020)

As a middle-aged white female, having been educated in a model-C school in the apartheid era, my voice as a South African citizen, is in the minority and I am aware of the fact that it is not representative of the voice of many South Africans. In this research, the researcher is investigating parent involvement in teaching foundation phase learners, space and shape. My first concern with regard to positionality, is my belief system in parent involvement. I believe that parent involvement is essential and of great benefit to the child. This belief is not uniform to all parents in South Africa. Many believe that it is the school's responsibility to educate the child and parents should refrain from being involved. Many parents in South Africa were not given the opportunity to be well-educated themselves and feel ill-equipped to assist their child. There are also many homes where the family structure is different and diverse, as many do not have biological parents or any caregiver taking charge of their education. This research therefore had to allow for a broader definition of parent involvement.

Secondly, I am coming from a viewpoint of someone who enjoyed mathematics at school and have not been intimidated at all with helping my own children do their mathematics homework. However, this is also not the case with many parents. Many feel very intimidated by mathematics and incapable of helping their child.

Thirdly, I am a high school teacher and not a primary or pre-primary schoolteacher. There is a certain stigma attached to being a high school teacher as opposed to being a primary or foundation phase teacher and this may have affected the connection between interviewer and interviewee in the teacher interview process.

As a researcher, an effort was made to include schools from all socio-economic backgrounds, and the schools that were approached were all within one area, which is a rural community in the Midlands of KwaZulu-Natal. Many of the types of schools that form the scope of South African education were not included in the study, due to access. These included elite private schools as well as the very poor and under-resourced township schools. The ability of parents to help their children in these schools may be very different.

4.10 Data Quality Issues

4.10.1 Validity

Validity refers to whether a research study is scientifically and conceptually sound (Marczyk et al., 2005). Validity in qualitative research is significantly different to that of quantitative research. As this study deals with qualitative data, it will focus on qualitative validity only. Qualitative validity deals with whether research is trustworthy, plausible and credible (Johnson & Christensen, 2014). Various factors were considered in ensuring validity, namely, the use of pilot studies to ensure the effectiveness of research tools, purposive sampling where possible, to attempt to ensure that a variety of schools were involved in the research process and methodological triangulation. Sampling and pilot studies have already been discussed. Triangulation will be discussed in more detail.

4.10.2 Triangulation

One of the most popular strategies of ensuring validity in qualitative research is triangulation. This involves approaching the research topic from different angles and using a variety of data collections methods in order to get a convergence of results. According to Guion et al. (2011), there are five types of triangulations, namely data triangulation, investigator triangulation, theory triangulation, methodological triangulation, and environmental triangulation. This research falls in the realm of methodological triangulation. According to Fusch et al. (2018), methodological triangulation can either be within or between data methods. This research uses teacher interviews, parental questionnaires, and observations of the learning process as well as pre and post assessment, in order to gain an in-depth insight as to how effective parents are in teaching space and shape. It is therefore within data sets, pertaining only to qualitative data. Two key issues are being addressed in this study. The first is the learning of geometry. The second is the efficacy of parent involvement as an intervention strategy to improve geometry learning in foundation phase. The use of a singular data set would not have been able to address both issues and the convergence of data from different stakeholders was essential to draw meaningful conclusions.

Triangulation is advantageous in that the variety of data sets adds confidence to the research data and can provide for a clearer understanding of the problem under investigation (Guion et al., 2011). It can, however, be disadvantageous in that it is time-consuming. Fusch et al. (2018), also caution novice researchers to be mindful of the fact that multi-methods of data collection can lead to inconsistencies and contradictions. It is up to the researcher to interpret and find semblance from these inconsistencies.

4.10.3 Reliability

According to Cypress (2017), the more times the results of a study are able to replicate themselves, the more reliable the study is. So, with data sets containing large volumes of especially quantifiable data, attaining reliability is straight forward. However, with qualitative data and especially case studies, reliability is not as straight forward. In this study, the researcher attempted to extend the case study scenario to eight families in order to get a more reliable and thematic result, as opposed to an incidental result. Cypress (2017) also states that "Reliability is based on consistency and care in the application of research practices, which are reflected in the visibility of research practices, analysis, and conclusions, reflected in an open account that remains mindful of the partiality and limits of the research findings."
The researcher attempted to garner consistency in interviews by having a guideline of questions, so as to stay on topic in the interviews. All interviews were transcribed and analyzed by the interviewer personally. This assisted in consistency on technique but may have been disadvantageous in that only one researcher's opinion, may foster bias.

Reliability in the process of parent intervention was attained through the careful and consistent structure of the research packs. All parents were given exactly the same set of instructions conveyed n two forms. Written presentations with pictorial illustrations were included in the resource packs. Daily audio instructions were also given. Another factor that was considered was that all learners were given the intervention after they had had the allocated class lessons on the section, according to the CAPS document. The intervention also came soon after space and shape was taught in school so that it was fresh in their minds.

4.11 Ethical Considerations

Before the commencement of this research, ethical clearance was obtained from the College Research Ethics Committee. Headmasters were contacted and informed of the nature of the research and asked to give consent for research to commence. Teachers that were interviewed were assured of their anonymity and were informed that the interview would be recorded. Informed consent was received from the teachers in writing.

Parents were asked to volunteer for the process of research. Parents were given a consent form informing them of the nature of the research and asking for their permission to conduct research in their homes. They were asked for permission to record video sessions and assured that they could withdraw at any stage. Parents were asked to explain the process to their child and assist the child in filling in the child accent form.

In using participants' work in the data analysis, all names of participants were kept confidential and anonymous. The videos recorded by the parents were only viewed by the researcher and not made public.

In the process of data collection and analysis, the researcher made every effort to remain professional, yet friendly and not to show bias where possible, although researcher bias is inevitable.

CHAPTER 5

DATA REPRESENTATION AND ANALYSIS

5.1 Introduction

The previous chapter studied the research methodology used in this research. In this chapter, the thematic analysis approach will be used to present the findings of this study. Although there are different techniques of analysing data, thematic analysis has been used in this study as it is particularly effective in producing qualitative data, especially when trying to synchronize the analyses from different data sources. It is accessible, flexible, and increasingly popular among researchers and learners in many different disciplines (Boyatzis, 1998).

5.2 Thematic Analysis

According to Braun and Clarke (2014, p. 79), "thematic analysis is a method of systematically identifying, organizing, and offering insight into patterns of meaning (themes) across a data set." Themes may be directly observed or visible in the information gathered. Themes "capture something important about the data in relation to the research question and represent some level of patterned response or meaning within the data set" (Braun & Clarke, 2006, p. 82). They are abstract constructs identified before, during and after analysis by the researcher.

Thematic analysis may be used as a way of seeing, a way of making sense of seemingly unrelated data, a way of analysing quantitative data, a way of systematically observing a group, a person, an interaction, an organization or a culture and a way of changing qualitative information into quantitative data (Boyatzis, 1998 p. 4-5). Braun and Clark (2006) cautioned against certain pitfalls in thematic analysis. These include possible failure to analyse data effectively, using data questions as themes, doing a weak analysis and mismatching data and the analysis thereof. Boyatzis (1998) also cautions against three obstacles, namely, researcher projection (where the researcher is too familiar with a phenomenon), sampling (where the sample group cannot guarantee to reflect expected results) and mood and style, where the researcher's state of mind, patience and clarity of understanding may negatively affect their ability to undertake thematic analysis. On the other hand, Braun and Clark (2006) emphasize that good thematic analysis shows clarity in function and shows that what you say you are doing matches what you are actually doing.

Thematic research was chosen for this study as there is data collected from teachers' interviews, from parents' questionnaires, learners' assessments, and observations made by the researcher from video analyses of the intervention activities. All four processes of data collection happened independently, and thematic analysis allowed the researcher to find threads which brought the data together and linked key concepts. As the researcher was working in unfamiliar settings there was little chance of researcher projection. However, sampling was carefully considered. The researcher's aim in this discussion is to either reinforce or refute the following theories:

- Constructivism: more specifically, that adult-supervised play, is effective in constructing geometry knowledge and understanding
- Learning trajectories: Through the assistance of carefully selected goals and tasks, parents can meaningfully engage in the process of geometry learning.
- Van Hiele's theory: geometry learning happens in developmental levels and unless previous levels are attained, a child cannot proceed to a higher level.

The three key themes used in this research are:

1) The teaching of space and shape in foundation phase
2) Facilitating the teaching of space and shape beyond the classroom: i.e. parent engagement.
3) Factors affecting the teaching and learning of space and shape.

5.3 Theme 1: The teaching of geometry in foundation phase

Data was collected from various teacher interviews, parent questionnaires, researcher observations and learner assessments. Teachers were not observed (due to lockdown) and were therefore not the subjects of observations. It was their knowledge, experience and insight, gained through interviews, that gave the researcher a window into how geometry is normally being taught in junior schools in the Howick community.

5.3.1. Content taught

Space and shape, according to the CAPS curriculum, has a few components. These include the names and properties of two-dimensional shapes, the names of three-dimensional shapes and whether they are able to slide or roll, and orientation words. When asked, "what do you understand about space and shape?", none of the teachers needed to refer to documents to reveal teaching content. All were very clear as to what the curriculum required of them. Discrepancies in content involved how many shape names and properties they revealed to their learners. Some teachers stuck with the basic shapes (square, circle, rectangle, triangle), while others included hexagons, pentagons, diamonds and hearts, for example. All teachers understood that space included the use of orientation words and were able to give clear directives as to what the orientation words were. This implies that teachers are aware of what the curriculum requires of them and have a good understanding of the content.

What was of particular relevance in the discussion of the teachers' understanding of space and shape, was that most teachers adhered quite strictly to the CAPS document. The CAPS curriculum is viewed in different ways by teachers. Most find it quite a thorough document that has been improved on significantly over the years. It would seem as if most teachers adapted it to suit their individual style of teaching. Some teachers said that they learnt from other more experienced teachers and tapped into their creative interpretation of activities. Others found the CAPS curriculum to be too rigid, and preferred other systems which were unfortunately not affordable to government schools.

There was a conscientiousness on the part of the teachers in fulfilling their obligation to the curriculum and all of them knew what was required of them. They fulfilled their requirements competently. This was evident in the accuracy at which almost all the foundation phase learners were able to perform in the pre-test. Of the eight participants, all of them correctly identified the circle, square, equilateral triangle, and rectangle. A few were not able to identify the oval, which is not part of the grade R requirements. Their ability to name, give number of sides and corners of required shapes, was good. The participants were also competent with their orientation words and could accurately draw shapes orientated to other shapes. Where participants did not perform as well in the pre-test, was in their ability to recognize non-examples that were difficult distractors of shapes. This included shapes with slightly curved corners or sides that did not meet to form angles. Four out of the eight, identified a shape with corners not joining as a triangle. This was an activity that they seemed not to have been exposed to and there is no evidence in the curriculum indicating the need to recognize these. Many of the participants mis-identified distractors. Understandably, the children were making errors in concepts they had not been taught before. It was content that related to more in-depth property identification, rather than basic classification. The implication in this observation is that what the children know, is based on what they are taught and what the teachers are teaching, is driven by the curriculum. Thus, in order to see a fundamental change in what the children are able to know and do, the curriculum will need to be adjusted.

Having said that, two teachers showed that they had extended their knowledge beyond the CAPS curriculum. One teacher had been on courses voluntarily, which included the works of Brombacher and Number Sense as well at the works of Jo Boaler and her You-cubed concepts. She was thus able to adapt her traditional teaching style to a more modern problem-solving approach. Another teacher who worked in a school for under-privileged learners, had a mother who worked at a private school which purchased expensive resources that she learned from:

Teacher A: My mom bought a program specifically for grade R which is called “Keys to Learning” and I have looked through it. I obviously can’t use it because it’s something they have bought. I have looked through it and seen what they have done. It’s really different, out-of-the-box thinking which I think is something that is an important thing in our country to be able to teach from a young age. So, while it’s still covering

all the basics of literacy and numeracy, its different, which I think is really cool. You have to buy it though, so it's not accessible to everybody which is a bit bleak.

Besides these two teachers who took the initiative themselves, there was no indication of training of educators beyond what they had studied at university and what they knew from the curriculum.

Clements and Sarama (2019) in learning trajectories, placed emphasis on a 3-phase process, namely learning goals, a developmental path, and a set of activities for each level. Space and shape goals extend far beyond simple classification. Skills such as composing shapes, decomposing shapes and disembedding shapes, are expressed as an important part of mathematical goals in space and shape development. The South African curriculum does not point to any of these skills specifically, and none of the teachers indicated any knowledge of these types of activities. High school geometry requires learners to be able to apply complex skills. It is often the case that learners can pick up a geometric concept such as the exterior angle of a triangle being equal to the sum of the interior opposite angles when the diagram is given on its own. However, even though this is taught in grade 8, a grade 12 learner may still struggle to identify the same concept when it is embedded in a more complex diagram. A comparison is shown in Figures 3a and 3b.

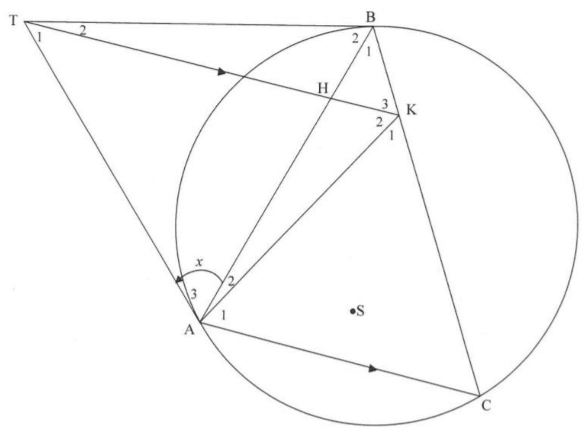

Figure 3a: Exterior angle of a triangle equals the sum of the interior opposite angles embedded in more complex diagram

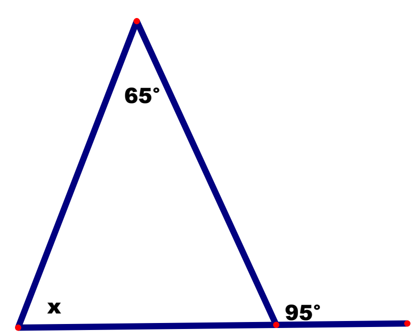

Figure 3b: Exterior angle of a triangle equals the sum of the interior opposite angles in a simple diagram

In addition to this, when the interviewed teachers were asked if learners find space and shape learning easy, every teacher agreed that the learners find this to be one of the easiest sections. However, some teachers believed that more depth is required.

Teacher B: **So, when space and shape come up, it is quick and easy. We whip through it, and it's done…. knowing where they are going with geometry, what we're doing just seems too basic. Like I think we should be discussing more about angles and getting more into angles, but we haven't.**

According to Van Hiele's levels of geometric development, level 0 is visualization. This involves recognizing shapes as a whole and comparing that with everyday objects such as cell phones. Here, they are not identifying properties (Vojkuvkova, 2012).

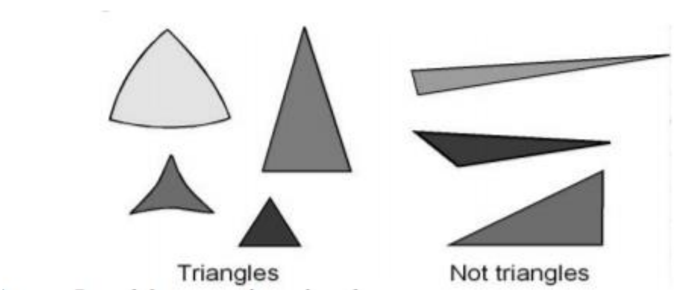

Figure 4: Children at Level 0 categorize triangles (Vojkuvkva, 2012, p 72)

Level 1 starts the process of property identification. At this stage there is no relationship between properties and properties are not proven (Vojkuvkova, 2012).

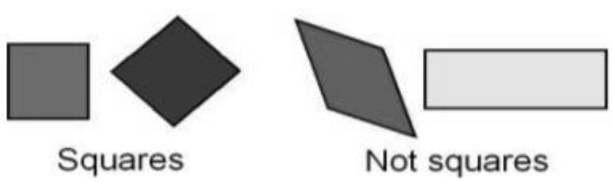

Figure 5: Children at Level 1 identify only one of the properties of squares

(Vojkuvkva, 2012, p 73)

In the grade one “Mathematics in English” book provided by the Department of Basic Education, triangles for example, appear on 27 different pages and often with many triangles on one page. The emphasis on shapes throughout the book, in various activities, is very effective. However, all, except one page used equilateral triangles with a flat base. This means that the concept image of a triangle for the learners using these books will tend to be:

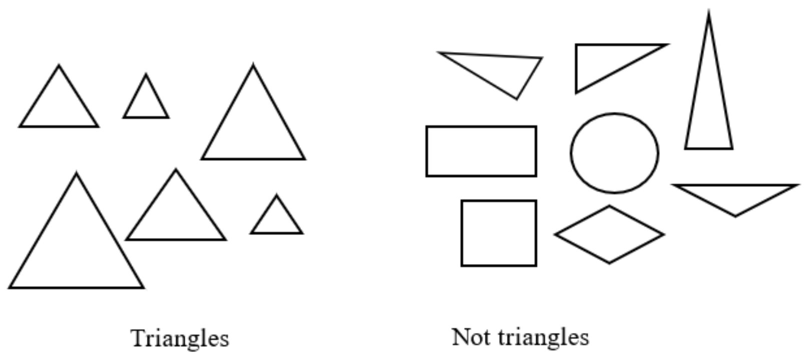

Figure 6: Perceived concept image formed through incorrect exposure

It is only at level 2 that informal deduction occurs. This is where learners start to see relationships between properties and figures. Van Hiele (1986) was deliberate about the development being level-specific and not age-specific. Clements and Sarama (2017/19) give guidelines on an approximate age range, in which a child should be able to achieve various goals in learning trajectories. It is therefore not appropriate to assume that children should be able to achieve certain levels in certain grades. It is, however, necessary that the curriculum guides teachers such that the appropriate levels can be reached.

It was of level 2 that the Pierre Van Hiele wrote, “My experience as a teacher of geometry convinces me that all too often, students have not yet achieved this level of informal deduction. Consequently, they are not successful in their study of the kind of geometry that Euclid created, which involves formal deduction” (Vojkuvkova, 2012, p. 73).

In the CAPS curriculum, the progression of space and shape from one year to the next, involves the identification of an increased number of shapes learnt. For example, in grade one learners are only expected to know circles, triangles and squares, whereas in grades 2 and 3, rectangles are also included. In terms of features of shapes, up until grade 3, learners describe, sort, and compare shapes only in terms of shape, straight sides, and round sides (DoBE, 2011).

CAPS

TOPICS	GRADE R	GRADE 1	GRADE 2	GRADE 3
3.3 2-D shapes	**Recognise, identifies and names two-dimensional shapes in the classroom and in pictures, including:** • Learners Symbols • Class name	**Range of shapes** Recognise and name 2-D shapes • circles • triangles • squares **Features of shapes** Describe, sort and compare 2-D shapes in terms of: • size • colour • straight sides • round sides	**Range of shapes** Recognise and name 2-D shapes • circles • triangles • squares • rectangles **Features of shapes** Describe, sort and compare 2-D shapes in terms of: • size • shape • straight sides • round sides	**Range of shapes** Recognise and name 2-D shapes • circles • triangles • squares • rectangles **Features of shapes** Describe, sort and compare 2-D shapes in terms of: • shape • straight sides • round sides **Draw shapes** • circles • triangles • squares • rectangles

Figure 7: Summary of 2-d shape content from CAPS curriculum (DoBE, 2011 p.27)

The researcher attempted to set tasks for the learners to do with parents, that involved more challenging goals according to the learning trajectories. Their knowledge and skills were pushed beyond content knowledge. For example, when families played “is it or is it not”, they had to identify basic shapes which also included examples, non-examples, pulpable distractors and difficult distractors. Many of the learners were initially not familiar with the subtleties of defining shapes. For example, four of the learners described number 18 (Figure 8 below) as a triangle. Only once the parents had shown them in the exercise, that shapes are only shapes if the sides meet, did they grasp the concept. The children were able to pick this up when shown, but they are not necessarily taught it in class. Knowledge on angles is not part of the CAPS curriculum, but most of the grade R participants were able to learn the concept when working one-on-one with their parents.

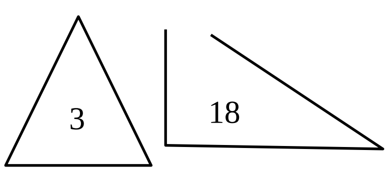

Figure 8: An example and non-example of a triangle from the “is it or is it not” activity

Also, one of the children only identified number 3 from figure 8 as a triangle. This is the equilateral triangle with a flat base, the typical triangle taught in school. However, once given the opportunity to make shape graphs, where a variety of triangles were given and the mom was asked to emphasize that orientation doesn't matter, just how many sides and angles it has, to be a triangle, she was able to correctly identify triangles in the post test.

Learners also struggled with activities such as having to orientate a combination of shapes correctly, as shown in the diagram below:

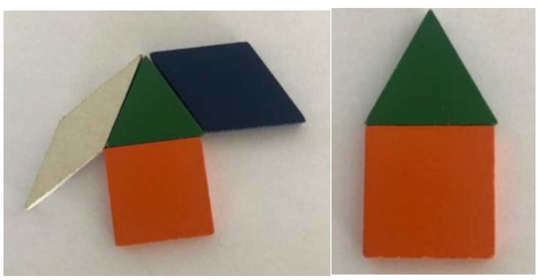

Figure 9: Shape orientation examples

They were shown the blocks by their parents, had a few seconds to look at them and then had to create the same design themselves after the design had been covered. Examples of the kinds of arrangements are illustrated in figure 9. When it was something familiar, like when it looked like a house, it was easier. However, when it was something unfamiliar, they struggled to duplicate the design. Here learners were tasked with the skill of holding an image in their minds, while doing something else with it at the same time (like re-creating it). Tasks such as these are the foundations of the harder tasks required of learners later, where they are required to dis-embed a portion of a diagram in their mind and then, from the given diagram, perform calculations to find the size of angles for example. These foundational activities train the young minds to perform progressively more complicated levels of manipulation later on.

When learners worked with their parents, they were exposed to a variety of skills which they may not have been used to. They had to create Venn diagrams of shapes which slide and roll, and shapes which have straight edges, curved edges and those with a combination. They also had to make "shape graphs", by lining all the shapes in the same category up together. Activities such as these, extended children beyond levels 0 and 1 of the Van Hiele models and into level 2, where they were starting to make simple, informal deductions.

Figure 10: Examples of activities used to illustrate Venn diagrams and shape graphs

Parents were purposefully told to only have 'rectangle' and not include 'square' as one of the headings in the shape graphs, which some, but not all chose to do so. This was to break the pre-conceived idea that rectangles have 2 long sides and 2 short sides and to show learners that rectangle have opposite sides the same length and angles that are right angled or "L-shaped". This was new information to the learners (and many of the parents), but most of the learners were able to correctly define a square as a special type of rectangle when shown. One parent had a discussion with their child about diamonds and squares. When the child was able to hold and manipulate the square in their hands and turn it sideways, she could see the size of the angle compared to the angle of a square. Her mother had a discussion with her about what type of angle it had and took out the original square they had identified. They put the corners on top of one another and she could see that one "diamond" was a square because the corners were L-shaped and sides the same length. Another "diamond" was not a square because the angles weren't L-shaped. The child's concept image was challenged and expanded due to adult-supervision and hands on shape-manipulation.

So, in summary, the content that was alluded to by teachers accurately reflected what was required according to the CAPS document. Teachers in this study showed a commitment to familiarize themselves with what was required of them, and two teachers had the opportunity to expand their content knowledge. The content however, showed a lack of the depth required to scaffold an effective concept image of shapes, that was required to progress to appropriately higher Van Hiele levels. Activities which involved adult-supervised play, were effective in building on the content, even though the adults were not qualified teachers.

5.3.2 Teaching styles

The teaching of space and shape seemed to happen in two distinct styles. Some teachers worked according to the CAPS recommendation and taught it as a two-week block, whereas other teachers emphasized the importance of blending the teaching of space and shape into other areas like art, reading, counting and arithmetic throughout the year. Some teachers taught it in a two-week block and then continued to bring it into other aspects of learning. Two teachers emphasized the importance of bringing it into every aspect of learning.

Teacher C: Mathematics is not mathematics on its own. Mathematics with us, what I feel, what I see and what I have done, it is incorporated in basically everything we do.

Teacher B: So, on a daily basis we do what is called mental mathematics. Questions pop up. This is a pyramid. How many corners, how many edges?

As opposed to:

Teacher A: So, we did that more towards the beginning of the year where we kind of did a week or two on shapes and looking at shapes specifically and their properties and all of that and then as the? continued I just kind of bring it into wherever I can I suppose.

Teacher C: So, I have a numeracy lesson and I have a language lesson.

Teacher D taught mathematics at certain times of the day but combined mathematical content into different aspects of the day as well.

Teacher D: **…so yes, we do mathematics as a subject on its own…But they teach you that you want to get the children interested so you want to teach them throughout the day. So, it's not just during their lesson times that they are learning mathematics, but its outside jumping or counting leaves, looking at the patterns, or looking at the patterns the animals like a caterpillar, you know, that kind of thing.**

Due to Covid-19, the researcher was unable to go into the classrooms and observe actual teaching styles in action so no conclusion could be made as to whether teachers were teaching using the more traditional chalk and talk method or a more hands on approach. However, it was evident from the interviews, that the teachers understood the importance of learners' constructing their own understanding and that an effort was made to allow learners to have access to their own resources when learning about shapes. For example:

Teacher E: **At the beginning when we start shapes, I cut out my circles, squares, triangles and that, and we give it out so they can feel it and know that it is flat and things like that.**

We take pieces of equally cut string and you make your square. And then when we do rectangles, we do the same with the rectangle where we do a long string and then a shorter string.

Teacher C: **How we build up the shapes is, we talk about straight and curved lines and then they play with string or match sticks, or lollipop sticks and then they build it out of that so we can see a square has 4 equal sides.**

There are some people that can see things geometrically, better than other people, but there is no way you can prove those skills without being able to touch things physically and interact with those things.

Teacher B observed that the hands-on approach seemed to matter more to the boys in her class than the girls:

Teacher B: **Quite often I'll hold it (a shape) and then let the kids see so they don't hold it in their hands. But the boys really need to hold it.**

Interviewer: Do you find the boys more so than the girls?

Teacher B: **They want to yes.**

Interviewer: So it's just a need? It's what they physically like to do?

Teacher B: **Yes. They physically want to turn it around whereas the girls are happy to look and say, "oh ja". They know there's a corner behind. The boy wants to turn it over and see it."**

5.3.3 Play-based vs worksheet-based activities

It seemed apparent that teachers wanted to get away from worksheet-based tasks and use a more hands - on approach. There were however, two reasons to use hand-written activities. Firstly, written activities were used for assessment purposes. SA-Sams, which is the department prescribed assessment tool, seems to have brought frustrations among teachers in that it requires very specific assessment marks even as early as in foundation phase. Comments from the teachers included:

Teacher A: **In Grade R, I would never have thought that I would come in and have to mark a child out of 10. Even in grade 1 that's a bit much. So, what I will do is I will create an observation about it and then I'll rate them on a scale of 1-4 and say where do they fit in the scale… rather than a mark out of 4"**

The second reason for hand-written activities is that parents like to see what their children have been doing and hand-written activities allowed this to happen. In one of the private schools, a dual system was adopted where school readiness books were used on a daily basis and then, other parts of the day were filled with more hands-on activities.

Teacher D: Well, you see the thing is that we have got our school readiness books. That's our formal workbook. In there, we have got worksheets that follow with shape…So, all that kind of mathematics will be formal training and those will be in their school readiness books. Then obviously when it comes to practical, we have the Geostacks that they use and the strips, the Geostrips, where you have your layering of shapes. So that will be your other one and you have to decide which shape goes on which shape. They are actually physically doing that. Plus, you have got your other logic shapes, where you are given the picture next to you and you've got to build."

The Department of Basic Education disseminated books with colour-printed worksheets on space and shape and other aspects of mathematics to schools across all provinces. Most of the teachers commented that these books were used as a spare resource but not as their main resource as they had a specific way of teaching that did not always fit in with how the book used the worksheets.

A few teachers commented on the fact that it was important for the parents to see written work produced by their child so they could have evidence of their progress. The teacher created various forms of written work such as school readiness books or flip folders. The learners' worksheets were cumulatively placed in the flip folder and then kept in the classroom until the end of the term. One teacher mentioned that since the Jo Boaler workshops, she wanted to get away from the more traditional flip folder work and use photos to show evidence of group play and individual play as skills taught, rather than simply knowledge gained. In addition to producing work for the parents, a varied school assessment program was required, and written assessment was often necessary for this as well. One teacher showed an assessment form which included a ticking system of skills attained, rather than simply marks for worksheets completed.

Play time was an important part of every teacher's day and many teachers spoke of the challenges of making play time possible during Covid-19. Most play time allowed for children to choose toys and play together with other children. When they wanted to move on to other toys or other groups of children, they were free to do so. Children were usually given free play time at the beginning of the day and at the end of each day. Some teachers made a conscious effort to ensure that shape-based toys were put out when they were learning about shapes. Many toys naturally tend towards space and shape development, so children often had exposure to Lego, wooden blocks, magnetic shapes, and Geostacks, for example. The one school had various resource sets which were bought for the whole grade. Teachers could sign out resources such blocks or measuring sets for a period of time and then return them to the resource library for other teachers within the grade to use. Morning and afternoon play time was free play, so the choice of activities was not insisted upon. Children who wanted to play with space and shape-based toys chose them. This was outside the formal teaching time, but as children were arriving at/ leaving school, time was allowed for them to have access to resources, where they could play on their own or with a friend if not during the Covid-19 pandemic.

It could therefore be seen that teachers appropriately used both free play and worksheet-based activities. Free play happened when children were arriving and leaving. This meant that it was a time when teaching could not happen anyway because the whole class was not present. Worksheets were used when necessary, however, teachers understood the importance of activity-based teaching as well.

5.3.4 Adult supervision

Children are able to build on their existing knowledge when they are guided by adults. So, another key aspect to ascertain the learning of space and shape, is how much time children get to experience adult supervision in a manner that builds on previous knowledge of space and shape. There are, of course, many benefits to free play, but also certain aspects of space and shape that children can only learn with the assistance of adults (Clements & Sarama, 2017/2019).

Of the teachers interviewed, there were different approaches noted. In some schools, there was time allocated to group work. Desks were set up so four to six learners sat around a desk, or they worked together on a playmat. Some of the group work time was allocated to adult-supervised play.

Learners at different tables were given different activities, and the teacher would engage with one group at a time. Some teachers mentioned the privilege of having an assistant to help when doing group work, but this was not usually possible. While one group was being attended to, the other children were often working on their own.

The depth of adult supervision varied. One teacher stated that instead of just letting them play with their Lego blocks, she would guide them by asking them to build a plane, for example.

Teacher B: …when I did group work, I would put (work) out for that day. They had 20 minutes on the mat with toys or they would play a game. I would explain the game, show them what it was, and they specifically had a thing to do and a game to play. So that was very intentional. So now it is not as intentional, but hopefully we can get back there because that's what needs to happen.

Adult supervision also happened more specifically in formal teaching time, but this was not necessarily one-on-one. A teacher would put resources at each child's desk and then give them instructions on how to manipulate the resources. For example:

Teacher E: Build a square from the sticks on your desk.

She would walk around and see how the children were progressing. So, typically, the reality in most classrooms, is that a child must share the attention of the teacher with about 20-40 other learners. Only in the smaller, more privileged schools do the children get meaningful, regular individual time with teachers.

5.3.5 Resources

The use of resources for space and shape learning involved colourful, cut-out shapes, wooden blocks, magnetic tile shapes, Geostacks, sticks, straws, and string. Resources are generally made available for free play in the mornings and afternoons and sometimes when it was group work activity. When they had allocated "mathematics time" in their day, learners focused on space and shape for those two weeks. In this mathematics time, they learner were given resources such as matches and straws to create their own 2-D shapes at their desks, thus showing their understanding of properties of the various shapes. The progression from grade R to higher grades in foundation phase seemed to be on the number of shapes they learnt the names and properties of. Most teachers have access to hands-on resources and were using items such as lollipop sticks and string to get the children to construct their own shape. Teachers seem to understand the importance of letting children play freely with resources in order to build their own understanding and figure concepts out for themselves. It was evident that teachers were often creating their own resources to work with space and shape as they were easy to make, it allowed them to develop the resources they wanted and sometimes they weren't given resources, so they had to. Some schools were asked by the teachers to buy specific resources and the schools were normally able to provide these. Most teachers alluded to the fact that they did not receive too many resources from the Department of Basic Education.

Thus, as far as how learners are being taught space and shape, evidence has shown that they learner have very good knowledge of names of shapes and of orientation words as is required by the curriculum. There does however seem to be a lack of depth in understanding, the reasons being threefold: The curriculum does not focus on a deeper understanding; learners are not given enough time to work with an adult through supervised play; space and shape learning is seen as less important than other areas and is thus not given sufficient time in the curriculum.

5.4 Theme 2: Facilitating the teaching of space and shape beyond the classroom: parent engagement.

The focus of this research was to look at intervention methods which could facilitate the learning of space and shape so that children are better equipped to face the higher Van Hiele levels of geometry understanding required of them in high school. The researcher felt strongly that when intervention is addressed at its foundational stages, learners have the best chance of building the foundation that is needed to assist them in later years. Parental engagement is by no means the only form of intervention that is possible, but time allowed to scaffold a proper understanding of geometry, needs one-on-one interaction, which is very difficult to attain in the classroom, especially when classes are large. At the time of this study, lockdown also meant that parent engagement was highlighted and the opportunity to explore its effectiveness was particularly relevant. Research has shown that the correlation between child success and parent involvement can be positive. Even though this is not always the case, it was worth exploring as an intervention strategy.

The effectiveness of parent engagement will be explored from various angles, namely:

- How did teachers feel about using parents to facilitate the learning process?
    - Did teachers find that parents did a good job?
    - Did teachers think it was sustainable?
    - Are teachers planning to continue with the process?
- How did parents feel about being part of the learning process?
    - Did parents think they did a good job?
    - Did parents think it was sustainable?
    - Would parents like to continue?
- How did the researcher perceive parents' opportunity to assist in space and shape learning?
- Did learners show an improvement from the intervention?

At the time of this study, teachers had experienced a set of circumstances that they had never encountered before. During the period of 2020 and 2021, the world was experiencing the Covid-19 pandemic. This meant that every teacher, almost throughout the world, was asked to teach differently as schools were closed to curb the spread of the Covid-19 virus. Although Covid-19 was not the first pandemic ever, it certainly was the first pandemic since online learning became an option. Some countries were a lot more technologically advanced than others. South Africa found itself in a situation where only a portion of the country had access to technology and others didn't. Teachers had to come up with ways to continue the process of education under extremely different circumstances. For a part of the year, schools were closed completely for long periods, at other times, they were partially closed with learners attending on a rotational basis. Regardless of the ages of the children or the technological circumstances, teachers all had to rely on parent engagement in some form, especially with younger children who were not mature enough to learn on their own. Whether the parents were mere facilitators of providing a sound technological platform and a home conducive to studying, or whether the parents actually had to engage in helping their child with their schoolwork, their input to the child's education, was invaluable. These, were extenuating circumstances. When interviewing teachers, they were asked to consider the effectiveness of parent engagement both before and during Covid-19.

5.4.1 Views of teachers

When looking at the views of the teachers in terms of how they interacted with parents, the approach that the researcher used was to look at each individual teacher and her set of circumstances and then draw conclusions regarding all the teachers thereafter:

Teacher A:

Teacher A taught at an underprivileged kindergarten which relied almost entirely on donations to fund the education process. There were 26 learners in the class. It was quite well funded and therefore had fairly good quality facilities and a well-educated teacher. Teacher A felt that it was not necessary to involve the parents under normal circumstances, so tended not to. However, during Covid-19, the teacher sent booklets home with two weeks of work content in them. She said the parents generally did well with a few exceptions, eg where parents worked shifts or didn't have materials to do the activities, etc. She did not like sending workbooks but preferred encouraging activities. The work that was sent home was not specifically related to space and shape. It depended on what was taught at the time. She had a WhatsApp group which she would use to explain activities.

For example:

> "**So I will say 'please will you add number 14 to your bottle top lids and then they will have to order them, order them backwards, put one bean/stone with number 1, all the way to number 14. They don't have to do it every day, but it's nice to do at home."**

Even though the learners are back at school since lockdown, she still uses WhatsApp to communicate with parents, especially those of weaker learners who needed additional assistance. So although parent engagement has not continued in the same manner, communication with the parents has, with the occasional need to include them in the process of helping weaker learners.

Teacher B:

Teacher B taught at a well-established, ex-model C public primary school which catered for grade R to grade 7. It accommodated children of all socio-economic backgrounds from the immediate area and surrounding township areas. She is an experienced teacher with diverse teaching experience, including working overseas. At the time of the research, she was teaching a grade three class of 23 learners. Her class tended to be more advanced than the other grade R classes in this research.

When asked how she found it working with the parents during lockdown, she said:

"**I've had a most amazing class this year. So I can say that the families of my class have done amazing jobs. Every child worked in lockdown. Some of the kids that I didn't think were working actually did work, with the exception of one child."**

When asked if she would continue to work with parents after Covid-19, she said that it had been discussed amongst all the grade three teachers and decided not to. The school had a no homework policy so the only work they would send home, was reading.

"**So it will take off all the other pressure and then those guys can read with their mom, then we take the pressure off mom. And then I feel more comfortable to say to mom, 'listen, her skills in that area aren't so good. Could you maybe build some puzzles or get some Lego or um encourage that sort of games', so they are more hands on. It's not doing stuff that they should be doing at school. It's totally different. So making forts and then looking at the angles and climbing trees."**

Teacher B said that she would continue to use the WhatsApp group to communicate with parents as this worked well:

"**Because of lockdown, we started a WhatsApp group and with my class, it works a dream. So everyone is on my one group, and I am happy, and my parents seem to be happy. If I want one-on-one, I can just WhatsApp them personally… On Friday, if kids done really well, I take a photo and send it home to mom. The mom is like "ah that's amazing". So before the kids even walked in the door, she has already got feedback on how her kid has done that week."**

Teacher C:

Teacher C worked at a Christian-based, small, private kindergarten that was started by a local church. She had been teaching grades RRR to grade R since 1997. Her class consisted of 13 learners.

When asked to comment on how she found the parent engagement, her comment was that only 50% of parents did it properly:

> “**One of my problems was, I think one of the parents actually did the work for the child. So, her work came back, and I was like ‘Wow, this child is doing so well, and the colouring- in is definitely become much better!’ and then it turns out no, the child is battling and so that was the one problem. The second problem was some children’s parents didn’t do it with their children at all.”**

Teacher C had engaged with parents even before lockdown:

> **“I had twins in my class, and I asked their father to maybe just do some more puzzles with them at home as they were not at the place that the other children were, so they needed that extra help. And they did, they came back, and they were good with their puzzles, so they had had the practice.”**

She believed in the importance of getting one-on-one time when an individual was struggling with a concept and knew that parents provided a great opportunity to give children this individual time, to scaffold on their understanding. Although parents do not have the experience to pick up on areas of concern, the teacher can use her expertise to do so, communicate with the parents, and get them to play appropriate games to assist in the necessary development. Although teacher C believed in parents as a useful resource, she was clear about the fact that it really depended on which parents she approached, concluding that parents are not a consistently reliable resource. Extenuating circumstances may also reduce their ability to assist.

Teacher D:

Teacher D taught at a small, well-resourced, private kindergarten with good facilities and qualified teachers. She was an experienced teacher with 30 years of teaching foundation phase

and had a passion for educating young children. Although they were a private school, they followed the CAPS curriculum as they mainly fed into the local government preparatory school.
Teacher D had mixed feelings about parent engagement. On the one hand, she had a fairly positive experience during lockdown where she found about 90% of the parents effectively engaged in activities with their children. She produced videos and developed activities which were mainly interactive for space and shape. Her videos were sent via WhatsApp and showed parents what to do with their child.

In spite of a positive outcome during lockdown, teacher D felt that if it was not lockdown, parents would not do activities with their children, even though the teacher had gone to great lengths to provide very effective resource packs with everything they needed.

> "**Parents wouldn't do it! They were forced to do it. They weren't working. They were sitting at home, and they had to do it, but I think now they wouldn't."**

> "**It's definitely our job. Even behaviour wise, they are sent to school to be taught discipline**."

So, for teacher D, she was able to make parent engagement work effectively, but did not see it as sustainable in the long run.

Teacher E:
Teacher E taught at a larger, government primary school which serviced mainly the Indian and African communities in the area. She had a good reputation for being an excellent teacher and had ten years of teaching experience.
She found the interaction with parents during Covid-19 to be a very positive experience:

> "**Ok, from the first day of lockdown, I actually started a book. Basically, every day I used to write what the children need to do. I do a lesson, I used to video the lesson, I used to**

do voice notes for pronunciation and things because they battle with that so even mathematics as well. I used to take the book and show how the work must be done, explaining what to be done and before I actually showed them the book, I explained the concept and have some fun thing to do. And then I send it off on a WhatsApp. And I had brilliant parents this year. They really (really) did a good job."

Her colleagues agreed that they would continue to work with the parents after Covid-19 and that they would use the WhatsApp group to send them homework.

The experience of the teachers regarding the effectiveness of parent engagement was not specific to space and shape, but more generalized. Some activities involved space and shape, but teachers tended to look more holistically at the issue of parent engagement. This research did not involve a large number of participants, so cannot possibly be generalized, but what seems evident is that when parents are motivated to help their child, they seem to be effective in doing so.

Hoover-Dempsey and Sandler (1997 and 2005) spoke extensively of the importance of parent motivation and clearly, this cannot be under-estimated. Jay et al. (2018) re-iterated that parent-centred involvement as opposed to school-centred involvement, is more effective in reaching education goals. The experiences of the teachers in this study have shown that a buy-in from the parents is essential. During lockdown conditions, motivation generally came from the fact that parents knew that if they didn't participate, their child could not get educated. However, family circumstances were simply too hard for some, therefore parents could not effectively help their children. This, I feel, is the main reason why teachers do not see parent engagement as sustainable. If they covered all the work in the classroom, they felt certain that the children will be doing the work.

5.4.2 Views of the parents

There were nine children who were involved in the intervention study overall. One family had two siblings (in grades R and 2), so they were counted as one participant. Another participant was not able to transfer her recorded videos before deleting it off her phone and was therefore eliminated as a participant. Finally, the results compared the feedback from seven families, called participants A to G. The views of the parents were looked at related to specific questions.

Table 2: Age and gender of children in this study

Name	2) Age of child	3) Gender of child
Parent A	6	Female
Parent B	5	Male
Parent C	5	Female
Parent D	5	Male
*Parent E	5	Female
*Parent F	5	Male
Parent G	5 and 7	Male (5) Female (7)

* Intervention activities were administered by an older sibling (approx. 18-year-old) and not the parent but will still be referred to as the parent in the discussion.

Responses to questions

When parents were asked how they felt about the opportunity of helping their children with these important aspects of mathematics before starting the intervention, responses included:

Parent A: **Enthusiastic**

Parent B: **Optimistic**

Parent C: **Little apprehensive about finding the blocks of time to be able to complete them as well as how to explain some of the concepts that were covered, but excited to try them. Felt it was nice to have been given the opportunity to do activities that someone else had planned and structured, rather than trying to think of things myself.**

Parent D: **Was excited to open new forms of play for his mind**

Parent E: **I didn't mind, I saw it as an opportunity to help my child learn so I didn't mind**

Parent F: **I felt demotivated because I thought it would be a lot of work and frustration, but I grew to love the quality time spent.**

Parent G: **Enthusiastic to try new teaching material**

The responses given by the parents generally tended to be positive. Some parents simply looked forward to doing it as they relished the opportunity to help their child. The parents who volunteered seemed naturally motivated in wanting the best for their children and were in a position to be able to do so.

It is worth mentioning that the process of choosing samples for the research, was voluntary. All the parents from six grade R classes in six different schools, were given the opportunity to voluntarily be involved in the study. The same message was received by all six schools asking parents to submit names to the class teacher if they wanted to volunteer. The researcher requested, via the principals and teachers, that a voice recording be sent on the parents' WhatsApp groups. It was interesting to note that almost all the volunteers came from one school. Only the parents that wanted to, volunteered. That meant that the parents who participated probably felt capable enough, had enough time, thought it would be beneficial for their children and were motivated to work with their children. They also knew that it would only be for five days. It meant that well over a hundred parents chose not to get involved, for unknown reasons.

The circumstances experienced during lockdown were unique. Very few parents were at work initially, and many had been through a long period of having to work with their child at home. For many parents, this was a difficult time. They may have had the time to help their child, but other factors such as their education levels, the home environment, access to technology, poverty, emotional anxiety created due to the pandemic, etc. may all have played a role in their inability to help. It was encouraging to see that some parents were still enthusiastic at the thought of helping their child, and at the same time, understandable that both educators and parents were apprehensive.

Did parents think they did a good job

When parents were asked how they felt the activities went, the responses from the parents were as follows:

Parent A: Alright

Parent B: I could see the benefit and enjoyed doing it. Obviously for research purposes we had to film the sessions, but it would have been a little easier to do if we did not have to film the activities. Sometimes I found 30 minutes difficult to do because I would get home late from work and then my son would be tired and filming a tired child for about 30 minutes was not ideal. When I continue to do the activities at home, I will probably choose one activity from the day to do (so perhaps do a 10- or 15-minute activity).

Parent C: I don't know. Some "days" went better than others. Found that when we got to the activities (my child) was tired and concentration wasn't great. I also struggled to find the words to explain some of the concepts at an appropriate level for her. Overall, I think she enjoyed them as did I.

Parent D: **Mostly they went well - but at times he was too tired and because I was trying to get it done in a time limit, I had to push him a bit to do it. Also, I found working through a specific set of instructions and because I was videoing it, just because I was trying to figure it all out made it a bit more regimented, however now that I know the different formats of games and can just out the blue do it myself, think that will work better.**

Parent E: **They went well, they were fun and easy to do**

Parent F: **I actually enjoyed spending time with my younger brother**

Parent G: **They were fun and educational at the same time, the activities went well, keeping the kid's attention**

The parents mostly felt like the activities went well, however, the time frames and the need to record sessions, seemed to have been a hindrance. Sometimes the parents were tired and finding time to do activities at the end of a long day was daunting. At times the children are involved in extra-curricular activities such as music, swimming lessons, ballet, and other sports and by the end of the day, they were also tired and struggled to concentrate. The significance of this impacts greatly on data acquired. The teaching day for foundation phase learners finishes at around lunch time. The ideal time to spend half an hour growing mathematical ability would be in the early afternoon. However, it is unusual that even one parent is available at this time, due to work commitments. If there is a parent available, the time is often filled with sporting activities. When we look at key sports in South Africa such as rugby, hockey, and cricket, we are certainly not performing as we are in mathematics and Science. This is because sporting ability is culturally important in South Africa and seen as a priority, and parents that do spend time developing their child often prioritize sporting development over mathematical development. This is often seen in parent's' choice of schools as well as the marketing of schools in South Africa. The ability to perform well in sports, not in mathematics or science, attracts the attention of parents).

When parents were asked whether their child benefitted and grew in their understanding of space and shape, the responses were generally very positive.

Parent A: Yes

Parent B: Definitely

Parent C: Yes, I do think so. There were also a few issues highlighted for me that I thought she knew/understood from activities that we'd done before, but it became apparent that she didn't.

Parent D: Definitely, out of the blue he will now say, look mom, that's a rectangle etc.

Parent E: Yes, he now knows the difference between a square and a rectangle

Parent F: There was a huge growth, and he began teaching his friends at school about pentagons and hexagons. He also benefitted because the teacher at school told him he performs much better at identifying shapes.

Parent G: Yes

It can be seen from the responses above, that the parents showed a consistent, positive outlook to whether their child benefitted. The specifics of how the child benefitted are more clearly outlined in the observations of the researcher. For parent C, it was beneficial in that she was able to identify problematic areas when working with her child. For the rest of the parents that specified, it was beneficial to for child's understanding of space and shape. Comments made by parents D and F also pointed to growth in the confidence of the learner.

When parents were asked which specific activities worked well, they said the snakes and ladders shape game was favoured as well as the slide and roll activities where children were using themselves as objects to slide and roll on the lawn or on a carpet. An interesting comment from parent E was:

> **"Day five all tasks worked well for us. They were fun, quite easy concepts to grasp. I do think? in our case was a little confounded by that fact that the other days we had to fit them in around other activities, most of the others were done after 5 pm in between cooking supper and when tired. Day five we did on the public holiday in the morning, there was no time pressure, no tiredness so it was**

relaxed and fun. The symmetry task on day 3 went the worst, and again I think it was the circumstances under which we were trying to do it rather than the task itself"

The learning environment played a big role in the effectiveness of parent engagement, and it is perhaps not so much the activities that determined the success of parent engagement, but also incidental circumstances. When both parents and children are tired, it is hard to be effective.

Although there was extra effort on the part of the parents, when asked, "if there were more of these activities designed specifically to make your child better at mathematics, (perhaps in different areas of mathematics) would you want to do them", most parents were in favour of the idea:

Parent A: If it came with instructions and everything was done, I just needed to help/play with my child I would consider it.

Parent B: Yes, because they helped my child.

Parent C: Yes, I think in the foundation of learning it's been a great opportunity to use fun ways to stretch the mind.

Parent D: Yes! Learning through play makes the subject a lot more enjoyable. Sometimes we just need ideas to get us started.

Parent E: Yes, any extra help will be beneficial to the child.

Parent F: Yes, if it came with instructions.

Parent G: Yes, definitely as long as it was at our own pace and could do 15 minutes a day at most. It was great to have the structured activities and they also prompted more ideas.

Parents seemed eager to get involved if the work was planned for them, came with instructions and they could do shorter periods of fun activities. Parents do not want parent engagement to be onerous as for most of them, their days and their child's day is busy enough. However, they do see the value in helping their children mathematically and do see the potential they have to help.

Do parents feel it is sustainable

Parents were asked if they would consider doing activities such as these with their child if it wasn't lockdown. 63% said they would and 38% said they would not. When asked to explain, the parents that said "no", commented that:

Parent A: I wouldn't be aware of them (the types of exercises). Due to lock down I have had to become more involved with her learning. Therefore, now I am more aware and willing to help now to make her schooling career a little easier.

Parent D: We didn't pay attention to schoolwork during lockdown, we just wanted to get through the day.

Parent G: Insufficient time and I was doing my own work with both my children.

Harbour (2020) alluded to the fact that lockdown created a positive catalyst to unlock educational opportunities never considered in the past. This seemed to be the case for parent A. However, the comment made by parent D, where home circumstances were so difficult that schoolwork became secondary, may be the voice of the many parents who were offered the opportunity to participate in this research but chose not to. The education of a child is never created in a vacuum. The environment in which the education takes place has a major effect on the individual. Many theoretical frameworks such as Bronfenbrenner's ecosystem model (1986) and Vygotsky's activity theory (1986), emphasize the importance of external factors in the life of a person l. This was also true for parent G, who had her time taken up by other factors. Even parents who would consider activities such as these, are affected by external factors. However, the circumstances of participants, made it a viable option. Parents who did consider it as an option made the following comments:

Parent B: **It was a way to connect meaningfully with my child while he learned in a fun way. Boys are also always seeking movement so if we can teach mathematics through movement or play, I think this will really benefit them.**

Parent C: **Lockdown didn't have any bearing on decision to take it on in the first place.**

Parent E: **(It) is a wonderful opportunity to spend time with a child and better understand the way their child thinks and learns.**

Parent F: **I enjoy spending time doing something constructive with my kids.**

In spite of 63% of parents in favour of parent engagement in mathematics activities, when the same parents were asked if they thought other parents in the class would do activities such as these, only 37% said "yes". They reasoned that the parents were not disinterested or incapable, but all five parents who said "no", spoke about the fact that parents with full time jobs are very busy, come home tired and just want to relax at the end of the day. The comment made by parent C was:

> "**Two factors may hinder some parents: lack of time and lack of education. If the activities were kept to 10 or 15 minutes, I think parents would more likely do them daily. As per my comment in point 10, I think some parents would battle if they had not received a good education themselves, but perhaps if there were exact examples given or a video sent to show them how to do the activity, that would help."**

The researcher is very aware of the fact that parents who volunteered to take part in the research, are not fully representative of the South African socio-economic demographics. The researcher was intentional about creating activities that could easily be performed with almost nothing, other than a few pieces of cardboard, paper, and a few general household items.

Instructions were explained both on paper and via a voice recording which is very low in data usage, however, parents from lower socio-economic groups, did not volunteer to participate. One of the parents happened to be out of South Africa at the time of the research, even though she lives in the Midlands area. She had to rely totally on making her own resources and communicated via WhatsApp and email. She was still able to participate in all the activities fully. Bower (2011), pointed to the fact that a great deal of parent involvement research is based on middle class, western education systems. This has important implications in terms of what parent involvement looks like. Statistically, at the time of this research, the unemployment rate among 25- to 34-year-olds (the average age of parents with young children), was over 40% source. This indicates that a large percentage of the population of young parents were unemployed, and circumstances were very difficult for many families. It may not have necessarily been that they were tired after a long day of work, but that they were coping with the difficulties of being unemployed.

The final question asked of parents was whether they thought that schools should be encouraging parents to be part of the process of giving children more one-on-one time in mathematics. Comments from the parents varied:

Parent A: **For someone like me who struggles with mathematics and not very confident in it, I would prefer the teacher to take over on this one and maybe send some games home on the weekend to do. To help practise what was learnt during the week.**

Parent B: **Yes! I think parents may not do this because we do not know of fun ways to teach mathematics. Learning through play would be far better than getting homework in the very young age groups (e.g. grade R and 1). If the "homework" was building a tower out of blocks, for example, it would be both fun and connecting with the child. For me personally, now that I have some ideas, I will definitely be doing this more at home.**

Parent C: This is a difficult one to answer. Yes, I do think that parents should be actively involved in all aspects of their children's education including mathematics and boosting all aspects of the education their children are receiving. Without the involvement of parents doing one-on-one activities I don't believe that a child will reach their full potential and will battle through school. That being said, many parents are struggling to get through the day normally. Although they would probably see the need and have the good intention of doing one-on-one activities, I think it may be lost in the "mess" of everything going on. I had every intention of making a concerted effort to focus on the activities each day, but it didn't happen. Working 8 - 5 with the bonus of a little bit of flexibility I am probably luckier than most mom's; once 5 pm came and trying to do the activities in between cooking supper was challenging. Normally our one-on-one time was incorporated into the supper activities - like cut the potato into four pieces, or get me three carrots out the fridge and now another two- how many are there in total, or weighing ingredients, etc. At this stage we don't have the challenge of getting homework done.

Parent D: So, my 5c opinion, yes, I do think parents should be encouraged but how that is done needs to be given careful thought in order for it to not be swept aside in the mad rush and probably should be "incorporated" as much as possible into everyday activities.

Parent E: Absolutely

Parent F: Yes, because learning shapes is important and starting at home will help the child later at school

Parent G: Yes, it is great to get ideas on how to engage more with your child to help with something as important as mathematics

In general, parents liked the idea of encouraging mathematics games. For some parents, they needed the initiative from teachers to give them the ideas for the right kinds of games. For others, engaging in adult supervised play, seemed to be better than sitting at a table and thrashing out homework as it created better bonding time with their child.

5.4.3 Researchers Observations from activities

Parents were asked to film a series of activities over five days. The researcher studied the videos of the parents engaging in space and shape activities in order to ascertain if parent engagement is an effective interventive means of teaching space and shape.

A full summary table of results on the activities is presented in the annexure, where daily observation of each activity was commented on, for each participant. The observations of the researcher will again be based on thematic analysis.

Presence of a camera

The effectiveness of parent engagement was affected by the presence of a camera. The participants were young children and probably had few experiences of being filmed doing work. It seemed particularly noticeable when the laptop was placed in front of them, and they could see themselves being recorded. It was better when a cell phone was used, but if the parent did not have someone to help them film, it was difficult to engage in an activity and film at the same time. It is therefore worth noting that this affected the results, most noticeably on day one.

The length of the activity and the time of the day

The activities were designed to complete a few different tasks every day. This was so that faster learners could move on to more advanced tasks. Even though the instructions clarified that parents only do what they were capable of and limit sessions to no more than 30 minutes, some parents really pushed to finish all the activities. The researcher was able to clearly observe the tiredness in both children and parents, in some videos. Here, parents were less patient and the children less willing. One has to consider the reality of the conditions under which parent engagement occurs. This was alluded to by one of the parents:

> **"Day five we did on the public holiday in the morning, there was no time pressure, no tiredness so it was relaxed and fun. The symmetry task on day three went the worst, and again I think it was the circumstances under which we were trying to do it rather than the task itself"**

Parents own knowledge and attitude towards mathematics:

None of the parents involved in the research were teachers and none of them were mathematics experts. In two of the families, the older siblings (both in grade 12) took mathematics as a subject and the parents let them do the teaching as they felt that the siblings were more capable. Some parents specifically mentioned that they found mathematics hard themselves:

> "**For someone like me who struggles with mathematics and not very confident in it, I would prefer the teacher to take over on this one and maybe send some games home on the weekend to do."**

Many intervention studies point to the significance of the parents' own mathematical abilities as a concerning factor, affecting parent involvement. However, this study has shown that if parents are given play-based activities to help foundation phase learners, they are very capable of producing effective learning. The observations made by the researcher showed that parents had a good rapport with their children and were therefore able to harness the interest of the youngsters. As they understood the nature of their children, they managed to control learners' frustrations when they struggled and boosted their confidence when they succeeded. Parents were able to gauge the child's competence well and adjust the level of the activity to suit his/her ability. This was not as obvious when the older sibling was the teacher. The one area of concern was the content knowledge of the parents. They were given the information necessary to complete the activity but were sometimes lost if challenged with questions beyond what had been explained. In this intervention project, the researcher had a WhatsApp group for participants, and they could ask questions whenever they needed to. This meant that concerns could be addressed quickly. The questionnaire answered by the parents showed that they all felt the intervention was beneficial to their child's growth. From the perspective of an observer, this was clearly evident, regardless of the parents' own knowledge of space and shape.

Parents were vigilant at following instructions, although some concepts t were new to them, in spite of this being foundation phase mathematics. For example, some of the shapes used in the shape graph included trapeziums and parallelograms. Some parents did not know the names of these shapes. Many of the parents did not know that a square was a type of rectangle, but after this had been explained to them, they were quite capable of conveying it to their child. There were occasions when the researcher noticed cultural differences. Instructions had not been given on how to play "snakes and ladders", only to adjust the game to involve shapes. However, some families had never played the game and were not aware that you go down the snake and up the ladder.

In conclusion, the observations of the researcher were that, provided the instructions are clear, play-based games that parents do with their children were very effective, despite mathematical knowledge of the parents. Every child benefitted from connection, interaction, the time to engage with resources to scaffold their understanding, and the time to have a dedicated person answer their questions.

What could not be directly observed, but could certainly be noted, is the attitude of parents' towards both the importance of mathematics and the importance of their role in developing their children. All the parents involved in this research knew that their day would be busier and harder when signing up to participate. The researcher knew none of the participants, so none were doing it as a favour to the researcher. They chose to do it because their attitude was that of helping their child being more important than the vulnerability of being involved in research or the time and effort it would take. However, a much higher number of parents chose not to participate. This, and the comments from both teachers and participating parents pointed to the fact that many parents believe that it is the school's job to educate their child. It is possible that parents are too busy, have little time, or do not have faith in their own ability, to be involved. Thus, as stipulated by Hoover-Dempsey and Sandler (2005), motivation to be involved is paramount. Parents will never know how capable they are at helping their child if they are not prepared to try, for whatever reason.

5.5 Theme 3: External factors affecting the teaching and learning of foundation phase geometry

In the chapter on research design it was specified that the research was inductive as opposed to deductive. This implies that patterns and themes are induced from general observations. These patterns and themes help the researcher to come up with a tentative hypothesis after the research has been reviewed (Trochim & Donnelly, 2006). One of the undeniable themes that emerged from this study, is the extent to which different levels of influence affected the results of the intervention. Although Bronfenbrenner's Ecological Systems theory was not discussed in the theoretical framework, as the focus was on geometry learning, it certainly emerged as significant in the unfolding of the results.

Within the microsystem, is the child's peers, siblings, caregivers and teachers. It was evident from the observations of the recorded sessions, for example, that when the activities were played within the family that had two children participating, the behaviour of the children was completely different compared to when only one child was involved. There was competition, comparisons and sibling rivalry between the siblings, which affected how they performed. Sometimes the parent allowed a friend to join in the activities and this also created a different dynamic as the child felt more comfortable with a friend around and was more playful.

The interaction between the child and the parent in the activities highlighted many different dynamics. It was difficult not to get emotional about the beauty of the bond and the connection between the child and the parent when the parent was dedicating one-on-one time. For some children, it seemed like they were used to having such close attention and it seemed very natural. For other children, they could not stop smiling for all the attention they were receiving, and they were over-joyed to be getting so much positive feedback.

The home environment also played a major role in the interaction. There was a significant difference in the noise levels noted within each home. In some s, there was lots of talking, the television was on, and there were sometime many other people in the space where the activities were taking place. However, the child did not seem in the least bit affected as it was a normal environment for them. In other homes, it was quiet and spacious, and the child may have had their own dedicated play area. Another example of how occurrences in the microsystem affected the learning, was when a child stood on a nail and participants had to abandon the activities for the rest of the day.

The time of the day also had an effect on the quality of learning. Activities were often done in the early evening after a long day. The comments of the parents showed the significant impact that this had on them and their child.

Bronfenbrenner's exosystem deals with the effect that formal and informal social structures have on the child (Guy-Evans, 2020). These may include neighbours, extended family and where the parents work, for example. In one of the families, the father was a seaman and was called to do work in another country at the time that the research was being conducted. This meant that all resources had to be self-made as the researcher was unable to deliver a resource pack. The child may also have been in an unfamiliar home environment. Another example was the fact that one family was unfamiliar with the rules of 'snakes and ladders. It should therefore be remembered that the lived experience of each participant is unique, enhancing or limiting their involvement in a study. The normal games that happen within communities are often culturally and ethnically influenced and this affected their ability to learn from the game. In the one home, the grandmother was always present and sometimes assisted in the filming of the activities. In this home, the older sister was being the teacher and the grandmother was getting quite involved in the activities.

However, it seemed to be the macrosystem that had the greatest effect on the learning process. For example, the political complexity of South Africa's curriculum development in a post-apartheid era meant that the curriculum had been 'unstable'. and therefore, the curriculum as well as its content, are strongly influenced by the socio-political background in which it was developed. The global pandemic was also a major factor in this research as the dynamics between participants, their stress levels, health, financial and emotional well- being, and a host of other issues, were thrown into disarray.

Chapter 6

Conclusions and Recommendations

6.1 Conclusion

The aim of this research was to explore the effectiveness of parent-engagement in teaching geometry to foundation phase learners. The three key objectives were:

1) To explore how learners in the foundation phase are normally taught space and shape schools.
2) To explore the effectiveness of parental-engagement in the teaching of foundation phase space and shape.
3) The explore the views of parents in assisting in learning of space and shape.

What the study revealed in terms of how geometry is being taught in foundation phase is that teachers follow the curriculum quite closely. The curriculum allows for a two-week block period where space and shape are taught. Some teachers had a specific mathematics time allocated in their day and others like to bring it into all aspects of the work they do. Teachers all seem to understand the importance of giving learners access to resources which allow them to have a more hands-on approach to learning as opposed chalk and talk. That being said, the sizes of classes did not always allow for very much adult-supervised play and free play tend to be used more commonly. Regardless of the method of teaching geometry, the content remained as prescribed by the Department of Basic Education's CAPS document. The content therefore focused on learning the names of shapes and how many sides and angles they had. It also emphasized the use of direction words.

In contrast the literature review revealed that a far greater depth of both skills and content are considered worldwide. The emphasis seems to be on going deeper rather than broader.

Constructivism emphasized the importance on building on previous knowledge and allowing learners the time and opportunity to engage in a meaningful learning experience. In reality, teachers are only giving students the opportunity to learn the names of shapes and basic properties as this is all that the curriculum requires. Discussions with teachers revealed that most of the time given to engaging in resources was free play where no connections were made to important learning concepts. Van Heile spoke about level sof geometric development. The high school geometry curriculum requires students to have a good grasp of visual level and descriptive level. As a researcher with little to no experience of teaching at foundation phase, it was easy to see the discrepancy of the quality of experience gained by working according to Clements and Sarama's learning trajectories in comparison to simply following the required DoE (2011) CAPS requirements for space and shape learning. Learning trajectories covers a wide variety of well researched activities which allowed the learner to grasp meaningful concepts through set activities. Learners for example, engage in composing, decomposing, disembedding, sliding rotating, and mentally moving shapes. All theoretical frameworks pointed to the fact that it takes time to scaffold a proper understanding of the concepts of space and shape. This time is best spent using adult-supervised play to give learners the opportunity to manipulate resources in activities that allow them to form effective concept images of space and shape. Within the South African school structure, the pieces are in place. The curriculum places emphasis on the importance of adult-supervised play, there is a culture for the new post-apartheid generation of South Africans to use education as a tool to overcome poverty, organisations like the Melissa and Bill Gates foundation have made excellent resources freely available. There only seems to be a lack of connecting the dots so to speak. The resources are not making to the indivuals that need it most as they simply do not know they are available.

The second objective in this study was to explore the effectiveness of parent-engagement in teaching geometry to foundation phase learners. The observations of the researcher revealed that parents that were motivated to participate in the study were very effective in supporting the space and shape learning process. The use of play-based activities allowed the experience to be meaningful and enjoyable for both the child and the adult. The children performed better in their post assessment tasks and effective learning was observed in the analysis of recorded activities.

The research showed that parent-child engagement activities need to be shorter than 30 minutes. The families who participated were all under time constraints and children were tired by the time their parents came home. Activities that were easy to administer worked particularly well and parents enjoyed the opportunity of being able to learn with their children, where clear instructions and simple resources made it easy for them.

None of the caregivers involved were mathematics experts, yet all were able to effectively spend time with their child/sibling and improve their foundation knowledge of space and shape in the home. This shows that it is not necessary for the parents to be experts. Teachers who are the experts can make the effort to produce basic activities which allow children to have adult supervised one-on-one time in order to solidify their understanding of basic concepts.

The third objective of this study was to explore the views of the parents in assisting in the learning of geometry. In hindsight, the views of the educators were as insightful as the views of the parents and just as significant. The view of both teachers and parents indicated that they did not think that parent engagement was a sustainable option, as not all parents would do it. When activities are only completed by a segment of the class, the teacher has to repeat it. Creating an activity for home and then having to repeat it in class doubles the work of the teacher. It is not that parents do not want to see their children thriving in knowledge and skills, but merely that most families need both parents to work in order to survive. Exhausted parents are drained by the end of the day and basic hygiene and nutritional needs being met, supersede meaninglful learning opportunities.

Another significant finding is that parent motivation is critical. There are many external factors which cause parents to believe that they should not be responsible for the education of their child and without a buy-in from the parents, it is difficult to get them to be involved.

Having said that, Covid-19, and extended periods of lockdown across the entire world, created a unique opportunity where teachers did have to ask parents to help. Feedback from the teachers revealed that they were mostly pleasantly surprised by how well a large majority of parents did during lockdown. Many parents were successful in assisting in their children's education and the teachers became aware of this. Teachers also learnt that with the use of technology, especially WhatsApp groups, it was much easier to involve parents than they had previously thought and with social media, more teachers have garnered parent involvement, especially with learners that are struggling. So, although teachers may not continue to use parent-engagement for whole-class activities, they felt motivated to communicate more frequently with parents via WhatsApp groups and use parents to help individual learners where necessary.

When it comes to the learning of geometry, both teachers and parents have time constraints. In families, often both parents have jobs, and the running of a household can take up a lot of time. In the classroom, teachers are not only teaching mathematics, but also reading, writing and other foundational essentials. The importance of being able to read and write, often supersedes concepts such as space and shape. Therefore, even if teachers are using parents to assist their child with one-on-one time, it may be reserved for reading and writing activities.

6.2 Recommendations

At the end of the research process it is important to reflect on why this research topic was initially chosen. As a high school mathematics teacher, it is evident that geometry the section that learners struggle the most with. Based on Van Hiele's (1985) theory it is just not possible to reach higher levels of geometric development without mastering the initial levels first. Accordingly, it is too late to start intervention at a high school phase and hence the following recommendations are made:

Foundation phase and intermediate phase teachers are encouraged to create more opportunity for adult supervised play, especially when teaching geometry. They are also encouraged to make use of parents to facilitate the learning of geometry. It is not advisable to get parents to teach concepts, but simply to enhance the learning process by using their normal homework time to play carefully selected games. Many parents would be happy to have the opportunity to grow their child, but often don't know how to. The use of WhatsApp groups and simple video or audio instructions can make this a very viable option for teachers to involve parents in a meaningful way. An array of well demonstrated activities involving very few resources are available on line and a WhatsApp post from a teacher could be as simple as posting a link to a well demonstrated activity and asking parents to emphasize a concept taught by playing a demonstrated game with their child for 15 minutes a day for the next few days. Teachers could post a video of them doing the activity with their class to it is possibly language and culturally more relevant. Parents could ask questions on the group should they have any.

Teachers are also encouraged to use this channel of communication to assist learners that are falling behind for whatever reason. This would be on a more individual basis and not necessarily to the whole group. If parents are unable to assist, it is recommended that school ask other parents who have extra time to come into the school to spend time working with the learners that need extra assistance. This system of parent assistance is often used already to assist in reading skills. Mathematics skills can be emphasized in similar ways where a parent came into the classroom and assisted in a spare hour on a more individual basis with learners who are struggling.

So, on a systemic level, the issue of class size needs to be addressed, especially in foundation phase. Smaller classes would allow children to have more one-on-one time with their teacher. This will not only significantly help in the scaffolding of geometry learning, but other learning as well.

It is also recommended that the curriculum allows for more time to teach geometry in the foundation phase syllabus. This will allow for time to deal more specifically with fundamental concepts such as disembedding, composing, decomposing, spatial visualisation and spatial orientation skills, so that teachers adhering to the curriculum are aware that these must be included. There is an imbalance in how much emphasis is placed on geometry at high school and how much attention it is given in foundation phase. There are 2 solutions to this imbalance. More time can be allocated to geometry in the early years or less time and emphasis must be placed of geometry at a high school level.

In my opinion, the value of geometry cannot be understated, and it would indeed be disadvantageous to the development of a child to see it underplayed. Geometry is not only practical in terms of everyday functioning and certain vocational skills, but it trains the mind to see mathematics visually, to be methodical in reasoning and deductions, and to understand other areas in mathematics. It also provides parents and teachers with the opportunity to play with mathematics and help children develop a love for mathematics due to the variety of playful and visual activities that can be developed in geometry.

Leo, F Buscaglia (1924 – 1988), a professor at the university of Southern California once said:

"It is paradoxical that many educators and parents still differentiate between a time for learning and a time for play without seeing the vital connection between them."

This wisdom deemed valuable almost half a century ago, is as relevant today as it was then.

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www.hsrcpress.ac.za

Appendix A: Ethical Clearance

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

04 September 2020

Mrs Siobhan Kerry Hopkins (204400617)
School Of Education
Edgewood Campus

Dear Mrs Hopkins,

Protocol reference number: HSSREC/00001800/2020
Project title: Exploring the effectiveness of parent engagement in the geometric development of foundation phase learners
Degree: Masters

Approval Notification – Expedited Application

This letter serves to notify you that your application received on 14 August 2020 in connection with the above, was reviewed by the Humanities and Social Sciences Research Ethics Committee (HSSREC) and the protocol has been granted **FULL APPROVAL**

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment/modification prior to its implementation. In case you have further queries, please quote the above reference number. PLEASE NOTE: Research data should be securely stored in the discipline/department for a period of 5 years.

This approval is valid until 04 September 2021.
To ensure uninterrupted approval of this study beyond the approval expiry date, a progress report must be submitted to the Research Office on the appropriate form 2 - 3 months before the expiry date. A close-out report to be submitted when study is finished.

All research conducted during the COVID-19 period must adhere to the national and UKZN guidelines.

HSSREC is registered with the South African National Research Ethics Council (REC-040414-040).

Yours sincerely,

[redacted]

Professor Dipane Hlalele (Chair)

/dd

Humanities & Social Sciences Research Ethics Committee
UKZN Research Ethics Office Westville Campus, Govan Mbeki Building
Postal Address: Private Bag X54001, Durban 4000
Tel: +27 31 260 8350 / 4557 / 3587
Website: http://research.ukzn.ac.za/Research-Ethics/

Appendix B: Informed Consent: Principal

June 2020
School of Education, College of Humanities,
University of KwaZulu-Natal,
Edgewood Campus,

Dear Participant

PERMISSION TO CONDUCT RESEARCH (PRINCIPALS)

My name is Siobhan Hopkins. I am a Master's candidate studying at the University of KwaZulu-Natal, Edgewood campus, South Africa. My study is titled:

Exploring the effectiveness of parent-engagement in the teaching of Foundation Phase Geometry

I would appreciate it if you could read this document and sign the declaration below and email is to me at hops@iuncapped.co.za as an attachment.

The research aims:

1) To explore how learners in the foundation phase are normally taught space and shape schools.
2) To explore the effectiveness of parental-engagement in the teaching of foundation phase geometry
3) The explore the views of parents in assisting in learning of space and shape.

To gather the information, I am interested in asking you some questions to educators in your school and asking parents to be involved in helping their child learn about space and shape. Educators will not be involved in the research process as such, but we are interested in their opinion of the materials and the methods that schools are using and how effective they think they are. Parents and their children will be directly involved in the study.

Please note that:

- The confidentiality of you, the educators, parents and students is guaranteed as your inputs will not be attributed to you in person, but reported only as a population member opinion.
- The interviews with parents may last for about 45 minutes to 1 hour.
- Any information given by educators/ parents cannot be used against them, and the collected data will be used for purposes of this research only.
- Data will be stored in secure storage and destroyed after 5 years.
- Educators, parents and students have a choice to participate, not participate or voluntarily withdraw from the research. They will not be penalized for taking such an action.
- Their involvement is purely for academic purposes only, and there are no financial benefits involved.

I can be contacted at:
Email: hops@iuncapped.co.za
Cell: 083 636 1113

My supervisor is Prof Vimolan Mudaly who is located at the School of Education, Edgewood campus of the University of KwaZulu-Natal.

Contact details:
Email: mudalyv@ukzn.ac.za
Phone number: 082 977 0577

You may also contact the Research Office through:
HSSREC Research Office
Tel: 031 260 3587
Email: hssrec@ukzn.ac.za

Thank you for your contribution to this research.

Yours sincerely
[redacted]
Mrs SK Hopkins
(Researcher)

DECLARATION

I………………………………………………………………………… (full names of principal) hereby confirm that I understand the contents of this document and the nature of the research project, and I consent to allowing educators, parents and pupils at my school to participate in the research project.

I understand that I am at liberty to withdraw them from the project at any time, should I so desire.

School Stamp

SIGNATURE OF PRINCIPAL **DATE**

……………………………………… …………………

Appendix C: Informed consent: Educators

29 August 2020

School of Education, College of Humanities, University of KwaZulu-Natal,

Edgewood Campus,

UNIVERSITY OF KWAZULU-NATAL

INYUVESI YAKWAZULU-NATALI

Dear Participant

INFORMED CONSENT LETTER FOR EDUCATORS

My name is Siobhan Hopkins. I am a master's candidate studying at the University of KwaZulu-Natal, Edgewood campus, South Africa. My study is titled:

Exploring the effectiveness of parent-engagement in the teaching of Foundation Phase Geometry

To gather the information, I am interested in asking you some questions. As the title suggests, it is the parents that are involved in the study, so as an educator, you will therefore not be involved in the research process as such, but we are interested in your opinion of the materials and the methods that schools are using and how effective you think they are.

Please note that:

- Your confidentiality is guaranteed as your inputs will not be attributed to you in person but reported only as a population member opinion.
- The interview may last for about 45 minutes to 1 hour.
- Any information given by you cannot be used against you, and the collected data will be used for purposes of this research only.
- Data will be stored in secure storage and destroyed after 5 years.
- You have a choice to participate, not participate or voluntarily withdraw from the research. You will not be penalized for taking such an action.
- Your involvement is purely for academic purposes only, and there are no financial benefits involved.
- If you are willing to be interviewed, please indicate (by ticking as applicable) whether or not you are willing to allow the interview to be recorded by the following equipment:

Equipment	**Willing**	**Not willing**
Audio equipment		

I can be contacted at:
Email: hops@iuncapped.co.za
Cell: 083 636 1113

My supervisor is Prof Vimolan Mudaly who is located at the School of Education, Edgewood campus of the University of KwaZulu-Natal.
Contact details:
Email: mudalyv@ukzn.ac.za
Phone number: 082 977 0577

For any questions or concerns about the rights of your child as a participant, then you may contact the Humanities & Social Sciences Research Ethics Administration Research Office, Westville Campus, Govan Mbeki Building Private Bag X 54001 Durban, 4000; KwaZulu-Natal, SOUTH AFRICA Tel: 27 31 2604557 -Fax: 27 31 2604609. Email: HSSREC@ukzn.ac.za

Thank you for your contribution to this research.

Yours sincerely
[redacted]
Mrs SK Hopkins
(Researcher)
DECLARATION

I………………………………………………………………………… (full names of participant) hereby confirm that I understand the contents of this document and the nature of the research project, and I consent to participating in the research project.

I understand that I am at liberty to withdraw from the project at any time, should I so desire.

SIGNATURE OF PARTICIPANT DATE

……………………………………… …………………………..

Appendix D: Informed consent: Parents

UNIVERSITY OF KWAZULU-NATAL

INYUVESI YAKWAZULU-NATALI

Dear Parent/ Guardian

REQUESTING INFORMED CONSENT FOR YOUR CHILD'S PARTICIPATION

My name is Siobhan Hopkins and I am a student at the University of KwaZulu-Natal. In fulfillment of the Master's degree qualification I am required to conduct research that will require learners and teachers. The research is titled:

Exploring the effectiveness of parent-engagement in the teaching of Foundation Phase Geometry

The purpose of the study is to explore:

4) To explore how learners in the foundation phase are normally taught space and shape schools.
5) To explore the effectiveness of parental-engagement in the teaching of foundation phase space and shape.
6) The explore the views of parents in assisting in learning of space and shape.

I request permission to include your son/daughter in this study. S/he will be involved in a pre and post-test to ascertain understanding of space and shape that will take about half an hour. They will also need to be engaged in about half an hour of geometry activities a day for one to two weeks. Due to COVID and the necessity to further analyse data, the activities will need to be video recorded. The study will be scheduled at the most convenient time to you and will not disturb normal learning time.

Please note:

- The information will be used for scholarly research only.
- There will be no financial benefits for participants in this study.
- Your child's participation is entirely voluntary. They have a choice to participate, not to participate or to withdraw from participating in the research and will not be penalized for taking such an action.

- The identity of the school and your child's identity will remain strictly anonymous as pseudonyms will be used, and all the responses will be treated with confidentiality.
- The recordings as well as other items associated with the group discussion will be held in a password-protected file accessible only to me and my supervisors. After a period of 5 years, in line with the rules of the university, it will be disposed by shredding and burning.
- Should you agree, please sign the declaration attached to this letter.

For further questions/concerns or queries related to the study contact the researcher at:
Cellphone: 083 636 1113
e-mail: hops@iuncapped.co.za
or my supervisor is Prof Vimolan Mudaly. Contact details:
Cellphone: 082 977 2577
E-mail:mudalyv@oukz.ac.za
For any questions or concerns about the rights of your child as a participant, then you may contact the Humanities & Social Sciences Research Ethics Administration Research Office, Westville Campus, Govan Mbeki Building Private Bag X 54001 Durban, 4000; KwaZulu-Natal, SOUTH AFRICA Tel: 27 31 2604557 -Fax: 27 31 2604609. Email: HSSREC@ukzn.ac.za

DECLARATION

I hereby confirm that I have been informed about the nature, purpose and procedures for the study**: Exploring the effectiveness of parent-engagement in the teaching of Foundation Phase Geometry**

I have also received, read and understood the written information about the study. I understand everything that has been explained to me and I consent that my child may participate in this study.

Thank you

SIGNATURE OF PARTICIPANT DATE

_______________ _______________

INQUBOMGOMO YESIVUMELWANO SEMVUMO YOKUBAMBA IQHAZA KOMFUNDI KUCWANINGO

Mzali

ISICELO SEMVUMO SOKUBA UNMTWANA WAKHO ABAMBE IQHAZA KULOLUCWANINGO

Igama lami ngingu Sindisiwe Lungelo Xulu (210527012). Ngingumfundi owenza iMasters eNyuvesi yaKwazulu-Natali, Edgewood Campus, ese Pinetown. Ngenza ucwaningo olugxile ekubukeni izingqinamba ezibhekene nabafundi abahlala ezindaweni ezingakathuthuki ngokuphelele. Inhloso yalolucwaningo ukubheka izindlela ezingatholakala ezingaba usizo kubafundi ukuze bahlale besesikoleni bangavinjezelwa izinkinga ababhekananazo. Ngingathanda ukucela imvume yokuba umntwana wakho abe ingxenye yalolucwaningo. Ukuzibandakanye kwakhe kulolu cwaningo angeke kuphazamisane nezifundo zakhe.

- Sicela uqaphele ukuthi: Ulwazi azosinikeza lona luzosentshenziselwa lolucwaningo kuphela.
- Imibono yomntwana wakho kulenhlolombono izovezwa ngokufihlekeleyo negama lakhe ngeke lidalulwe.

- Ingxoxo izothatha isikhathi esingaba ihora.

Uma unemibuzo ephathelene nokuthile ungaxhumana name ku-072 1983 427 nomaku email ethi luhxulu1@gmail.com

Ungathinta nomphathi wami u Dokotela Ncamisile Mthiyane utholakala eEducational Psychology Department, CF132 Main Tutorial Building, University of KwaZulu –Natal, Edgewood Campus, Corner of Marianhill and Richmond Roads, Pinetown. Inombolo yocingo: +27 (0)312603424, E-mail: mthiyanen1@ukzn.ac.za

Ungaxhumana nehhovisi lase nyuvesi lakwa Humanities & Social Sciences Research Ethics Administration Research Office, Westville Campus, Govan Mbeki Building Private Bag X 54001 Durban, 4000; KwaZulu-Natal, SOUTH AFRICA inombolo yocingo: +27 (0)31 2604557; iEmail: HSSREC@ukzn.ac.za

Ngiyabonga ngegalelo lakho kulolucwaningo

IMVUME ESHICILELWE

Mina____ ngiyaqinekisa ukuthi ngiyaqonda okubhalwe kulomshiqilo nokungesimo salolucwaningo futhi ngiyavuma ukuba umntwana wami athathe iqhaza kulolucwaningo.

Ngiyaqonda ukhululekile ukuphuma kulo nanoma inini, uma efuna. Mina ngiyaqonda inhloso yocwaningo. Ngiyavuma ukuthatha iqhaza.

Ukusayina komzali_________________

Usuku____________

Appendix E: Learner Assent Form

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

LEARNER ASSENT FORM
(Child participant)

Project Title:

Exploring the effectiveness of parent-engagement in the teaching of Foundation Phase Geometry

Researcher's name: Siobhan Hopkins

I am Mrs. S. Hopkins from the University of Kwa-Zulu Natal. I am doing a study to figure out how children learn about space and shape and we will be doing some activities with your families to see if it helps you learn about shape and space. We are asking you to take part in the research study because one of your parents volunteered for your family to be part of this study.

For this research, you will do a little activity to see what you know about space and shape already. It isn't for marks and you can stop at any time if you feel uncomfortable. Your parent or guardian will help you if there is anything you don't understand. We will keep all your answers private, and will not show them to your teacher.

After that, you will spend a little bit of time (about half an hour a day for 5-6 days) doing some activities with your parent or guardian to help you learn more about shapes and space. You can ask questions at any time and if you are feeling uncomfortable, you can stop. You are not going to be forced to do anything that you don’t feel comfortable doing.

One of your parents or siblings will record you while you are doing activities. These videos will not be shared with anyone without your permission.

These activities won’t hurt you in any way and shouldn’t be uncomfortable in any way.

Hopefully, after these activities, you will know more about space and shape which is a very important part of mathematics. You will also be doing us a big favour by helping us learn more about how we can teach space and shape so you and other children will really understand.

You should know that:

- You do not have to be in this study if you do not want to. You won’t get into any trouble with your parents, your teacher or your school if you say no.
- You may stop being in the study at any time. (If there is a question you don’t want to answer, just leave it blank.)
- Your parent(s)/guardian(s) were asked if it is OK for you to be in this study. Even if they say it’s OK, it is still your choice whether or not to take part.
- You can ask any questions you have, now or later. If you think of a question later, you or your parents can contact me at 0836361113

Name of participant: ……………………………………………………………………

1. Has the researcher explained what s/he will be doing and wants you to do?

YES	NO

2. Has the researcher explained why s/he wants you to take part?

YES	NO

3. Do you understand what the researcher wants you to do?

YES	NO

4. Do you think anything bad can happen to you during the research?

YES	NO

5. Do you know that your name and what you say will be kept a secret from other people?

YES	NO

6. Did you feel you need to ask the researcher any questions about the research?

YES	NO

7. Has the researcher answered all your questions?

YES	NO

8. Do you understand that you can refuse to take part if you do not want to take part and that nothing will happen to you if you refuse?

YES NO

9. Do you understand that you may come out of the study at any time if you no longer want to continue?

YES NO

10. Do you know who to talk to if you are worried or have any other questions to ask?

YES NO

11. Has anyone forced or put pressure on you to take part in this research?

YES NO

12. Are you willing or happy to take part in the research?

YES NO

13. Are you willing to allow the activities to be recorded?

YES NO

____________________________ ________________________

Signature of Child **Date**

Appendix F: Interview Schedule for Educators

1) *How long have you been teaching grade R/1/2/3?*
2) *What are your feelings towards teaching mathematics?*
3) *What training have you had in teaching mathematics?*
4) *What do you understand about spatial development?*
5) *Did you enjoy geometry in high school?*
6) *Which do you think are the most important years in geometric development in a child?*
7) *How do you teach the concepts of space and shape to your students?*
8) *What resources do you have and use to teach space and shape?*
9) *How often do students use these resources?*
10) *How much of the time that they are using these resources are they assisted by an adult? How does the adult assist?*
11) *How do you assess spatial development?*
12) *How do you think the students feel about learning space and shape and how are they doing compared to other areas in mathematics?*
13) *How has the department of education helped you to teach this section better?*
14) *In speaking to other teachers in the foundation phase, how do you think they feel about teaching mathematics compared to other areas in the curriculum?*
15) *Do you ever send activities related to space and shape (0r other areas of mathematics) home to parents? Why or why not?*
16) *Any other comments?*

Appendix G: Pre and Post assessment for learners

Pre- Assessment Sheet: For child to do (with assistance)

Age: Years: _______ Months: _______________

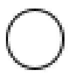
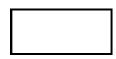
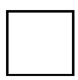
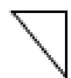
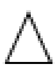
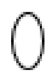
Date: ___________________ Time: _______________

Gender: ___________________

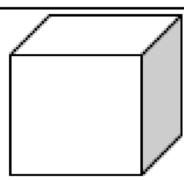
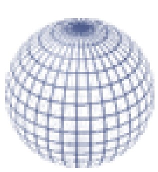
Who is administering assessment: _____________________ (relation to child)

School: ____

1) Ask your child about the following 2D shapes:
   a) parents tick if names correctly identified
   b) ask how many sides (place eg 4S if 4 sides)
   c) ask how many angles (place eg 3A if 3 angles)

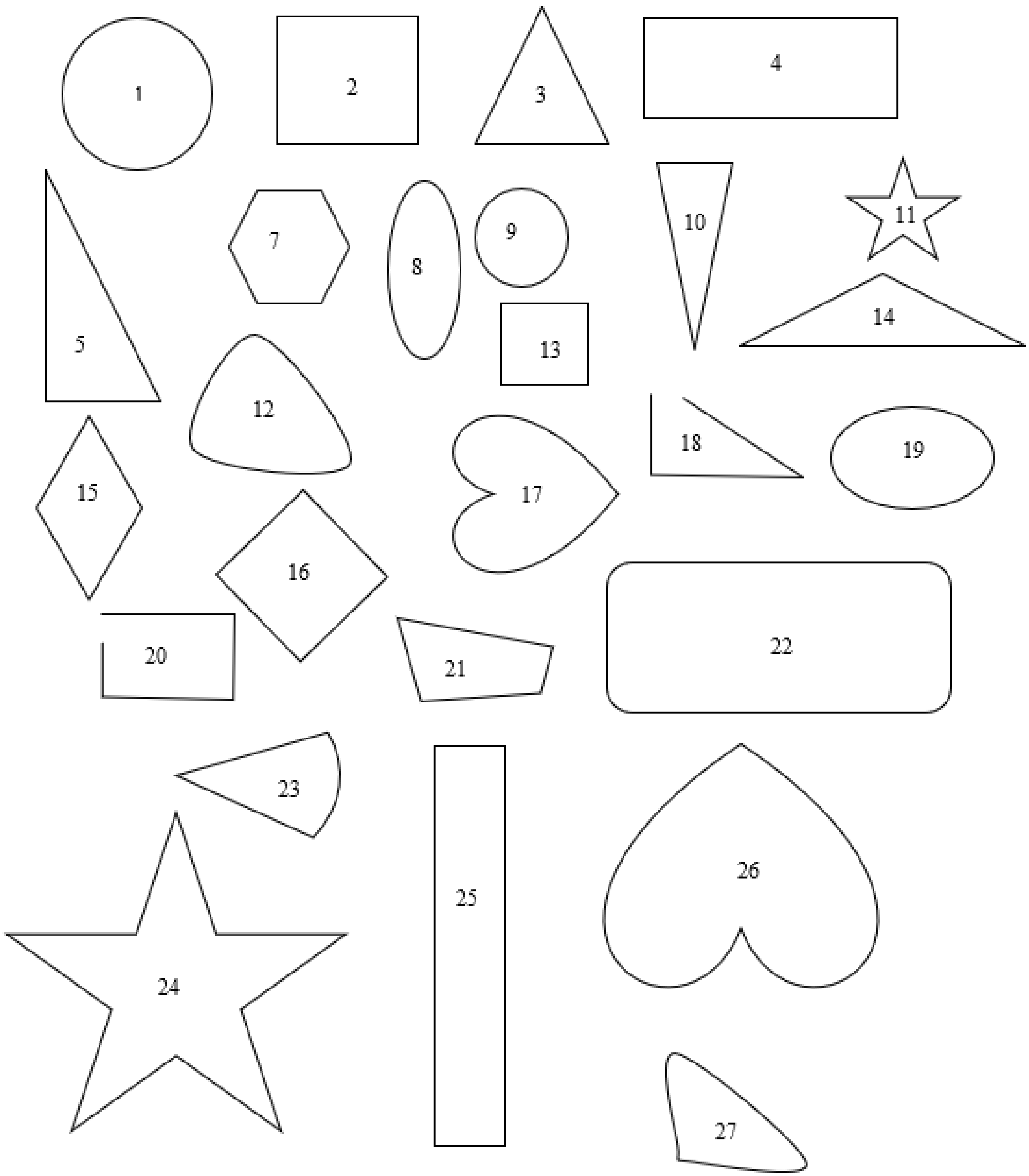
	
	
	

2) Ask your child about the following 3D shapes:
   a) parents tick if names correctly identified
   b) ask if the shape can slide (put a "S" next to the ones that are identified as being able to slide)
   c) ask your child if the shape can roll (put a "R" next to the ones that are identified as being able to roll) [you can have slide and roll with a shape]

3) Draw a big red circle in the middle of the page. Draw a blue triangle on top of the red circle. Draw a green square next to the red circle. Draw a green rectangle inside the red circle.

4) **Put a blue dot on all the triangles. Put a red cross on all the rectangles.**



Post- Assessment Sheet: For child to do (with assistance)

Age: Years:________ Months: ________________

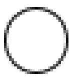
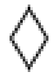
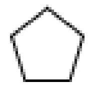
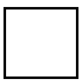
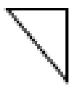
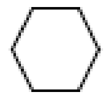
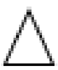
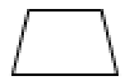
Date: ____________________ Time: ________________

Gender: ____________________

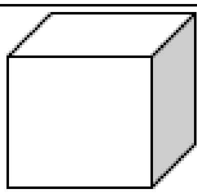
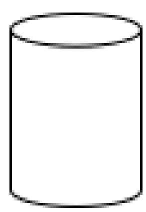
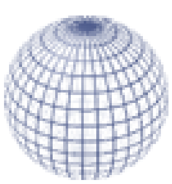
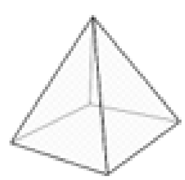
Who is administering assessment: ______________________ (relation to child)

School: ____

5) Ask your child about the following 2D shapes:
   a) parents tick if names correctly identified
   b) ask how many sides (place eg 4S if 4 sides)
   c) ask how many angles (place eg 3A if 3 angles)

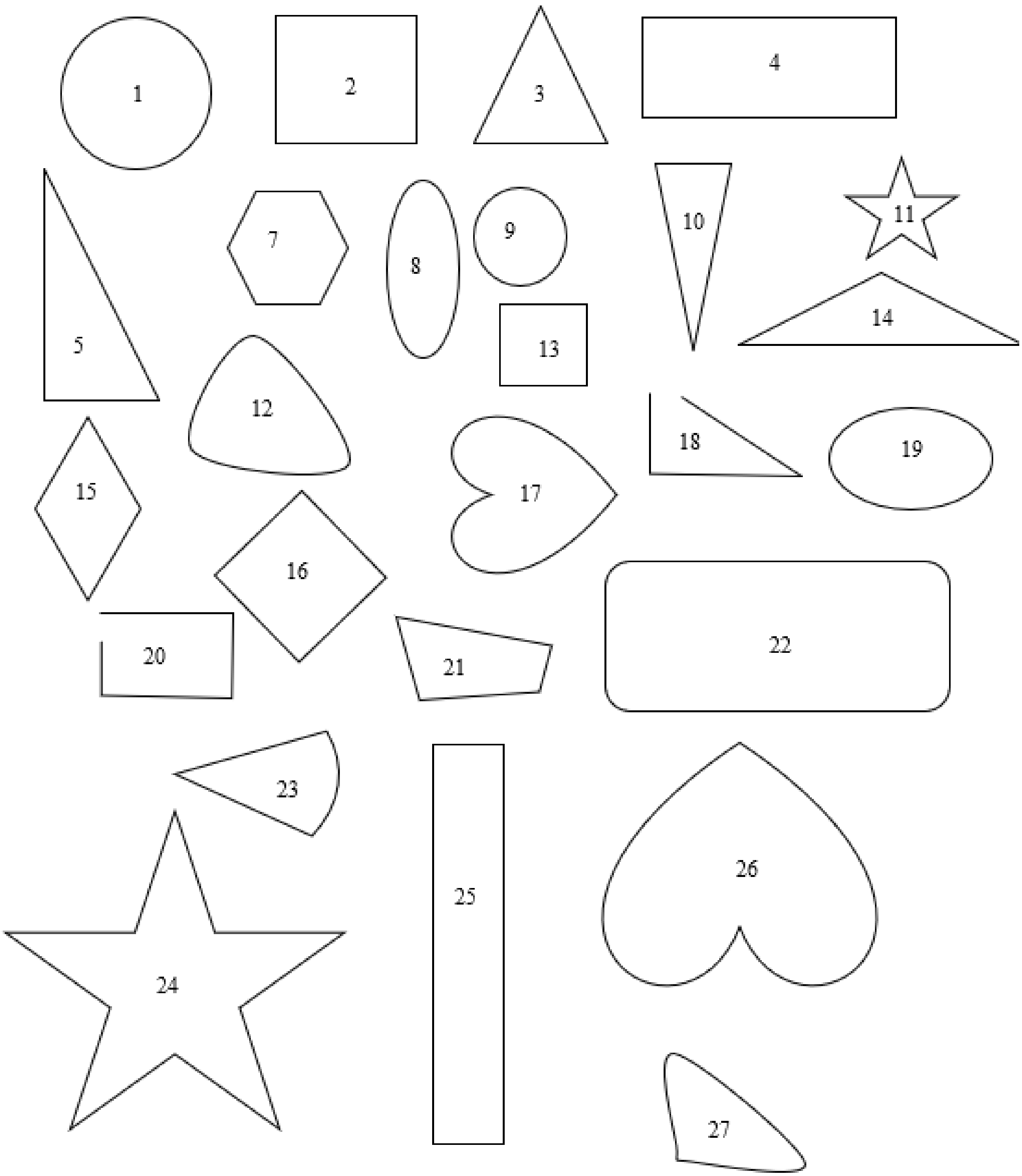
			
			
			

6) Ask your child about the following 3D shapes:
   a) parents tick if names correctly identified
   b) ask if the shape can slide (put a "S" next to the ones that are identified as being able to slide)
   c) ask your child if the shape can roll (put a "R" next to the ones that are identified as being able to roll) [you can have slide and roll with a shape]

7) Draw 3 circles next to each other at the bottom of the page. Make the left one small, the middle one bigger and the right one the biggest. Draw a long blue rectangle above all three circles. Draw a green square on top of the rectangle. Place a red heart inside the square.

8) Put a blue dot on all the triangles. Put a red cross on all the rectangles.



Appendix H: Parent Questionnaire

Questionaire with Parents after Research is complete:

1) *Name of school:* ____

2) *Age of child:* ____

3) *Gender of child:* ____

4) *Job of father:* ____

5) *Job of mother:* ____

6) *Normally, how many minutes a day did you spend helping your child with maths? (Circle the most appropriate answer)*

   0-15 *16-30* *31-45* *46-60* *>60*

7) *How did you feel about the opportunity of helping your child with these important aspects of mathematics before you started?*

____

____

____

8) *How do you feel the activities went?*

____

____

____

9) *Do you think your child benefitted and grew in their understanding of space and shape?*

____

____

____

10) *Were the instructions clear enough? Comment if necessary.*

____

____

____

11) *Which activities (eg Day 3:task 1) do you think worked well or didn't work well and why?*

____

____

____

12) *If there were more of these activities designed specifically to make your child better at mathematics, (perhaps in different areas of mathematics) would you want to do them? Explain.*

____

____

____

13) *If it wasn't lockdown, would you consider doing activities such as these with your child?*

Yes *No*

*Reason:*____

____

____

14) *Do you think that all parents in your child's class would be able to help their child with activities such as these? Please comment:*

____

____

____

15) *Do you think that schools should be encouraging parents to be part of the process of giving children more one-on-one time in mathematics? Please comment:*

____

____

____

Appendix I: Powerpoint notes for parents

Introduction

- In this day and age, mathematics is more important than ever as it opens the doors to so many careers.
- Research has shown that the early years are critical in maths development.
- It is not so much age (so don't panic about lockdown), but just that a strong foundation is laid.
- Spatial development is a very important (and sometimes neglected) part of maths but will eventually make up about 30% of their final matric maths paper.
- Parents can play an important role in helping your child's maths development.
- The good news is that spatial development is fun and can be used to show that both you and your child can feel comfortable and enjoy doing maths.
- Here are some activities which lay down some fundamental concepts in spatial development...ENJOY!

Note

- Some days have tasks that may take more than half an hour. Please don't go over 40 mins.
- Either
  - select some activities and leave others out
  - take a few extra days to get through them.
  - have a morning and afternoon session

REMEMBER:
Be patient and
encourage lots!!!

Day 1:

2D Shape Recognition

Day 1: Task 1 (5 mins)

Day 1 Resources:
- Big shapes
- Small shapes
- Pillowcase
- 3-page shape recogniser

Use big shapes made from cardboard, to introduce shapes to your child. Start with just basics (circle, square, triangle, rectangle). You can introduce others if your child is finding it easy (heart, star, pentagon, hexagon, trapezium, diamond)
- Let them hold one up at a time.
- Count edges, corners, feel flatness, turn it, compare shapes.
- NOTE: A circle has 0 sides, because sides must be straight and not arced.
- They show you: Hold up each shape and tell adult about shape.

Day 1: Task 2 (10 mins):

Task 2: Place the shapes into a pillowcase.
- Get your child to close their eyes and place both hands into the pillowcase and grab a shape.
- Ask your child to guess what shape they have found. Before they pull the shape out, ask:
    - Why they think it is that shape?
    - How many edges and sides does it have?
    - Are the corners right angles (like an "L")
- You can take turns if you want.

Day 1 Task 3: (15 mins)

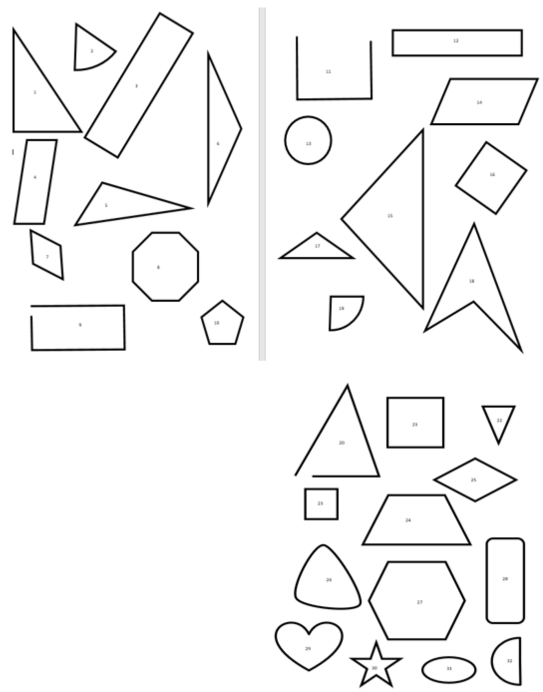
"Is it or is it not…" (sheets in the resource pack)
The aim of this is to nail down some of the detail.
Use a pencil to point to a shape and say "is it or is it not a …triangle/square etc". Alternatively , if you have a little whiteboard, you can draw a shape . You don't have to get through all of them, but the yellow are NB misconceptions.

Triangles: 1, 5, 6, 15, 17 & 22 are triangles
- 2 – no because 1 side isn't straight
- 20- no because the one angle isn't closed
- 26 – no because no angles, sides not straight

Rectangles: 3, 12 are typical rectangles
- 16, 21, 23 are squares – a special type of rectangle (rectangles only need to have all right angles and opposite sides must be the same length)
- 4, 14 - no because angles aren't right angles
- 9, 11- no because angles aren't closed
- 28 – no because corners are rounded not pointy

Other shapes: (only do if your child finds this easy)
- Diamond/ rhombus (7; 23) Pentagon (10); Octagon (8), Trapezium (24); circle (13), heart (29), star (30), oval (31), semi-circle (32)

You can let them have a turn to ask you as well, get some wrong and see if they correct you.



Where possible, try and do maths in nature. Not only is nature full of shapes but being outside has so many other benefits to children.

Day 2:

Extending shape knowledge to real world

Day 2: Task 1 (10 mins)

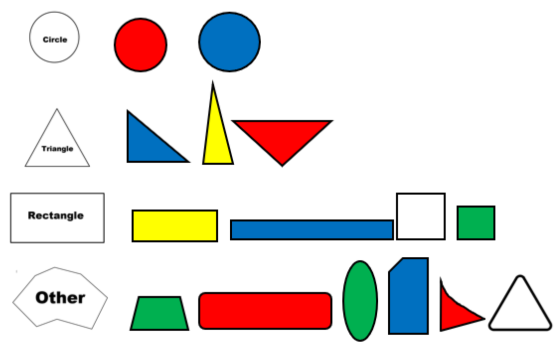
Treasure Hunt

- In the bag are a few shapes. Hide them around your house (don't forget where you put them ☺).
- Use orientation words (above, below, next to, over, under, between, behind, in, around, through forwards, backwards etc) to help your child find the shapes.

- Get them to lay the shapes in lines as shown on the right, Use the big shapes as "headings" (like graphs).
- Ask them if all the triangles look the same?
  - If not, how are they different? (size, shape, colour)
  - In what way are they all the same (3 sides, 3 angles)
  - So what makes them a triangle?
  - If I turn it, is it still a triangle? Why?
- You can do this with other shapes too if children are more advanced
- NB: discuss rectangle vs square
  - Rectangle (opposite side same length and all right angles). Are all squares rectangles? ...yes
  - Square (all sides the same length & all right angles). Are all rectangles squares?..... no

Day 2 Resources:

- Variaty of shapes
- Big shapes from day 1



Day 2: Task 2 (10 mins)

Task 2: Walk around your home/ garden and see if you can see any shapes that are "like" the ones that you have in your box.

- They can take pics (with cell phone) of shapes independently and then come back and show you.
- Or they can walk around with you and point to them.
- Or they can find things and make a shapes graph by laying them in lines next to the shape (illustrated alongside).

Some ideas: Legos, CD's, plates, plugs, car lights, clocks, books

Encourage words and sentences like the swing beneath the tree had a tyre like a circle.
NB: try to correct details e.g. pizza = triangle… but why not a triangle? (triangles must have ALL straight edges)

Day 2: Task 3 (5 mins)

- Now play "Simon says" with your child use orientation words,
- EG Simon says
  - Climb on the chair
  - Put your ball next to the chair
  - Place a triangle on your head
  - Walk around the chair
  - Wave forward 3 steps
  - Hop backwards 4 steps
  - Jump left and right 5 times

  (remember it you tell them to do something without saying "Simon says" first, they mustn't do it. If they do then swap turns/ tickle them etc

Don’t forget to hand out lots of high fives… and one to you too for making the effort to grow your child.

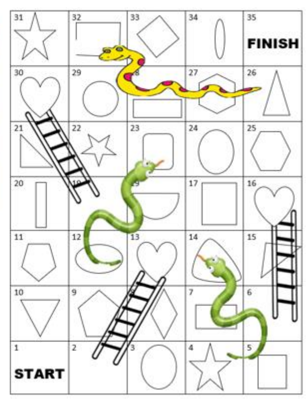
Day 3:

Constructing shapes from parts

Day 3: Task 1 (15 mins)

Day 3 Resources:
Cut-out template for dice
Scissors
Glue
About 20 pencil/straws etc
Snakes and ladders game
Day 3 shapes

- Take the cutout sheet for the dice. Let your child colour in the shapes different colours. Ask which shapes are which colours, name shape etc
- Help child cut out the dice template:
- Fold and glue
- Take the snakes and ladders game out and play.
- When you roll the dice, you move as many places as your shape has sides. (Remember: circle had 0 sides)
- See who can get to the finish first (involve siblings- they will love playing with the dice they made themselves).
- Encourage use of words.
    - What shape is that?
    - How many sides does it have?
    - Where have we seen these shapes in our house or garden?



Day 3: Task 2 (do as alternative if your child is more advanced)

- Use straws/ blunted skewer sticks or slithers of cardboard or old pencil crayons to make a number of straight "lines" of different lengths
- Make a shape and say: can you make a triangle like my triangle
- Then name the shape and ask them to make it
  - Square/ rectangle/triangle with 2 long sides and one short side etc.
- For more advanced children:
  - Make harder shapes
  - Ask them to use a separate pencil (or whatever you're using) and show you where you would put it to cut the shape in half exactly. This is the line of symmetry. There may be a few.
  - Or where would you put a pencil to make a square into 2 triangle or 2 rectangles




Day 3: Task 3 (15 mins)

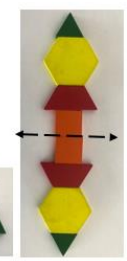
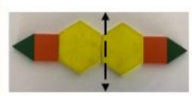
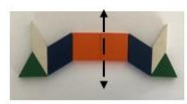
Now use the shapes to play games (these can be made from coloured cardboard or use from resource pack).

- **Show and hide**: Start with 2 pieces and place them in some way. Show your child what you have done and then cover it and get them to copy it. Reveal. If not quite right, discuss orientation etc. so they can get it right.
- **Mystery shape** – I am building something. Listen carefully and see if you can make my shape and guess what it is. (hide what you are doing).
- **Mirror the pattern** – can you copy the pattern on the opposite side so it is the same mirror image (you do half and get them; to do the other side).
- **Complete the pattern**: If I had more shapes, describe what the next 2 shapes in the pattern would be.

(all of these can be made easier or harder according to your child's ability. All of these can be extended to 3D as well)

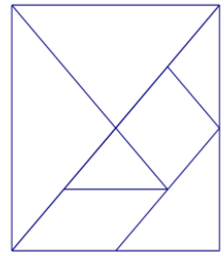


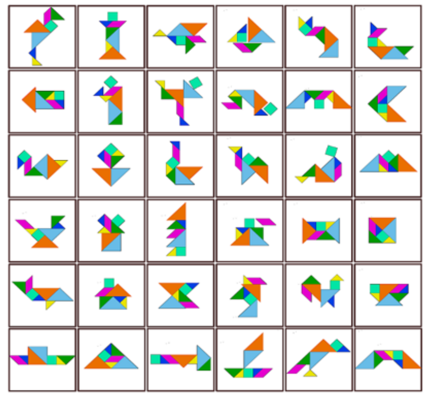



• Optional:

If your child is good at this, allow them to play with tangrams. In the “printables” is a template that can be cut out onto cardboard. There is a sample of lots of different images they can construct from shapes. They can do this on their own.





Day 4:

Block Play: 3D Shape Development

Day 4: Task 1 (15 mins)

Day 4 Resources:
Blocks
Hoops/ rope/cord
Pillow case

Supervised block play: If you don't have blocks, used recycled material and common objects at home (Tupperware, cereal boxes, tins, scrap wood or lego).

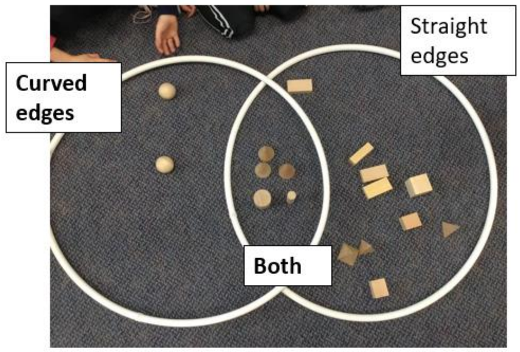
- Instruct children to build a tower as tall as they can to rescue the princess.
- While building, use words to encourage spatial understanding. For example, put the square block on top of the rectangular block.
- Encourage problem solving. E.g., what if I put this long block on top of the square block?
- Count how many blocks are in your tower.
- What shapes do you have in your tower?
- Can you make a pattern when you make your tower?
- Perspective – where do I have to stand to make the tower look wider/narrower?
- Whose tower is the tallest /shortest /widest?
- How will we see whose tower is the strongest?
- Can you make a tower with exactly 10 blocks?

Day 4: Task 2 (5 mins)

Carefully select a few blocks/objects that you know will work well (see examples below).

- Explain what a cube is (3D) and compare it to a square (2D). How are they different/same?
- Explain what a sphere is (3D) and compare to a circle (2D). How are they different/same?

- Can you separate blocks into those that can have straight edges/curved edges/both, using hoola hoops venn diagrams. You can use household items as well.

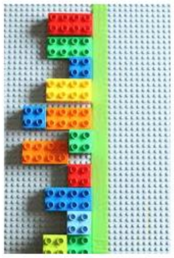


Day 4: Task 3: (10 mins)

Block copy and memory games.

- Make a shape or pattern out of firstly just 2 blocks (Lego works really well) Ask you child if they can make the same pattern as you. You can expand on this by:
- Making them harder by adding more blocks.
- Making blocks in different planes.
- Make a shape, show your child and then hide it and make them build it, (start easy).
- Put a barrier between you and explain to your child what you are making by giving instructions and see how theirs turns out. Give them a turn to explain one to you too
- Make symmetry patterns that they can finish.
- If you have enough lego of your own, make symmetry patterns they can cope

(You do not need to do all of these. Only do what your child is capable of doing)



REMEMBER: Not everything has to be neat. Mess is OK. Make cleaning up part of the valuable experience.

Day 5:

Things that roll and slide

Day 5: Task 1

Day 5 Resources:
Old clothes
Slide/plank/ tilted table
A few 3D objects
hoops

- Time for some fun!
  - Make sure your child has some slippery shoes and some old clothes on… you too
  - Find a safe place and see if you can teach your kids the difference between slide and roll
  - have feet-sliding competitions on slippery floors
  - Hold their feet and pull them on a smooth floor

  [Let them know they are sliding because one smooth surface (their feet/pants) is moving across another smooth surface (the floor)]
  - Now lie them down and roll them across the carpet/grass

  [Let them know they are rolling because you are moving by turning over. Lots of parts touch the surface as you roll.]
  - Give them a turn to try and slide and roll you too… it might bring in some interesting discussions as to why its harder with a bigger person ☺

  OPTIONS:

  Have some fun making cardboard sleds with boxes and slide them round the garden with a rope (good exercise for dad)
  - Do somersaults down a gentle bank

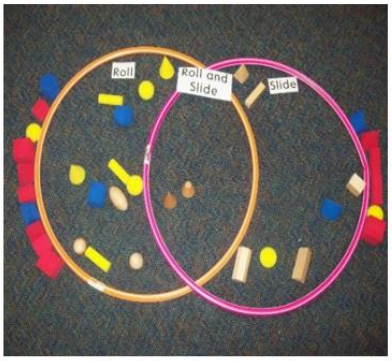
Day 5: Task 2

Carefully select about 5 slide/roll shapes and hide them around the room.

- Use orientation words to help your child find them. Take 5 steps forward/ look under the table/ go backwards and look inside the cupboard etc. Gather blocks centrally.
- Go outside to where there may be a slide or create a slope by tilting a table/plank of wood inside. Demonstrate what role and slide looks like.
- Give your child an object and let them go to the slide and call from the top what they think it will do… and then let it go.
- Reward them if they get it right. Chat about ideas if they get it wrong.

Day 5: Task 3

- Take roll/slide objects inside and place hoola hoops on the carpet with categories: Roll / slide/ both as illustrated.
- Get your child to decide where their object should go. Use some objects around the house as well.



References

- Clements, D. H., & Sarama, J. (2013). Building Blocks, Volumes 1 and 2. Columbus, OH: McGraw-Hill Education.

- Clements, D. H., & Sarama, J. (2020). Learning and teaching with learning trajectories ([LT]2). Retrieved from Marsico Institute, Morgridge College of Education, University of Denver website: www.learningtrajectories.org

Appendix J: Language Editing

To whom it may concern

This is to confirm that the master's thesis submitted by
Siobhan Hopkins
has been language edited.

TOPIC: Exploring the effectiveness of parent engagement in the teaching of Foundation Phase geometry

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Appendix K: Turnitin Report

Exploring the effectiveness of parent engagement in the teaching of Foundation Phase Geometry

ORIGINALITY REPORT

10%	9%	3%	3%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

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