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Giving feedback in investigative tasks in grade 10.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Assessment in South Africa has taken a different turn when compared to the manner in which it used to be carried out before the introduction of the new curriculum. Aldous (2004:72) alludes to this fact when he points out that "assessment requirements in C2005 are revolutionary in nature". He continues to state that teachers who were used to the traditional way of teaching would encounter many challenges with new assessment practices. The main change being the use of continuous formative assessment. The Department of Education (DoE) (2007:1) argues that continuous assessment should be used to "assess learners' strengths and weaknesses and provide additional support to learners". Black (1998) defines formative assessment as assessment that provides short term feedback that assists the teacher and learners to deal with obstacles that still exist after teaching. It is important that planning for future learning ensures that there is proper grasp of ideas taught earlier. Summative assessment, according to Black (1998), assesses what has been covered in a previous area in a phase, a grade or a term. It gives an overview picture of what a learner can and can't do and can also inform one teacher on the abilities of learners from another teacher. In the old curriculum, learners would be assessed mainly from tests and examinations used only for summative purposes; otherwise they would be assessed formatively using class work, homework and assignments. Since the introduction of the New Curriculum Statements (NCS), learners are assessed using a range of tasks that they need to complete from the beginning of the year, and these are used both formatively and summatively.

In Grade 10 Mathematics in particular, there are two tasks that learners need to complete for continuous assessment (CASS) every term. According to the Assessment Guidelines for Grade 10, in the first term, learners should do an investigation and a test, as forms of assessment. In the second term, they need to do an investigation and an examination. In the third term, they do a project and a test and in the fourth term, another assignment and an examination. In this study I have chosen one of these tasks, an investigation and aim to explore how I give formative feedback to learners on an investigative task.

This study is based on the assumption that giving feedback in investigative tasks requires teachers to have effective conversations that can enable the development of learners' thinking. This assumption comes from a framework of sociocultural theory. Through the lens of this theory, learning takes place in interactive environments where shared ideas and meanings are developed and modified through interaction (Daniels, 2001 and Vygotsky, 1981). In the case where conversations are between the teacher and learners discussing mathematics, they are called math-talk (Hufferd-Ackles, Fuson and Sherin, 2004). It is also assumed that during the math-talk, learners' misconceptions can be elicited. My aim in the study was to develop better skills of developing an investigative task, administering it to learners, giving feedback to them and finding better ways of dealing with the misconceptions that arise during math-talk.

1.2 THE STUDY

This study is an action research study in which I focus on how to give feedback after administering one of the formal assessment tasks, an investigation. My hope is that after completion of the study, ways of giving feedback to learners to enhance my own teaching and their learning will improve. Opie (2004) explains action research as a process that provides a practitioner with ways of understanding a problematic situation. The reason I chose to conduct an action research is the fact that some of my shortcomings were in relation to dealing with giving feedback to learners especially on tasks that were included as part of formative assessment such as projects, investigations and presentations.

In 2007, I had an opportunity to video record a lesson where learners made presentations on an assessment task. When reflecting on the videos, I realized that it was challenging for me to give feedback to the learners when they were presenting. During the presentations, there were a number of misconceptions elicited and it was frustrating not to be able to address them immediately. These forms of assessment were not just a challenge to me. It also came to my attention that other teachers in my school were faced with similar challenges as some would come to me for assistance or they would administer the more familiar tasks first, leaving the unfamiliar ones until late in the year. The situation I found myself in resulted from the new which curriculum required teachers to both give feedback and assess learners for formative and summative purposes. The implication is that the work intended to assist the teacher to identify

learning difficulties, is the same work that will also be used to assist the teacher for promotional purposes. I therefore decided to explore some of the possibilities and constraints in giving feedback to learners. My research was guided by the following questions:-

1. How do Grade 10 learners respond to investigative assessment tasks?
2. What kinds of feedback assist learners in engaging with investigative tasks?
3. How are investigations useful in teaching?

1.3 RATIONALE

It had always been a concern for me when learners fail to grasp mathematical concepts. As I continued studying, my main interest was to learn effective ways of teaching for understanding. Studying about the five strands of mathematical proficiency (Kilpatrick et al., 2001) assisted me to identify more easily, activities that I could use to develop particular strands and the relationships between the strands.

The five strands are:

- *conceptual understanding* - comprehension of mathematical concepts, operations and relations
- *procedural fluency* - skill in carrying out procedures flexibly, accurately, efficiently and appropriately
- *strategic competence* - ability to formulate, represent, and solve mathematical problems
- *adaptive reasoning* - capacity for logical thought, reflection, explanation, and justification
- *productive disposition* - habitual inclination to see mathematics as sensible, useful and worthwhile, coupled with a belief in diligence and one's own efficacy. (Kilpatrick, Swafford, & Findell, 2001:116).

It is often the case that teaching is characterized predominantly by one or two strands, hence it does not achieve mathematical proficiency in its fullness. For example, if a lot of exercises in mathematical problems are given where the teacher gives an example and learners do these exercises to practice what they were told, they may develop procedural fluency to some extent

but fail to develop adaptive reasoning, because they are not required to justify their thinking. In DoE (2003), the stated learning outcomes show that the use of all the five strands are included in what South African learners need to master. For example, there are phrases, such as learners should "work confidently with numbers", "represent a wide range of functions" and "represent geometric figures on a Cartesian co-ordinate system", which would show learners demonstrating procedural fluency. Learning outcomes such as "provide explanations and justifications and attempt to prove conjectures" and "effectively communicate conclusions and predictions that can be made from the analysis of data", would show adaptive reasoning. It is possible that different teaching methods would lead to different attainment of such competencies. Some researchers argue that learner-centred teaching helps with the full range of mathematical proficiency.

Brodie, Lelliott & Davis (2002) state that in learner-centred teaching, teachers use strategies that allow learners to use their prior knowledge to create new meanings. The NCS encourages this way of teaching. For a teacher to use learner-centred teaching, learners need to be free to participate and contribute without fear of ridicule and intolerance. An environment of this nature needs time to be created as this style of teaching is still not commonly used in most classrooms (Slominsky and Brodie, 2001). Learner-centred teaching is more likely to develop mathematical proficiency in learners. For example, when learners understand that it is acceptable to make mistakes so that those mistakes are collectively engaged with for the sake of all learners, more and more learners will be willing to participate and misconceptions that would otherwise not be elicited would be dealt with. Formative assessment and feedback are therefore crucial to learner-centred teaching. As I carried out this study it was important for me to improve in using learner-centred teaching through giving feedback in formative assessment.

As I have already mentioned, some of the new forms of assessment are not that familiar to some teachers and a number of issues arise out of this. First, learners might be given tasks that are not well structured and therefore these tasks may not serve the purposes they are intended to serve. Second, teachers may find themselves administering tasks for the sake of doing so without understanding why. In this study, I focus on investigations as formative assessment: how they are structured and how they may help learners learn better. A definition of investigations will be

given and the investigative task that I gave to the learners during the research will be analyzed to establish whether it qualifies to be an investigation. It will also be important to find if there are any disadvantages when using investigations so that when making a choice to use them, the negative aspects can be limited. I will also analyze the conversations and misconceptions that arise during investigative tasks and will investigate my giving feedback to check whether it benefited the learners. It is very easy for one to simply give learners work to do, mark it and briefly comment on their mistakes and congratulate them on the good work and move on. However, it is something else for teachers to understand reasons why learners think the way they do and incorporate learners' thinking into the lesson, which according to Brodie, Lelliott and Davis (2002), is key to learner-centred teaching.

In understanding learners' thinking, a teacher can recognize misconceptions. Written work does not usually offer the opportunity for the teacher to ask questions where the learners' ideas are not clear enough. But if a teacher engages in ways that learners can verbalize their thinking and clarity can be sought when the need arises, then better understanding about the learners' thinking can be acquired and support can be given to the learner in appropriate ways. Black (1998) mentions the importance of the use of open-ended questions during interactions. He points out that the value of feedback is in the quality of questioning. He argues that questions encourage honest self-expression when learners are assured that their contributions are taken seriously and will be challenged to expand their thinking. Logical thought and reflection by learners is part of one of the strands of proficiency mentioned earlier - adaptive reasoning. Although these thoughts and reflections can be written down, verbalizing ideas in the classroom allow for the development of reasoning skills.

One of the critical outcomes[1] states that learners should be able to "communicate effectively using visual, symbolic and/or language skills in various modes." (DoE, 2007:2). All the four learning outcomes require learners either to describe, interpret or explain certain concepts. This is an indication that learners need to use communication skills in mathematics as evidence of

[1] These are outcomes expected from all learners after finishing their General Education Training (GET) or Further Education Training (FET), and they are inspired by the constitution (DoE, 2007).

their knowledge. All these competencies can be shown in writing but it can be more effective when there are conversations so that through interaction between learners and the teacher, greater acquisition of concepts and skills is gained. It is by using investigations that I hope conversations can be used to assist learners to elicit their ideas, even those that are misconceptions (Smith, Disessa and Roschelle, 1993).

When learners' written work is assessed, incorrect responses may be recognized but it may not be easy to find out whether these are mistakes, errors or misconceptions. How these three concepts differ will be briefly discussed in chapter 2 but the main focus will be on misconceptions. My assumption is that learners' misconceptions can be identified as the teacher interacts with them by probing and asking for deeper meaning rather than making a decision from their written work only. Why is it important that learners' misconceptions are elicited? This question makes misconceptions one of my focal points. Nesher (1987:34) found that learners' mistakes are welcomed but the teacher did not use them as "feedback mechanism for real learning…" It is not only crucial that misconceptions are elicited but that they are dealt with. Effective ways of dealing with misconceptions will be discussed in chapter 2.

The use of appropriate tasks can create a platform for the teacher to best achieve goals in generating a positive environment for learning. Stein et al. (2000) mention different kinds of tasks that can be used to develop different skills in learners. I usually give tasks that are from text books or previous question papers. For tasks such as investigations and projects, there are not as many examples readily available in textbooks. I sometimes have to use my own expertise to develop such tasks and at times I do not feel well equipped to do so. Recognizing this need, I took this study as an opportunity to develop my expertise in developing assessment tasks from a range of resources. Assessment tasks are usually assessed by using a memorandum or rubric. Memorandums are familiar to most teachers while rubrics were not previously used by most teachers. Therefore, teachers have to rely mostly on textbooks or need to design their own. Most importantly, even when appropriate tasks and rubrics have been developed, the teacher is still faced with the challenge of giving feedback in ways that will benefit the learners. This is why I chose to focus on researching my own practice in giving feedback in investigative tasks.

Feedback is important to me mainly because when used effectively, it can benefit learners. When feedback is given, a teacher needs to use the learners' responses to alter their teaching if need be or to assist learners to be more successful in their learning. Breen (2004) makes an important point that if formative assessment provides information that can be used as feedback; then feedback can be used to improve formative assessment. He continues to argue that "dialogue between learners and teachers should be thoughtful, reflective and focused to evoke and explore understanding" (Breen, 2004:2). This means that interaction between teacher and learners is important to give effective feedback.

This research will be useful for me, teachers in my school, and other teachers more generally. First, it will help teachers to understand how investigations can be used to enhance learning and teaching. Understanding ways of giving feedback from the investigations in ways that both learners and teachers can benefit will elaborate this. Second, it is anticipated that while assessing learners, the teacher will come across some misconceptions and errors that learners make. Feedback can include dealing with such misconceptions. Finally, teachers can be assisted to find ways of using conversations during feedback and having interactions that will assist them to teach concepts that arise from the investigations.

1.4 THE REPORT

This report consists of five chapters. In Chapter 1 I have provided the background to the study and conveyed what is to be expected in the study. In chapter 2 I outline my literature review and the framework that underpins the study. Chapter 3 gives an outline of the methodological approach used in this research and the method of data collection used. Chapter 4 discusses the analysis of the data and the results from the analysis are interpreted. The limitations and findings of this research are stated in chapter 5 and a conclusion about the findings is made.

In the next section I will situate my study within a theoretical framework and literature review. First, I will define feedback. Second, I will look into how best I can give feedback and deal with misconceptions that arise from learners' responses. Then I will specifically focus on

investigations, which are relatively unfamiliar to me and suggest how I might find ways in which they can be used to enhance my teaching and how I can use them to assist learners in their learning. It will be important to also focus on conversations that take place between the learners and me.

CHAPTER 2

LITERATURE REVIEW AND THEORETICAL FRAMEWORK

2.1 INTRODUCTION

In this chapter I will focus on the literature that I used and the theoretical framework through which the research was guided. This study focused on giving feedback in investigative tasks and as the study progressed, it became clear that conversations arose as I gave feedback and in these conversations, there were misconceptions that were elicited. I found it reasonable therefore to discuss these areas: investigations, giving feedback, conversations and misconceptions. Vygosky's sociocultural theory frames my study because ideas on mediation, scaffolding and the zone of proximal development are important in giving feedback.

2.2 INVESTIGATIONS AS FORMATIVE ASSESSMENT

The importance of investigations is highlighted by a number of researchers (Bird, 1988; Ernest in Costello, 1991; Haggarty, 2002; Laridon, Barnes, Jawurek, Kitto, Myburgh, Pike, Scheiber, Sigabi and Wilson, 2005). Investigations are said to encourage learners to inquire or search for patterns, make conjectures and be able to engage in mathematical reasoning (Bird, 1988). It is valuable that the curriculum designed in South Africa encapsulates the use of investigations as a formative assessment because then teachers are more likely to use this much desired approach to mathematics. Since this study focuses on investigations, it is important to define what they are and their role in the learning of mathematics.

According to Costello (1991), investigations refer to a range of open activities where strategies of working are not prescribed. An investigation "invites students to formulate questions and to look for explanations" (Haggarty, 2002). Laridon et al. (2005) describe investigations as authentic tasks that involve mathematical processes such as:

> "*systematic exploration, identification of patterns, relationships, systematic recording of data generated, taking a leap towards a solution by a suitable guess, formulation of conjectures, verification of conjectures, posing problems, asking questions which progress the investigation, use of special cases, use of counter examples, development of suitable notations, use of suitable language and listening to peers and adjusting ideas accordingly*".

Laridon et al. (2005) describe authentic tasks as those that use mathematics in tasks related to real-life situations. Brown, Collins and Duguid (1989:212) define authentic activity as "ordinary practices of the culture", i.e. authentic tasks are those that involve authentic mathematical processes such as those quoted on the previous page. For them, authentic tasks can be purely mathematical. Haggarty (2002) describes three types of investigations and some are authentic in terms of Laridon et al since they relate to real life while the other type is authentic to mathematics as Brown et al explain. I used Brown, Collins and Duguid's notion of authentic to the culture of mathematics for the task in this research. As will be shown in chapter three, the investigations that I will use in this research will be purely mathematical.

Pirie (1987) suggests a few things which an investigation is not: it is not an activity where learners are to use a prescribed route to a specific answer or a task where learners repeatedly practice a skill. The main aim as he states, is for learners to explore, and this process of exploration is the one that matters most. Characteristics of an investigation can be identified by asking the following questions (Costello, 1991:84):

- *Is it easy to start playing with the situation?*
- *Does it leave scope for the invention of individual strategies?*
- *Is there a specific answer to the problem as worded- or a generalisable answer?*
- *Does the problem suggest other related questions?*

These questions can assist educators when designing investigative tasks. An important aspect is that investigations can be used as "vehicles" for learning Mason , J. (1978). In this way they are used formatively and they become useful for teachers to evaluate their own teaching as well as

promoting the development of mathematical processes of learners (Jaworski, 1994). In cases where investigations were used for examination purposes, it was found that they were more "stereotyped" and sometimes teachers administered them for the sake of doing them (Jaworski, 1994). In my case, investigations are part of formative assessment, which means they are also used for instructional purposes. Since there are different types of investigations, it is important to discuss the type of investigation I used in this research.

2.2.1 Types of Investigations

Jaworski (1994) contrasts two approaches: the exercise paradigm and the investigative approach. An exercise paradigm is where learners are given exercises to work on as practice after the teacher has explained some mathematical techniques and ideas. This paradigm is similar to what is often referred to as traditional teaching.

In investigative approaches, learners are more involved in their learning. Jaworski (1994:12) argues that employing investigational work can assist the teacher to enable "concept development in students." She points out that investigations are about asking open-ended questions and "encouraging student enquiry rather than straightforward 'learning' of facts and procedures. Investigative tasks can exist in three different types: pure mathematics, semi-reality and real-life. **Pure mathematics** problems are located in numbers and geometric figures. Below is an example of an investigation in this category taken from Van De Walle (2004).

Given: $6+6=12$, when you make the first number **1 more** and the second number **1 less**, you get the same answer: $7+5=12$ It works for $4+4=8$. It is the same as $5+3=8$ What can you find about that $6\times 6=36$ and $7\times 5=35$? Examine other products and make a conjecture. (Van De Walle, 2004)

The problem shown above deals mainly with numbers and is a task that is authentic to the culture of mathematics explained earlier. Through this investigation, learners engage in real

mathematical reasoning. It also can be used to introduce algebra as learners realize the patterns emerging from the activity.

Semi-reality These activities are a simulation of a real situation. The problems do not necessarily make sense to the world and learners have to investigate in order to make explorations and explanations (Haggarty, 2002). Lowe (2009) explains a simulation as an activity that gives the same results as a real situation. The simulation produces results without the use of 'real' data. He gives an example of an activity that simulates a soccer game taken from Lowe (2009).

Use two dice or one rolled twice. The difference in the dice numbers is (the Bafana Bafana[2]) team's score. Develop scores for 20 games. Answer the following questions:

1. What is the mean score for (Bafana Bafana) team?
2. What is the median score from these results?
3. What are the quartiles? What is the interquartile range?
4. How close are the simulated results to the real thing? Is it a good simulation?

Lowe (2009)

In these investigations learners are offered an opportunity to explore the mathematics although some aspects of it are not in a real life context. However, learners can discuss whether the simulation can predict the outcomes of soccer games.

Real life problems are investigations where a real situation is investigated and learners have to work with the messiness of real situations. Learners can be requested to investigate rainfall patterns in their locality or the locality of their school. This kind of activity may spread over a long period of time and may be difficult to manage as the information collected is 'messy'. An example of this type is given below, taken from Brombacher (2008).

[2] Not the name used in the original source.

The environment club at your school would like to start a gardening project. They decide to harvest water from the roof of the building with the largest surface area so that a tank can be set-up at this building. Before they start the process, they have to make a number of calculations to determine whether the project will save them water.

1. Find the amount of rainfall that can be collected in a year by calculating:
    - the average rainfall per month/ year and
    - the surface area of the roof that will be used for collecting water.
2. Establish rainfall patterns as either seasonal or consistent, which impacts on the capacity of the storage container.
3. Find the surface area of the roof (only the footprint of the house matters).
4. Find the storage capacity of the tank.
    - It is important to establish the appropriate size for the project such that there is water throughout the year.
    - The club should be careful the tank is neither too big nor too small for the needs of their garden.
5. Calculate the weekly consumption rate (liters/plot/week)
    - This will be the amount of liters used per plot per week

Brombacher (2008)

The above example is a modification of a task suggested by Brombacher (2008). This task might be a year-long project or the teacher can use data that is already available on the internet as suggested by Brombacher (2008) which makes it less "real". Learners will have to be given the plan of the school building as well.

Haggarty (2002) claims the best situation is to expose learners to all types of investigations as well as exercises, based on the suitability of the activity according to the concept, the prior knowledge of learners and the availability of resources needed for particular investigation. The purposes of investigations need to be discussed so that I clarify the necessity to do them besides the fact that they are part of formative assessment in the new curriculum.

2.2.2 Purposes of Investigations

Van De Walle (2004) and Kilpatrick (2001) are very clear that although there is a place for drill in the mathematics class (which can be classified under the exercise paradigm), drill should never come before understanding. Learners must make sense of the mathematics. Kilpatrick (2001) mentions five mathematical proficiencies which are, conceptual understanding, procedural fluency, strategic competence, adaptive reasoning and productive disposition. Conceptual understanding refers to an "integrated and functional grasp of mathematical ideas" (pg.118). Mathematical ideas of learners who have attained conceptual understanding are more coherent and learners can make connections more easily when they have to learn a new concept. Investigations offer learners opportunities to reach this level of understanding especially where procedures are not explained to them but they do mathematics. According to Stein et al. (2000) "doing mathematics" refers to engaging in activities that require mathematical exploration. The Mathematics Centre (1989) observed that investigations give teachers a view into learners' understanding and give learners freedom to use their own language in their own way even though they deal with novel situations.

Boaler and Humphreys (2005:11) argue that learning mathematics "means getting better at the action verbs that are often used to describe the thinking habits mathematicians routinely employ: *looking for patterns, conjecturing, justifying, analyzing, wondering* and so on." These words describe what learners are doing and as they engage in mathematical activities, they acquire understanding. The Rand Mathematics Study Panel (2000:24) also defines mathematical practices as things that mathematicians and mathematics users do such as "being able to justify claims, using symbolic notification efficiently and making generalizations". They further claim that the absence of these practices can hamper the learning of mathematics. These mathematical practices relate to the definition that mathematics is a science of finding regularity and order (Van De Walle, 2004). He argues that when learners try to find this order and regularity and in so doing make sense of ideas, then that is doing mathematics. He also claims that learners are "learning mathematics by doing mathematics."(pg.37). This definition of mathematics continues

to reinforce that various aspects of mathematics should be explored in order to enable learners to understand mathematics. In the light of the claims mentioned here and what I have experienced in teaching, the view of doing mathematics is very important as learners are given a chance to grapple with concepts on their own and make connections to their prior knowledge. Investigations when encountered at the beginning of a new topic where learners can develop their own understanding, become an important part of assessment and instruction which can foster understanding.

In this section I discussed the definition of investigations, their types and purposes. The three types are pure mathematics, semi-reality and real-life investigations. I also gave examples of these types of investigations. Most authors agree that investigations foster conceptual understanding in mathematics through exploration. An important part of investigations is the feedback that teachers give to learners. I will focus on this in the following section.

2.3. WHY IS FEEDBACK IMPORTANT

According to Black and Atkin (1996), assessment is usually seen as a "divisive issue". This is because on one hand it can be an instrument that makes schools account to society and blames schools for learner failure. On the other hand, teachers can use it to improve their teaching. While teachers need to ensure that assessment is valid, they also need to use it in providing crucial information about their learners and their own teaching. Teachers need to give feedback that will assist learners to comprehend new concepts. Black (1998) is of the view that assessment should be used to improve learning, and feedback becomes important in conducting effective teaching.

Needs of learners can be responded to if teachers identify them. These needs can be identified through assessment but they are responded to through feedback. It is necessary therefore to have assessment that addresses learning and this can be achieved when feedback is given to learners in ways that it addresses their difficulties. Feedback is central in this study in that it holds together the investigative task, conversations taking place and misconceptions arising, as follows. Learners do the *investigative task* and thereafter they engage in whole class discussion. During

these discussions, feedback on the work that learners have done is given. There are *conversations* that occur in particular ways as discussions progress. From the conversations, the role of guiding the discussions and making inputs on learners' contributions is taken. When learners make contributions, *misconceptions* are recognized and dealt with. It is clear then that in all the three aspects mentioned, feedback will play a linking role.

Wiggins (2004) defines feedback as "information about what happened" or "the result or effect of our action". Wiggins also mentions that feedback informs one whether one is on track or not. That being the case, learners need to be helped at short intervals to ensure that even if there are misconceptions developed during teaching, learners work towards transforming them. Shute (2008) defines feedback as information given to the learners so that they can improve their learning. I regard this point as key in relation to giving feedback. The two authors agree that feedback should be goal oriented. This means that feedback should point out whether the learners attained the set goals or not. The Assessment Reform Group, (in Clarke, 2005:75), states that "learners need information and guidance in order to plan next steps in their learning." I can sum-up these views by saying that feedback redirects learners to what is expected of them so that they can improve their work.

There are different ways of giving feedback. Shute (2008) discusses formative feedback. The manner in which formative feedback is given and the time when it is given, are issues that this research seeks to address.

Ways of giving Formative feedback

According to Shute (2008), one of the main aims of formative feedback is to increase learners' knowledge, skills and understanding. Black (1998) points out that "because formative assessment is intended as the feedback needed to make learning adaptive and thereby more effective, it cannot simply be added as an extra to an existing, non-interactive, scheme of work" (pg 26). It is clear from this point that teachers can only do their best in reaching educational goals when they have enough knowledge of their learners' needs and this can only be achieved through assessment. There are guidelines on giving feedback which are stated below.

Corbett and Anderson (2001) suggest that feedback needs to be focused on the task rather than on the learners, making suggestions how learners can improve their work. Mason and Bruning (2001) state that elaborated feedback should be given but in controllable pieces to avoid overloading of information. Hoska (1993) cited that feedback should be linked to goals and be specific or else it might hamper learning. Learners should be encouraged to be goal orientated (put more effort in seeking solutions even if it takes time) rather than performance orientated (showing ones competence with an expectation to be positively evaluated by others).

Formative feedback should influence learners to move from a performance orientation to an emphasis on learning. This shift can be achieved through practice, giving effort in one's work and realizing that mistakes are part of acquiring skills and knowledge. The issue of feedback becomes crucial where the teacher has already received information from the task given to learners and discovered the areas of strength and weakness in the learners' responses. There are a number of ways of giving feedback that are suggested in the literature where the importance of giving feedback is to improve learning.

Kulhavy and Stock (1989) state two ways of giving effective feedback: a) *verification* which is simply giving judgment on whether information is correct or wrong and b) *elaboration* which is giving hints and guidelines towards the correct answer. Verification can either be implicit or explicit. It is explicit when a mark on the learners' book is made or highlighted and implicit when the learner's response is evaluated in class without an explicit comment. Elaboration feedback gives some guidance to learners on what is expected (Shute, 2008:158). Since verification does not give much information about learners' responses, I focus more on elaboration feedback.

Shute (2008) states that elaboration feedback is more *specific* and *directive* in cases where it addresses the topic, it addresses the response or discusses the particular error. It is more *general* and *facilitative* where worked examples are provided or gentle guidance is given, it can also give information about learners or misconceptions. When the topic has progressed, facilitative

feedback becomes more effective. Directive feedback is said to be more helpful during the introduction of a new topic than facilitative feedback. As will be shown later in the theoretical framework, learners' concepts can develop better when they are given support (scaffolding) during learning but this kind of support has to be removed gradually as they gain confidence.

Shute (2008) discusses the principle of scaffolding in relation to formative feedback. This principle is quite pivotal in sociocultural theories as indicated by Lave and Wenger (1991). Scaffolding is interpreted as distinguishing between support given at the initial stages of learning and the performance shown by a learner when the support is removed. Scaffolding enables learners to do more than they would without assistance. Hartman (2002) cited that scaffolded feedback "includes models, cues, prompts, hints, partial solutions, and direct instruction". This research explores which of the two types of elaboration feedback was more used in my teaching, directive feedback or facilitative feedback.

The time at which feedback is given is crucial since facilitative feedback can also be helpful in cases where learners become more confident in their knowledge. The implication here is that both ways of giving feedback (directive and facilitative) are important when given at appropriate times.

2.4 MISCONCEPTIONS AND HOW TO DEAL WITH THEM

Nesher (1987:35) defines misconceptions as "a line of thinking that causes a series of errors all resulting from an incorrect underlying premise, rather than sporadic, unconnected and non-systematic." Smith, DiSessa and Roschelle (1993) define them as conceptions arising from learners' prior knowledge as they interact with their environment whether in class or outside. Misconceptions are not necessarily taught to learners. The only explanation can be that learners themselves construct their knowledge in a specific way and this in turn results in what is called 'flawed conceptualizations' (Smith, DiSessa and Roschelle, 1993:132). It is important then to reuse and refine prior knowledge in order to make the learning of difficult mathematical concepts more manageable as stated by Smith et al. (1993). It is difficult to change incorrect prior learning

as it becomes part of learners' schemata. Once learners develop misconceptions, they hold strongly to them and these misconceptions may affect the learning of new concepts.
Nesher (1987) is clear about the fact that misconceptions should be welcomed rather than taken as a hindrance to learning. Swan (2001:142) re-iterates this notion by saying that misconceptions need to be "welcomed, made explicit, discussed and modified for long–term learning to take place. Swan (2001:146) continues to argue that the nature of classrooms will have to change if an environment that allows misconceptions to be discussed is to be created. The principle of having discussions in lessons is suggested as a way of dealing with misconceptions and encouraging learners to reflect on their own thinking. When learners reflect, they may come across some "inconsistencies" that will cause them to rethink their ideas.

Assessment can elicit a number of misconceptions that learners have. It is quite evident that learners do not understand everything that teachers say as teachers intend. It requires the teachers' expertise to pick-up these misconceptions as soon as possible so that they can be transformed. Misconceptions can be difficult to detect as at times learners can have correct responses even though they are using a wrong concept. This is illustrated well in Nesher (1987) with the example of a learner who looks at the digits after a decimal point as a whole number. For example, comparing the numbers 4.34 and 4.2345, the learner would see the first number, 4.34, as less than the second one, 4.2345 because it has more digits after the decimal point. Such a learner would be correct if the number of digits were the same i.e. 4.34 being bigger than 4.23 hence making it difficult for the teacher to recognize the misconception. In such a case, the teacher would need to ask a variety of questions to elicit this misconception or ask the learner to explain how they got the correct answer.

It is important to interact with learners in ways that elicit the misconceptions so that they can be dealt with. Swan (2001) encourages the use of cognitive conflict at times. This is where a teacher brings up a concept different from the one learners would usually expect in the form of a question. In this way, learners have to think of ways in which they can change their perspective and hopefully transform their misconceptions. My assumption is that since I am still learning about misconceptions, my reaction to them will develop as my knowledge also grows. My

reaction can also be affected by the understanding I have about misconceptions as explained in the next page.

When misconceptions are confronted only by the correct answer, Smith et al. (1993) point out that they will simply be pushed underground. When appropriate interventions are designed, conceptual change can be attained. In this study I seek to find the appropriate interventions that can assist me to avoid either confronting misconceptions or trying to replace them. Rather, conducting discussions on misconceptions during feedback may allow learners to reflect on their misconceptions. Smith et al. (1993) argue that learning is development of new concepts as prior knowledge gradually changes when learners make new connections. When misconceptions are simply confronted, the new concepts may just exist in isolation hence prohibit understanding. Requesting learners to reflect on their current knowledge is recommended rather than confrontation. Van De Walle (1991) puts it simply by saying that "constructing knowledge requires reflective thought, actively thinking about or mentally working on an idea." My hope was that I could design an investigative task that would enable conceptual change to take place.

If learners are to manifest misconceptions, then there must be a way this can be done. In my experience as a teacher, I have realized that learners would prefer to get positive feedback only. They do not want to be seen as not achieving. So it is the responsibility of the teacher to make learners feel comfortable in the fact that at times they will be incorrect and at such times they need to be open about their mistakes so that they can obtain help. It is during classroom conversations that a culture is developed where learners are free to express themselves without fear of being ridiculed by others for incorrect responses.

2.5 INFORMATIVE CONVERSATIONS

If reflection and thinking about ideas in the class room is important in learning, how can the teacher know what is in the learners' minds. This question will be answered in this section as we look at the issue of conversations.

Conversations in the classroom

Brodie (2007) argues that conversations in classrooms enable teachers and learners to reflect on their thinking. She further argues that in conversation learners express their own ideas rather than the teacher's ideas. In a study she conducted (Brodie, 2007) showed how two teachers began and ended conversations in their classes. In the process of the conversations, there are a number of ideas that learners raise and it takes skill on the part of the teachers to understand the learners' thinking and to consolidate the ideas such that learners come to a conclusion of the matter that was discussed. Calvert (2001) describes mathematical conversations as whole-class discussions, which are authentic and intimate. She points out an important idea that it is only when people accept their perceptions as certain that they stop seeking for answers. But when people realize that their perceptions are not in line with what is accepted by the community then they are willing to seek more knowledge. This idea is useful in this study as learners can have an opportunity to adjust their misconceptions during conversations.

My study is framed by a sociocultural view, which focuses on learning that takes place as people participate in a particular culture (Cobb, 1994). Learners can participate by working on their own, working together in groups or working as a whole class in a discussion. When learners begin to talk about the mathematics either among themselves or with the teacher for the purpose of supporting the learning of mathematics, a math-talk learning community develops as stated by Hufferd-Ackles, Fuson and Sherin (2004). Research has found that in a math-talk learning community, there are challenges that teachers come across. The first one is that when learners are faced with a difficult task, they may disengage from the task. Secondly, the discussion may lose focus as learners begin to make incorrect claims. Finally, teachers may feel inadequate as to what they need to prepare for, as the lesson in a math-talk community becomes unpredictable. Although there are dilemmas that teachers face, conversations in a mathematics classroom enables learners' mathematical meanings to be realized by the teacher so that they can be dealt with appropriately.

Hufferd-Ackles et al. (2004) argue that conversations that take place in the classroom do not only extend the learning of learners who are having a conversation but can also benefit other learners who are listening. Chazan (2000) claims that when teachers do not see mathematical ideas as

only “right” or “wrong” they leave room for learners to explain their ideas and hence encourage conversations in their classrooms. The learners no longer see the teacher as an unquestionable, unchallenged authority. In a classroom where conversations are encouraged, three practices are evident: “learners’ strategies” are elicited, their “conceptual understanding” is supported and their “mathematical thinking” is extended (Staples, 2007:5).

Four components that characterize math-talk in the classroom were identified. These are a) questioning b) explaining mathematical thinking c) source of mathematical ideas, and d) responsibility for learning, (Hufferd-Ackles et al., 2004). These components can be seen on four levels. Level 0 represents traditional teaching as there are short answers from learners; level 1 is where the teachers begin to search for mathematical thinking from learners but teachers’ roles are still dominant; in level 2 teachers begin to give some roles to learners, some learners assume leading roles; and in level 3 the learners are taking leading roles in the math-talk and the teachers mainly guide the learners. Each component can exist at any of the four levels.

Questioning learners is usually for the purpose of extending learners’ thinking about mathematical concepts (Hufferd-Ackles et al., 2004). When learners respond to these questions their ideas are available to the class so that they may be assessed by others and developed if necessary. At level 0 answers to questions are made in one or few words. Teachers at this level sometimes give answers to their own questions rather than wait for learners to respond. When learners give incorrect responses, the teacher simply corrects the learner without asking the learner to give reasons for her/his responses. In such cases, it becomes difficult for the teacher to recognize the cause of the error or the misconception. When “Why?” and “How?” questions are asked, questioning shifts to level 1(Hufferd-Ackles et al., 2004) and teachers may access. In cases where learners start asking each other questions and the teacher is not hasty to answer them but waits for the learners to clarify their own ideas, questioning moves to level 2. At level 3 of questioning, questions are asked by a number with genuine learner- learner interaction. Although learners at level 3 may be doing most of the talking, the teacher’s role does not diminish as there is need for the teacher to make sense of the learners’ thinking, and give feedback.

The second component, which is, explaining mathematical thinking, mostly depends on the climate created by the teacher. Learners usually feel uncomfortable to explain their ideas in front of their peers, but as the teacher encourages this practice, learners can get used to it. The shift from a lower level occurs when learners start supporting a learner who is explaining. This support should assist learners to develop in explaining their ideas more confidently and competently. When learners move from the practice of just giving procedural explanations to looking for meanings, then this component shifts to level 1. At this level, the teacher is not content with an accurate response but seeks for further strategies that learners could use. A lot of patience is required from the teacher so that learners are enabled to explain their thinking and when learners become familiar with explaining their thoughts to their peers, the level of explaining mathematical ideas shifts to level 2. The teacher at this stage can use learners' explanations consisting of mistakes as an opportunity for further learning (Hufferd-Ackles et al., 2004 and Staples, 2007). Learners' confidence is so high that they are able to justify and defend their claims. The more differing the explanations and disagreements the more learners' understanding grows (Calvert, 2001). At level 3, learners are so confident of their explanations that they are not afraid to explain strategies that have not been taught by the teacher before. They can justify their claims even more competently.

In the third component, source of mathematical ideas, at level 0 mathematical ideas are given by the teacher in a procedural way. Learners are often told how to do problems or sometimes the problems are done for them in level 0. In level 1 more focus is on eliciting learners' ideas and this gives the teacher an opportunity to understand learners' prior knowledge and misconceptions that arise (Hufferd-Ackles et al., 2004 and Maoto and Wallace, 2006). Hence learners are more involved than when the only source of mathematics is the teacher. In level 2, more open-ended questions are asked and the teacher is more willing to accept new strategies from learners, this gives the teacher a better chance to listen to learners' understandings and the misconceptions that they may have. The learners are also invited to disclose any misconceptions they might identify. At level 3 learners are aware that their contributions are valued hence they voluntarily explain their strategies.

The last component, responsibility for learning, is indicated by learners becoming more engaged in lessons. This is manifested when learners ask more questions, explaining their thoughts to the class on the board and helping their peers. Learners also want to make sure that their explanations are well understood by others. At level 0, learners are not interested in what other learners say because they know that the teacher will repeat the responses. In this way there is no deep engagement with other learners' thinking. The teacher is the one who confirms the correctness of the responses hence learners are not confident with their answers. Learners are not comfortable to explain to other learners in front of the whole class. It is the responsibility of the teacher alone to explain mathematical concepts. This component shifts to level 1 when the teacher expects learners to listen to each other and is no longer just interested in the correctness of the answers but also in learners' thinking. Learners' listening skills are developed in this way. Responsibility for learning moves to level 2 when learners are expected to explain the mathematical understanding of others in their own words and at this stage more complex questions are asked. Learners start taking the role of explaining other students' work both to themselves and to others. As learners begin to evaluate and explain why they agree or disagree, they become stronger in critically thinking of others' work and in helping others. At level 3, the classroom environment is such that more learners can capably assist others and the teacher has more time to focus on weaker learners. Learners at this stage are more determined to acquire understanding, even if they are the only ones who do not understand. They accept and offer help willingly.

The components and levels mentioned above will assist me to find out the level at which conversations took place during my feedback on investigations. These components as shown in this section can exist at different levels. It will be important to understand the level at which I operated in my lessons as that will give me a better understanding so that I work on my shortcomings. Chazan (2000) and Hufferd-Ackles et al. (2004), state that conversations in the classrooms may not be characterized by discussions at level 3 all the time. The reasons for this may be the fact that at the beginning of a new topic, learners may not be familiar with the language used and may not participate as they would in a more familiar topic. However, the more interactive mathematical classrooms become, the more learners' thinking will be elicited.

In the four previous sections, I have developed a literature review on issues that drove my research. In the following section, I will discuss the framework in which these issues discussed earlier are framed. I also discussed the different components of conversations, which are questioning, explaining mathematical thinking, sources of mathematical ideas and responsibility for learning. Each of these components exists at four levels.

2.6 SOCIOCULTURAL THEORY

My study is framed by sociocultural theory. The reason for this is that my study focuses on classroom interaction. Based on the interactive premises of this theory, it seemed reasonable to look into my teaching through its lenses. Sociocultural theory "attempt(s) to provide an account of learning and development as mediated processes" where "emphasis is on semiotic mediation with particular emphasis on speech" (Daniels, 2001:1). The origin of conceptual development is based in social processes (Waschescio, 1998). Cultural tools and signs are viewed as essential to development. Processes by which social, cultural and historical factors shape human functioning are investigated through methodological tools and they play a role in development. The key sociocultural concepts for my study are the concept of mediation and the zone of proximal development.

2.6.1 Mediation

Mediation is interaction between subject and object through the use of signs and tools. There are two kinds of mediation mentioned by Daniels (2001) which are mediation through psychological tools and mediation through material tools. Daniels continues to elaborate that material tools, psychological tools and human beings can all be mediators. Tools and signs are used to mediate between objects and subjects. The subject-object relationship is that of the learner (subject) and what has to be learned (object), with a range of tools and the teacher as key mediators. The psychological tools (signs) are used to guide the behavior and minds of the individual or others, whereas material tools (tools) cause changes to take place in the objects. Vygotsky (1981:136-7) give examples of psychological tools as "language…systems for counting, mnemonic techniques… and different conventional signs". Material tools are those that can be operated on

and are controlled by their users (Lee, 1985). Learning and development in sociocultural theory are mediated processes. Language becomes a very important psychological tool in social settings where meaning is negotiated.

There are processes of mediation that take place where individuals use words or text created by activities in which meaning is negotiated (Daniels, 2001). Meaning is mediated between subjects and objects through interaction. Vygotsky (1978) argues that concept development takes place first socially (taking place between people; interpsychological) and then later within the individual (intrapsychological). Vygotsky (1987) contrasts the lower mental functions and higher mental functions. The higher mental functions emanate from collaboration and instruction and lead to development of the child. Language becomes a crucial aspect in these higher mental functions as meditational means. He continues to argue that individual understanding is made possible through communication in social discourse and children can do more in collaboration than they can on their own. This relates back to the notion of scaffolding as feedback discussed earlier. Collaborative use of mediational means should be used to create, develop and communicate meaning within the context of the concept of the zone of proximal development rather than a transfer of concepts from the more capable to the less capable participant as stated in Moll (1990). In the following section I will elaborate more on this zone of proximal development.

2.6.2 Zone of Proximal Development (ZPD)

In Vygotsky's (1978) view, it is believed that prior learning is key to learning that takes place. The ZPD is defined as the distance between the actual development level which is what a child can do with the assistance of an adult or a more capable peer. (Vygotsky, 1978:86). The ZPD can also be seen as functions in a child which are still in the process of maturing, meaning that, when a child is able to do something for the first time, it does not mean that the child can now be said to be capable in that concept. Awareness of the ZPD can assist educators to understand the importance of scaffolding and formative assessment and when they can be given. This means that the educator can also know when learners are ready for summative assessment as it would only be fair to assess learners when they are capable of working on tasks individually.

Scaffolding and feedback become crucial in the ZPD as there is support given to a learner in the initial stages of tasks and subsequently it is gradually removed. The scaffolding given can be in the form of 'demonstration, leading questions, and by introducing the initial elements of the task's solution' (Moll, 1990:11). There can be a "rigid scaffold" or a "negotiated scaffold" where the former refers to the kind of teaching where support comes from the more capable partner whereas in the latter it refers to a more collaborative teaching (Moll, 1990). Problems should not be at a level too far from the level at which learners are (Moll (1990) and Waschescio, 1998). Daniels (2001) mentions the importance of the ZPD in teaching in that assessment and instruction should be informed both by the learner's potential and where they are headed, rather than only the currently demonstrated performance of learners. The implication here is that teaching and assessment should always take note of prior knowledge and its relationship with new knowledge, for example with misconceptions.

2.7 CONCLUSION

In this chapter, the meaning of investigative tasks, the importance of feedback, misconceptions and how to deal with them and conversations in the classroom were discussed. It is paramount that the definition of investigations is well understood as the development of such tasks is based on that foundation. As feedback occurs in the classroom, a platform for discussions is usually opened up and the manner in which these discussions ensue determines the opportunities that will arise for the teacher to identify misconceptions if there be any and this will be assisted by the conversations that occur between learners and the teacher.

The theoretical framework of my study was also discussed. I focused mainly on mediation which involves the use of material tools and psychological tools. Language as one of the most important tools of mediation will form an important part of my study when giving feedback to learners and having classroom interactions. The zone of proximal development is also crucial in this study as learners' prior knowledge and their potential knowledge form the bases of instruction and are areas of interest during discussions. In the next chapter, I will detail processes that took place in the methodology that was followed to collect the information which will assist me to make sense of giving feedback in investigative tasks.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

I carried out a qualitative study, which Opie (2004) says is usually used where a person seeks to create, change and make sense of their situation. This study is an action research project in which I focused on how to give feedback while using an investigation with my learners. The reason I conducted an action research is because I realized that I had shortcomings when giving feedback to learners especially on tasks that were included as part of formative assessment such as projects, investigations and presentations. Action research will be defined and explained in more detail in the following section. I will also analyze the investigative task that I used for this study.

3.2 ACTION RESEARCH

Opie (2004) explains action research as a process that provides a practitioner with ways of understanding a problematic situation. Kemmis and McTaggart (1988), Altrichter, Posch and Somekn (1993) and Denscombe (2007) define action research as an enquiry by participants wanting to reflect on themselves in order to improve their own educational practices, the understanding of these practices and the situations in which they are carried out. Denscombe (2007) further argues that action research brings change especially to the practitioner involved in the research, hence self-development. One of the disadvantages that he mentions is that generalizations cannot be made in action research due to the limited scope and scale of the research.

Kemmis and McTaggart (1988) emphasize that for the approach to be action research, it should be a collaboration of a certain group of people e.g. students, teachers, parents etc. Before an action research is conducted, a *thematic concern* has to be identified. This is when participants of the research select an area where they will focus on improving (Kemmis and McTaggart, 1988). After a thematic concern has been identified the participants then plan, act and observe and finally reflect on the outcomes of their action. In this study, I worked as an individual with the

advice from a research group organized by my supervisor. As I engaged in activities, I realized that I needed to improve in giving feedback on investigative tasks to learners. The four aspects mentioned above i.e. planning, acting, observing, and reflecting, are fundamental to action research. Each aspect will be explained below.

The Plan

During this process, participants should agree on ways in which they analyze and improve the action (Kemmis and McTaggart, 1988). The action that is planned must be treated with consideration that it may be risky and unpredictable and for this reason should accommodate any unforeseen circumstances. In my study, the plan involved two stages: 1. planning the investigative task and 2. thinking of how to improve my giving feedback for this task. I did the planning with assistance from my supervisor and my research group. I often met with the research group members where we discussed the task and ways of conducting it such that there was enough time for feedback during data collection. The planning of the investigative task was very important as it would allow me to realize my goals. I will analyze the task later in this chapter. This will assist me to elaborate on how I intended giving feedback which would be guided by the learners' responses. If learners are coping with an activity then feedback may not need to be as elaborate as opposed to when learners' responses are far from the expected goals. I had to think of ways in which I would give feedback to the learners such that it would benefit them. I will explain the different tasks that can be used and then later lay out the planning of my lessons.

I designed a plan for six lessons. The first lesson was for setting up the problem. Stein et al. (2000) explain the set up stage as the time where the teacher explains the task to learners, how they are expected to do it and what resources they should use. The task at this stage can be altered from its original cognitive demand. Task one consisted of four questions and task two had only two questions (see Appendix A). In the first lesson, learners had to do question one and two of task one after an explanation about the process of doing the investigation, and the resources such as a geometry set of instruments and mathematics dictionaries were given. In the second

lesson, a whole class discussion of the learners' work was to be done and feedback given on their performance. Learners' work would not necessarily be marked as they were still in the process of writing the investigation but their work would be looked at and they would be given feedback so that they could improve in the subsequent activities. Learners were expected to do questions three and four of task one in the third lesson and I hoped to find a lot of improvement at this stage as learners would be more experienced with the activity. In lesson four there would be another whole class discussion which would focus on what emanated from the previous lesson. In the fifth lesson, the plan was that learners would complete task two and in the last lesson, feedback on this task would be given.

As learners got used to dealing with the tasks, the hope was that they would gain experience and become proficient in dealing with the given problem. I intended giving feedback to learners after looking at the work they did the previous day. As I looked at their work, I would have indications of their difficulties so that I could give more support in the next lesson. I planned to give them their work every time I started the lesson so that they could see the areas where they needed to improve.

Action and Observation

Action is the area of practice that participants in action research are most interested in (Kemmis and McTaggart, 1988). For action to be successful, it has to be informed by prior practice. In my case, I once presented a video taped lesson which I had with my Grade 9 learners to a group of teachers and researchers. In this lesson, learners were giving presentations on a task given to them for formative purposes. When discussing my lesson, I realized that I needed to improve in giving feedback to my learners, hence the research I am doing now, which is informed by my prior practice.

Since taking action is risky, it is usually controlled by constraints that exist in the circumstances where it is conducted (Kemmis and McTaggart, 1988). Ideally, action should be controlled by the plan but this does not always happen due to the fact that it is affected by issues that arise in

real situations. As the action plan is implemented, then a move towards improvement is envisaged.

Action started with the first lesson. I was using someone else's classroom because I did not have a classroom of my own. I had to take all the resources I needed to the classroom. Learners were given an investigative task in the first lesson and I set up the task as planned and learners worked on it. In the next lesson they were to be given feedback after checking the task and there was a whole class discussion of the task. This process would go on for six days. As I took action I had to reflect on my practice and learners' work on a daily basis because this is a requirement as will be shown in the next section.

Observation

Observation is a process of taking stock of what happens on an ongoing basis. At this stage, in cases where a team is involved, there will be meetings to discuss the proceedings of the study and decide on changes that can be done. Feedback is also given to the research team (Manion et al., 2000). In my case, there wasn't much consultation. There was no time during the six lessons to meet with my supervisor and the research group. So what I did was to look at the work of my learners at the time they submitted, and think about issues I could emphasize and concentrate on in the successive lessons.

Reflection

Reflection is where action is recalled from recorded observation and changes are made. The plan is revised on the basis of the circumstances observed. Reflection serves as an evaluation tool as Kemmis and McTaggart (1988) state. This is where judgments about issues that arise from the action are made and decisions as to whether they were desirable or not are taken. Reflection is a stage where analyzing, interpreting, explaining and drawing conclusions are done (Kemmis and McTaggart, 1988). It is recommended at this point to involve the opinions of others.

There are different areas that I needed to reflect on. The first area was my practice during the lessons. I analyzed whether learners were coping with the content and if not, what type of support I gave them during feedback. Based on my analysis, I made conclusions as to whether I had to make changes and in which areas those changes had to be made. Then in the subsequent lessons I continued what I did or changed it, depending on the evaluation I made. However, as already mentioned since action is dependent on the circumstances, there were times where things did not go as planned even after reflection.

I also checked whether misconceptions that arose from the lesson were dealt with appropriately or not. I did this reflection individually. I looked at whether I seized opportunities in dealing with the misconception or whether I missed those opportunities. There were times when learners brought up misconceptions that needed my attention and during reflection I came up with ways that I could challenge those underlying misconceptions by doing things differently from the way I planned them or I maintained what I did if it proved to be working.

I also assessed my practice in terms of conversations that took place in class. An ideal situation would be where learners all participate in the math-talk. In cases where this did not occur in the desired manner after reflecting, other means were explored and changed or left as they were, depending on the circumstances of what took place in reality.

The last area that was reflected on was the task. Although changes on the task itself were not made, certain questions were done at times when they were not planned for after realizing that more time was taken for completing a certain question than was anticipated. Whether the cognitive demand of the task was maintained (Stein et al., 2000) or it declined was also determined so that changes in the successive lessons could be made if need be.

This section concentrated on action research, what it is, what is entailed in it and how it played out in my study. Since action research involves a cycle dealing with planning, action, observation and reflection, I explained how these stages were carried out and it became clear that

the stages are more spiral in nature as each cycle is repeated (Kemmis and McTaggart, 1988). In the next section I will discuss the context and the participants in the research.

3.3 CONTEXT AND PARTICIPANTS

The research project was conducted in my school which is located in a township in the West Rand of Johannesburg, South Africa. In 2008, when the study was conducted, the school had a roll of roughly 1400[3] and there were 49 teachers. The school had a pass rate of 84% in mathematics at the end of 2006 and 79% in 2008. The school had sufficient resources for learning and teaching and they were easily made available to teachers upon request. There was a computer centre as well at the school. There were some teachers who did not have their own classrooms due to the number of teachers at the school, and I was one of those who had no permanent classroom. Therefore I arranged with one of the teachers to use her classroom specifically for the lessons that were being recorded to avoid confusion for the person assisting with the recording of lessons.

Since the study is an action research, I was the object of study. I have been teaching since 1988 with a few breaks to continue my studies and relocated to South Africa from Lesotho. I currently have BSc. (Hon) in Mathematics Education, an Honours in Education, Training and Development (ETD), a Further Diploma in Mathematics Education, a Diploma in Science Education and a Secondary Teachers' Certificate. I also received a number of trainings in the National Curriculum Statements. I have mostly taught mathematics at High school level (Grades 8 to 12). I joined my current school in 2007 as the head of the Mathematics Department. I had been head of department for three years in my former school as well. I was exposed to reform[4] way of teaching when I did my BSc. (Hon.) and have since desired to align my teaching with this practice. My main interest has been in making mathematics accessible to learners hence a focus on how I give feedback when using investigative tasks.

[3] This roll had dropped from approximately 1600 in 2007 (when four mobile classrooms had to be erected).

[4] Reform teaching is new ways of teaching that focus on pedagogies that are learner centred and is opposed to traditional teaching where the teacher plays a centre role.

At the time this study was conducted, I was teaching Grade 10 Mathematics and Grade 11 Mathematical Literacy. The Grade 10 class took part in the study. There were 26 learners in this class. The reason for choosing this class was for convenience as it was the only Grade 10 class I was teaching then. However, I had not taught them in the year I collected data since I had been on maternity leave for four months prior to the data collection. I had taught these learners in Grade 9 which gave me an advantage as I could see the differences in the interactions more clearly based on how they were previously. Learners in our school mostly came from around the township but some came from neighbouring informal settlements and walked about five kilometres or more to and from school.

3.4 VIDEO RECORDINGS

Since I did action research, I used video recordings as my main instrument where I was interested in the response of learners to investigative tasks. My focus was also on giving feedback to the learners in ways that would assist them to engage successfully with the tasks. For this to happen, I focused on different kinds of feedback that can be given, as discussed in the literature review. I gathered contextual information from the video recordings. Since I was the main object of the study, it was important to videotape the lessons as I could not observe my own practice. Opie (2006) describes a complete participant as one who is totally involved in the research. This was true in my case as I taught during the recordings. Among other areas of my focus I also looked at the conversations that took place in the classroom and how I gave feedback about misconceptions that arose from those conversations.

When the time for recording came closer, I gave my time table to someone whom I requested to assist me with recording my lessons. She was in the research group with my supervisor and she had experience in recording videos. She had previously collected data for her Masters degree and recorded other lessons for research projects. She is currently doing her PhD in mathematics education. Since she had other commitments, she identified the times when she would be available and fortunately it worked out in ways that she could record for six days consecutively.

During the start of the first lesson, she stood on the right side of the classroom towards the front since she focused on me. When learners started working, I requested that she focused on one group. I chose a group that seemed to communicate well with each other so that I could understand how they reasoned as they worked. Her position was basically in the two positions, right side towards the front during whole class discussions and focusing on one group when learners were engaged in their work. It was only during the time when I used the overhead projector that she stood behind the class.

From the videotapes I categorized the classroom conversations as discussed in Hufferd-Ackles et al., (2004). The categories that I used are: questioning, explaining mathematical thinking, sources of mathematical ideas and responsibility for learning. These categories have been explained in depth in chapter 2. The video recordings assisted in enabling me to go back a number of times to observe each category and identify areas depicted in the lesson. It was mentioned earlier that there might be misconceptions arising from learners responses. It was important for me to analyze how these misconceptions were dealt with during feedback. The videotape enabled me to focus on certain misconceptions during analysis.

There are however some constraints with video recordings as they may not capture everything. In my case, learners worked in groups and it would have been ideal to record what happened in every group but this was impossible as there was only one video camera. The recordings were supplemented by learners' work which also enabled me to pick up areas that needed my attention. There were other limitations with video recording such as a number of inaudible voices because learners did not have microphones like I did. For this reason, there is sometimes important data missing. I also did not pickup the voices of learners in the group that the video camera focused on. It is also possible that some learners may have been conscious of the video recording hence the manner in which they would respond naturally was affected.

3.5 THE TASK

The task that learners had to do was an investigation on quadrilaterals and it will be explained in detail in this section. I had to administer this task with another teacher who was teaching the two other grade 10 classes. Learners were arranged in six groups of four or five. There was a chalk board that I used mainly for class discussions and an overhead projector which I used at one point. The learners were provided each with four shapes on a sheet of paper; a rhombus, a parallelogram, a kite and a trapezium (see Appendix B). They had to draw a square and a rectangle for themselves as I assumed that these are properties of the two shapes that they already knew. Learners were also provided with boxes of instruments and there were four mathematical dictionaries that they could borrow whenever they needed them.

Investigative tasks are authentic tasks that involve mathematical processes such as:

> "systematic exploration, identification of patterns, relationships, systematic recording of data generated, taking a leap towards a solution by a suitable guess, formulation of conjectures, verification of conjectures, posing problems, asking questions which progress the investigation, use of special cases, use of counter examples, development of suitable notations, use of suitable language and listening to peers and adjusting ideas accordingly" (Laridon et al., 2005).

Laridon et al. (2005) describes authentic tasks as those that use learned mathematics in tasks related to real-life situations. Haggarty (2002), gives a more extended definition stating that there are investigative tasks that exist either as pure mathematics, semi-reality or reality. My task is a "pure mathematics" task but it fits with Laridon et al.'s definition of mathematical processes.

This task was carefully selected for a number of reasons. The first reason is related to the time in which the collection of data was done. Since in my plan I had mentioned that data will be collected in the third term, according to my year plan, I decided that learning outcome three, assessment standard (AS: 10.3.2) which states that "investigation of polygons, using any logical method (Eucledian, co-ordinate and/or transformation)" will be done during this period and the task had to fit with this. In the Grade 10 curriculum, there is also an investigation task that has to be done during this time according to the assessment plan which comprises part of the portfolio for formative assessment.

The cognitive demand of a task as explained by Stein et al. (2000) is the level of thinking learners need in order to successfully engage with the task and solve it. There are four levels of cognitive demands which are memorization, procedures without connections, procedures with connections and doing mathematics (in order of the demand starting from the lowest level). Stein et al. (2000) explain memorization tasks as those that require learners to either recite information given earlier or simply store some information in memory. Procedures are not used in these kinds of tasks. An example of such a task would be: what is the sum of interior angles of a quadrilateral. Procedures without connections tasks require the use of an algorithm in a way that it was previously taught. Mathematical meaning is not required to do these tasks as there are no connections that need to be made with underlying concepts. An example of such a task would be to ask learners to find the area of a rectangle with a length of 7 cm and a breadth of 5 cm. In such a task, all learners need to remember is the formula for finding the area of a rectangle and nothing more. These two types of tasks require lower-level demands. The following two require higher-level demands.

In procedures with connection tasks, learners use procedures for the purpose of developing a deeper level of understanding and these tasks require learners to make connections to underlying concepts. Multiple representations of the problem such as diagrams, symbols etc are used so that learners can make meaning of the concept. Procedures are not followed automatically, learners need to engage with the idea in order to effectively complete the task. Lastly, doing mathematics tasks are those that require learners to think of new ways to do the problem because it has not been seen before and there are no previously learned actions that can be followed step-by-step. These tasks need to be carefully analyzed and learners need to put a lot of cognitive effort to complete them successfully (Stein et al., 2000). An example of a doing mathematics task would be to ask learners to find polygons that would form tessellations when given an example of two regular polygons as in the case of the task two given in this study. I use Stein et al.'s four levels to analyze my investigative task.

As I have already mentioned in the rationale, at times I did not feel competent in developing my own investigative tasks, so I found a good example in one of the text books that I use for my

Grade 10 classes (Classroom Mathematics) and this time I made sure that the task is investigative as I understand the term to mean (see chapter 2). Therefore, I arranged the task in such a way that it will address the features of such a task. What I then did was to select an easier investigation from the text book and another one that would require learners to apply investigative skills they acquired from the previous task. I also re-arranged the sequence of activities such that the learners will not see the properties of the quadrilaterals prematurely. This is why they were given the table with the properties after they investigated the properties on their own.

There were three mathematical processes mentioned by Laridon et al. (2005) that I identified in this task, I would classify as an investigation. These were: systematic exploration, systematic recording and use of suitable language. Learners are using an inductive process to come up with their own understanding of the properties of the six quadrilaterals given. According to Haggarty (2002), this investigation would be classified under pure mathematics. Laridon et al. (2005) identified fourteen mathematical processes altogether. It was important as I analyzed the task to find out if there were other mathematical processes that the task developed. Learners on their own may not be able to develop the mathematical processes if the task does not offer such an opportunity.

Task 1 question 1 and 2 can be classified as procedures with connections because the assumption was that they knew some properties of the square and the rectangle and there was some guidance into what learners should do. In question 3a) they worked with properties of the parallelogram, the rhombus, the kite and the trapezium. My hope was that learners would be familiar with what was done in the first question and they could find as many properties as possible. Question 3b) provided the learners with a table of properties already given and they had to tick those that were relevant for each shape. I would classify question 3 as procedures with connections as learners are using what they did with the square and the rectangle In question 4 b) they were given diagonals and they had to draw around them to find out which shape they are get. The purpose of the exercise was to deepen their understanding of the properties relating to diagonals. In question 4b), still working with diagonals, they then had to determine whether the diagonals are equal, intersect at right angles or bisect each other. Question 4 is also procedures with connections as

learners have to apply what they already know in a new context. When analysing the properties in the table provided, properties dealing with diagonal are more than those dealing with the sides and those dealing with the angles. I also knew from experience that learners can easily talk about the properties of shape using sides and angles rather than those that relate to diagonal. I thought that question 4 will assist learners to develop a better understanding of properties relating to diagonals.

Task 2 can be classified as doing mathematics as learners had no specific procedures to follow in order to solve the problem. There were no step-by-step ways of doing the problem. This type of cognitive demand is high and I envisaged not seeing learners function at that level without receiving much assistance. I intended therefore, to do some revision of rotation with them and let them find the apex angle of one regular polygon before they started working in their groups. Learners would then have to find apex of other polygons in order to find the apex of an n sided regular polygon in terms of n. The mathematical processes learners acquired in the previous lessons would be of great use at this point.

3.6 DATA COLLECTION

The focus of the study was to investigate my giving feedback to Grade 10 learners using an investigative task. Video recording was the method used for collecting data. Six video recordings were made, one of each lesson in which we worked on the task. In view of the fact that by virtue of the nature of action research, I am the participant and I am interested in studying my own practice, the use of the video recorder was necessary for me to study the recorded material and make sense of the main issues by going over the video recording a number of times. The learners' work was also collected and analysed to establish whether the feedback given assisted them to obtain the set goals. Maxwell (1996) stated the importance of triangulation which is regarded as collection of data using a variety of sources to reduce biases and limitations of one method. Besides the use of video recording, I also used the learners work to support what I found from the video recordings.

On day one, learners did question one and two of task one. The video camera focused on one group of learners as they worked so that I could later analyse the manner in which they approached the problem so that I could understand their thinking. Unfortunately, the sound of the recording was poor and I could not analyse the learners' interactions. The group was chosen according to conversations that took place and the level of interaction that occurred. As the learners communicated, I hoped that their conversation will be captured on video so that I could later listen to it and pick up any issues that may need attention as I give feedback.

Since learners focused mainly on the square and the rectangle, on the second day I gave them feedback on their work so that when they came to do question three they would pay more attention to details they had omitted previously. In question three, they had to repeat what they did in question one and two but this time investigate the properties of the rhombus, the parallelogram, the kite and the trapezium. Learners were given fifteen minutes to finish off the previous days work. At the end of the fifteen minutes, learners were not yet finished, therefore an extra five minutes was given. Since I had looked at their work the previous night, I realized that none of the learners used a table to arrange their findings. I then used a table on the chalkboard as an illustration of what they should have done. My goal was to illustrate a skill which they apparently lacked.

They still could not finish all the shapes so they had to take work with them to complete it at home. On day four I gave feedback on the rhombus and the parallelogram. The trapezium and the kite were completed on day five. In question 3(b) learners had to fill a table of properties for all the six shapes done in the earlier questions. Although I had planned that learners will work on day five, I noticed that there were a number of questions that were not covered whose discussions would not be captured on tape. I then decided that on day five we discuss the table of properties using an Overhead Projector (OHP). The remaining time was reserved for task two where the apex angle was explained as learners were not familiar with the concept. This time they had to do it as homework due to time constraints. On day six which was the last day of recording, I discussed task two with them.

I have already discussed that the main aim of giving feedback is to improve learners' learning. Therefore, the learners should be more confident as they did subsequent tasks. When I gave feedback, the video focused on whoever was talking during the discussions. It became a challenge for me to analyse this important section as the quality of sound on the video recordings was not clear especially when learners spoke since they were far from the microphone. Learners written work supplemented the missing information.

As I collected data, I picked a number of issues that were related to my study. These issues include misconceptions arising, the kind of feedback I was giving, the conversations that took place and the opportunities given by the task to highlight all the issues under question.

3.7 DATA ANALYSIS

I transcribed the recordings and first coded the misconceptions and later coded conversations and feedback. Hitchcock and Hughes (1995) warn that visual materials need to be "interrogated and interpreted" in order to make sense of them, and so I watched the video tape a number of times. Hatch (2002) defines data analysis as "a systematic search for meaning". Fisher (1999) defines analysis of qualitative data as:

> a highly technical process … time-consuming clerical tasks, going through the data to locate every time a particular issue is discussed, and trying to see connections to other issues and to other factors, such as the type of social situation under investigation…interplay between clerical rigor and intellectual creativity, a process so intense that few of us can maintain it at high levels for very long periods. (1999; 116-117).

The implication of this definition is that with the data I collected using the video recordings, I had to go through the data over and over trying to identify areas that I indicated as salient in this study. In my case, I started by transcribing my lessons and then coded the misconceptions that arose. My main interest was to decide how I responded to the misconception. As I continued looking at my responses I realized that in some cases I could have responded to the misconception in a particular way. I then coded the responses as either a 'missed opportunity

(MO)' or a 'seized opportunity (SO)'. Since my main interest was to look at how I give feedback, it was important to me to study the patterns of how I do this as it is central to the study.

Secondly, I looked at the mathematical processes that took place during the lessons. These processes are derived from a definition given about what constitutes an investigation by Laridon et al. (2005). There are thirteen processes in all namely; systematic exploration, systematic recording of data generated, use of suitable language and listening to peers, identification of patterns, formulation of conjectures, verification of conjectures, relationships, taking a leap towards a solution by a suitable guess, posing problems, asking questions which progress the investigation, use of special cases, use of counter examples and development of suitable notations. In task one I identified three processes that were exhibited by learners and in task 2 they were not so evident from the learners as there was a lot of scaffolding. This is discussed in detail in chapter 4.

I then focused on conversations that took place during lessons. Hufferd-Ackles, Fuson and Sherin (2004) implemented levels of conversations in the classroom which are level 0, representing traditional teaching, level 1, is where the teacher searches for mathematical thinking from learners but the role of the teacher still remaining dominant, level 2, learners are given some roles and finally, level 3, learners are taking leading roles in the discussions and they assist their peers. As I went through my lessons, I coded conversations according to the levels. The learners' work was also analyzed to find out whether the feedback used was effective.

Finally, I looked at the manner in which I give feedback based on Kulhavy and Stock (1989). I coded areas where there was evidence of verification or elaborated feedback. These two types of feedback as explained in chapter two, offered me an opportunity to analyze the manner in which I gave feedback and based on the advantages or the disadvantages of each type, made decisions that would guide me to bring improvement in my practice.

3.8 RIGOUR

When the study came to an end, it was satisfying for me to know that finally it will be useful to myself and others who might also benefit from it. This can only happen if my findings are reliable, valid and credible. In this section I will explain what this means. This does not necessarily mean that this study can offer generalizations about my practices but rather that individuals can learn from my practices, avoiding the mistakes and learning from the good practices.

Reliability is when a method or procedure consistently gives the same results in different settings or conditions (Cohen, Manion and Morrison, 2000 and Wellington in Opie, 2006). I knew that Research is considered "good" and "respectable" when reliability is evident (Opie, 2006). Cohen et al. (2000) and (Opie, 2006) argue that results found from research need to be consistent over time when using similar samples, otherwise the conditions would also change and this is contrary to what should be the case with reliability. Based on the fact that the study was in a classroom situation where repetition of similar conditions is not part of the research design. I did not base the judgement of my research on this attribute but on subsequent attributes.

Validity is when a method or procedure measures what it intends to measure (Wellington, 2000). Assessing the validity of my study requires me to focus on the relationship between the claims I generate and the whole process of data gathering including what is in the literature. This data should be suitable if I want to declare that a particular claim is valid (Opie, 2006). In order to support validity, triangulation needs to be done. Triangulation is the use of two or more methods of data collection with an intention to ascertain that conclusions drawn from the different methods yield similar results (Cohen et al., 2000). In this study, video recording was the main method used to collect data, however, the work done by learners also provided me with data that I used to understand my interaction with the learners. This implies that whatever claim I make should be evident in the data collected as well as in the literature. According to the above explanations, it is important to be cautious in the manner in which I make my claims and state my findings as I focused on my class and my teaching. I also took into consideration content validity where I needed to establish that issues dealing with feedback, conversations,

investigations and misconceptions were represented appropriately (Cohen et al., 2000). I did this by ensuring that the issues dealt with are fairly represented by covering literature widely.

In order that those who read this study should pay attention to the findings and take account of them, the study should be credible. In short, a study is credible if there is transparency in data collection and procedures are explained with biases acknowledged. Moreover data which may conflict with claims should also be reported (Opie, 2006). I have reported clearly the methods used for data collection as video recording. I also identified problems such as inaudible voices on the videotapes that were not expected. The purpose of mentioning these instances is so that the reader can make informed decisions whether the claims made are valid in my reporting of results taking into consideration all the discrepancies that occurred. Triangulation also ensures credibility as stated by (Opie, 2006).

3.9 ETHICS

For ethical purposes, I requested permission from the Gauteng Department of Education and the principal of my school to conduct the study. I also applied to the Wits University Ethics Committee for research on human subjects to approve the study. I received permission from all the mentioned institutions and my protocol number from Wits is 2008ECE231. Information about the study was given to learners and their parents through letters and their consent was requested and obtained.

When writing the data analysis and results I kept the identity of my school and the learners anonymous. The videos and transcripts will be used only for educational purposes where such permission was granted by participants. The manner in which I treated the learners was fair and honest. I was open about the intentions for the study, methods used and the aims for the research were disclosed to the participants (Leedy, 1997). Learners' integrity was respected and their privacy guaranteed. Learners were by no means humiliated, embarrassed, nor were there any violations of ethical standards (Leedy, 1997). I did not collect data for any reason other than that which for the research was intended. McKinney (2005) expressed similar issues I had in relation to my teaching in that there were ethical dilemmas that cropped up due to what I actually did and

what I thought I did. During analysis, I was surprised at some of the issues that I discovered I did which were in contrast to what I have studied and espoused to do. For example, there are moments where I spoke for long periods of time without involving the learners and on reflecting, I realized that this was in contrast to what I intended. The implication is that there might be other things that I may have done but in my analysis I did not pick them up as problems because I am involved as a researcher and a subject of the research. Action research becomes difficult in this way as I may not totally be as objective as I should be.

3.10 CONCLUSION

I have explained in this chapter the methodology followed in this study. The manner in which data was collected has been discussed. I mainly used the video recordings and collected the learners' work. Issues of rigour and ethics have also been considered and conclusions that were made from this study hopefully will not only assist me, but will also assist many other educators who might be going through similar experiences. For this support to be available, the study was conducted in ways fitting to a valid and credible research project. In the next chapter I will analyze the data that I have collected.

CHAPTER 4

ANALYSIS OF DATA

4.1 INTRODUCTION

In this chapter I will analyse the four areas of my study. First I analyzed the investigation by using the different mathematical processes exhibited by learners. With regard to giving feedback, I use Kulhavy and Stock's (1989) framework. I will look at whether elaboration feedback was specific and directive or general and facilitative. Feedback will be analyzed in two areas; during whole class discussions and learners' work. When giving feedback, conversations between the learners and I took place and misconceptions arose during these conversations. Regarding misconceptions I focused on the opportunities that I used when a misconception arose, the prior learning required for learners to master the topic and the interventions that can be implemented for the misconceptions that occurred. In my analysis I will put a spotlight on the four components of conversations as highlighted by Hufferd-Ackles et al. (2004) and hence be able to make conclusions about the classroom conversations and the level at which each component lies.

4.2 Investigations

In this section I focus mainly on analyzing learners' written work. Firstly I will establish which mathematical processes are present in the task (Perie, 1987 and Laridon et al., 2005). Then I will discuss areas where these processes are evident.

In order to understand learners' explorations, I looked at how the questions gave opportunities for learners to explore. In question 1, learners were instructed to measure angles and lengths and fold the shapes as they may decide. It is clear in that instruction that results expected would not be the same as some learners would measure only the vertices, while others may decide to measure angles between the diagonals at the vertices or at the point of the intersection of the diagonals. Some learners may have measured only the complete length of the diagonal while others might also have measured the lengths from the vertices to the centre and from the centre to the vertices.

In task one I recognized three mathematical processes: 1.) systematic exploration, 2.) systematic recording of data generated and 3.) the use of suitable language and listening to peers. Table 4.1 below shows incidences where these processes were evident during the lesson. I have stated them as they appear in Laridon et al.'s definition in chapter two.

Mathematical processes	**Incidents showing evidence of the skill**
i) systematic exploration,	Learners looking for the meaning of diagonal in the dictionary
	Learners measuring the diagonals
	Learners looking for line of symmetry in the dictionary
	Learners folding shapes to find-out about lines of symmetry
	Learners rotating shapes to find rotational symmetry (no evidence on video)
	Measuring angles
	Measuring sides
ii) systematic recording of data generated,	Evidence on written work
iii) use of suitable language and listening to peers	Angles are going the same direction Angles are perpendicular Angles are obtuse

Table 4.1 Mathematical processes exhibited by learners.

i) Systematic exploration

The process of systematic exploration was evident both during the lesson and in learners' written work. What is shown on the table is what was observed during the lesson. It is evident that learners explored with the different aspects of the shapes given. For instance, they used the dictionary to look for meanings of words they did not understand. These were words such as diagonal and axis of symmetry. In some cases I still needed to explain the words even after they used the dictionary. It is evident from their written work that even after explaining the words, some did not use them appropriately in their reports.

The investigation enabled learners to explore and search for meanings of concepts that were not familiar to them. As learners explored these meanings, they realized that concepts they held

earlier were incorrect or inappropriate hence they wanted to change those ideas for new correct ones. The extract below shows how Kedibone[5] struggled with the meaning of axis of symmetry.

> **Teacher:** ...I saw that some were looking for the axes of symmetry, did you finally understand what it means?
> **Kedibone:** According to our understanding mam, we've written that the axis of symmetry ...inaudible...why because each angle is about 7cm then we added, we added eh...
> **Teacher:** Which angle?
>
> **Kedibone:** Those four ones.
> **Teacher:** This angle?
> **Kedibone:** Yes 7+7+7+7 gave us 28.
> **Teacher:** Which angle gave you that?
> **Kedibone:** 28cm
> **Teacher:** Are we talking of the distance or the angle, the distance or the angle? Alright, remember the angle is that amount of turn between the two arms and usually we measure it in what? What do we use to measure angles, can you use a ruler to measure an angle? What do we use?
> **After explaining what an angle is, later an explanation about axis of symmetry was made.**
> **Teacher:** Axis of symmetry, when you fold your square or any shape and you fold it such that half of that shape fits exactly onto the other half, that line where you are folding, the folding line is your axis of symmetry.

As more discussions ensued, Kedibone's perception about the axis of symmetry changed as she correctly answered the lines of symmetry of the rhombus, the kite, and the parallelogram. For the two shapes where learners answered the question on symmetry relying on their understanding from the dictionary, Kedibone had written "28cm axes" for the square and "4 lines" for the

[5] All names used are pseudonyms.

rectangle. The two answers show that Kedibone's understanding of the axis of symmetry was incorrect but later on after feedback was given, she correctly answered the three lines of symmetry of the remaining four shapes. It is evident that, even though learners are given a chance to explore a new concept, they may end up with incorrect information, which is why feedback is crucial. The results of learners' performance show that there was some understanding of axis of symmetry although they still needed more understanding to be able to find any axis of symmetry without a struggle.

ii) Systematic recording of data

There were five aspects that learners had to record information on for each shape, these were the sides of the shape, the angles, the diagonals, the axis of symmetry and the rotational symmetry. Nine learners of the twenty-three who submitted their work, wrote two or more points on each aspect required. The rest of the learners simply recorded an answer to the questions with one phrase or sentence which indicated an inadequate recording of data collected.

There was a lot of measuring that needed to take place, e.g. measuring sides, angles and diagonals. As much as there was this measuring of sides, learners often did not measure aspects that would assist them understand properties of the given shapes. For instance, in the work shown in fig 4.1 below, the learner focused mainly on measuring different lengths of the square, which did not necessarily help him to answer questions relating to the diagonal of the square. Since the learner did not measure the diagonals, he could not say much about them. This was the only learner who showed measurements of the lengths inside the shape, other learners simply drew the lines but did not show the measurements. Although learners did not show the measurements I cannot conclude that they did not measure because there are learners who correctly answered that the diagonals of a rhombus are not equal as shown in fig. 4.2. Nevertheless, these learners were puzzled during feedback when other learners said the diagonals of a rhombus are equal. I had to direct all learners to measure and verify that the diagonals of a rhombus are not equal.

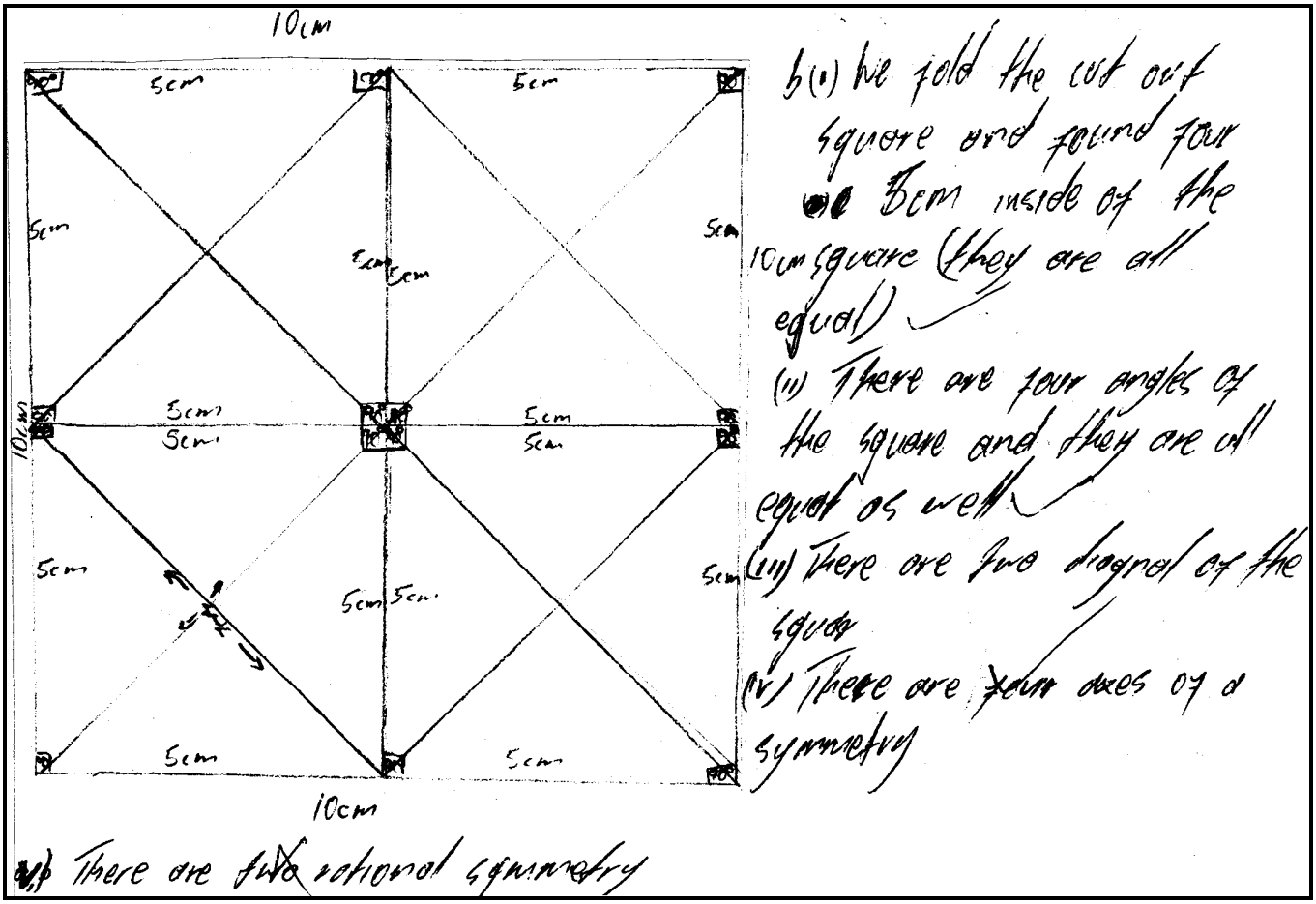


Figure 4.1 Moseti's measurements

In figure 4.2 the learner also measured the rhombus but this time the lengths of diagonals were measured. Although the learner has indicated on the figure the lengths from one vertex to the point of intersection of the two diagonals, he failed to use that information to mention that the diagonals bisect each other but are not equal. The learner simply stated that the rhombus has two diagonals and nothing else further. Another observation is that the learner focused more on recording the measurements of sides both in the square and the rhombus and did not record measurements of angles in a rhombus. One would assume that since the interior angles of the shapes done previously (the square and the rectangle) were 90°, Moseti would also measure the interior angles of the rhombus to find out more about them. Instead, he only recorded the number of angles and that of diagonals. Moseti recorded the angles of intersection of the diagonals of a square but did not mention that the diagonals are perpendicular. Steven (fig. 4.3) indicated that

the diagonals are perpendicular even though there is no evidence of recordings on shapes. His information on angles is misleading as he does not use appropriate notation for naming angles, hence making it difficult to know whether the measurements given are accurate or not.

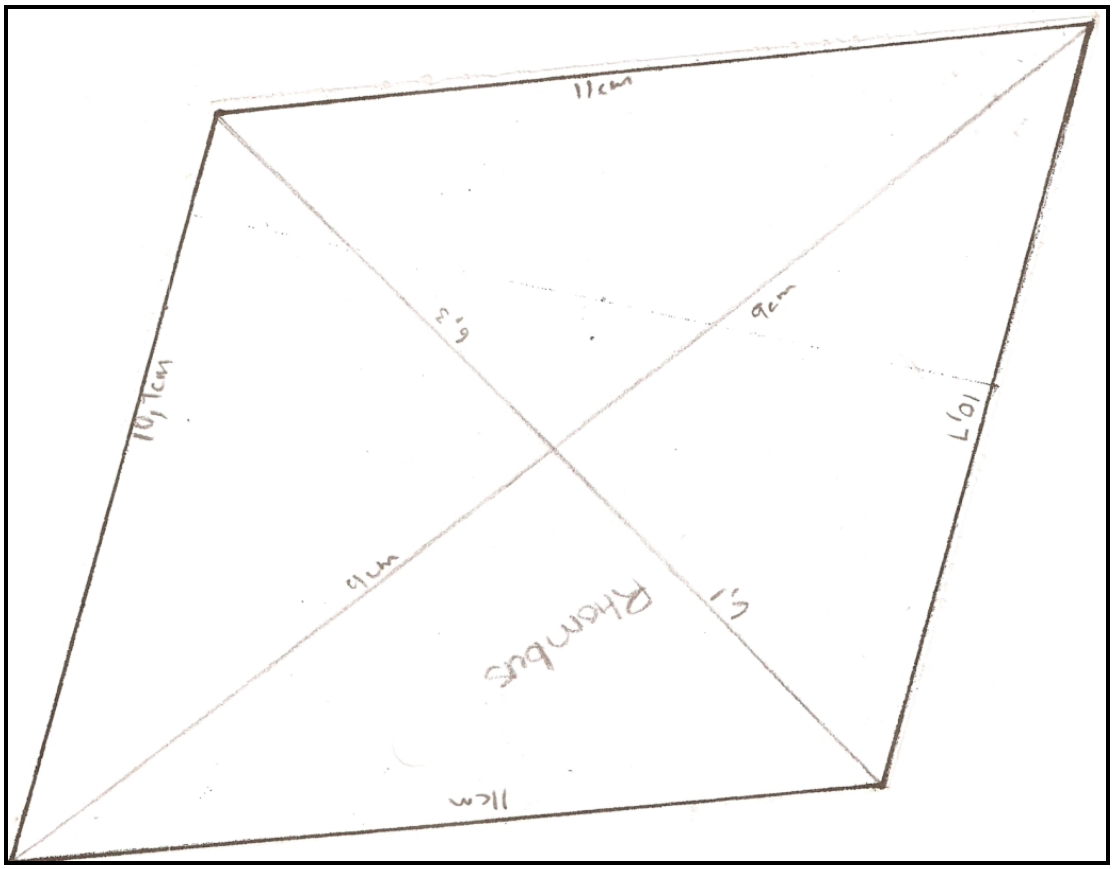


Figure 4.2 Moseti's Rhombus

An observation here is that it may not be very clear what learners are expected to do with the data collected. It was noted earlier that an investigation is not an activity where learners use a prescribed route to an answer by repeatedly practicing a skill (Costello, 1991). Exploration is key in investigations but if it cannot bring out characteristics such as development of individual strategies, the generation of answers to the problem and the suggestion of other questions to investigate, then the investigation loses its essence (Costello, 1991). As Costello (1991) mentions the "problem" it is clear that this particular investigation did not highlight a specific problem that learners needed to answer. Learners were therefore left to whatever seemed fit for them to do with the information collected. Learners needed to know the purpose of collecting the

information so that they could recognize aspects that were elicited by such information. In fig. 4.1, we can see that the learner explored measurement of sides but failed to make meaningful contributions from the information he gathered.

Perie (1987) stated a few things an investigation is not: it is not an activity where learners are to use a prescribed route to a specific answer or a task with an intention to repeatedly practice a skill. When analyzing the task, it is clear that as much as instructions were given, the learners could use their own discretion on how to approach the problem and there is no specific answer expected and no particular route has to be followed. The second mathematical process identified is systematic recording of data generated. Learners needed to understand that after data is collected, it is recorded in ways that it will be easy to see patterns and make interpretations from it. There are different ways of doing this depending on the type of data being collected. In this particular case, drawings showing measurements of sides, angles and diagonals and folding on the lines of symmetry could be one way.

Tables could also make it easier to read information. On the first day of writing, learners simply answered questions that were asked without exploring each aspect more deeply. After giving feedback on their work, where I recorded the information on a table, only two of the learners recorded their subsequent work on tables. Learners were given this alternative way of recording so that they can also use it. The rubric indicated that "data collected is organized neatly and can be interpreted e.g. use of a table." Learners were guided sufficiently about how they could record their data. During the beginning of the lesson, learners were also told to read the rubric and follow it carefully so that they could score as many marks as possible. It is difficult to conclude why only two learners used a table. One of the possibilities could be that it takes time for learners to acquire these skills and learners should be made aware of the importance of such skills. The fig. 4.3 below shows Steven's table. On this table, Steven was able to record two or more aspects under each category although some are not necessarily giving a property of the particular shape. For example, under angle, he simply records different angles he measured and does not mention whether the angles are all equal or two opposite angles are equal.

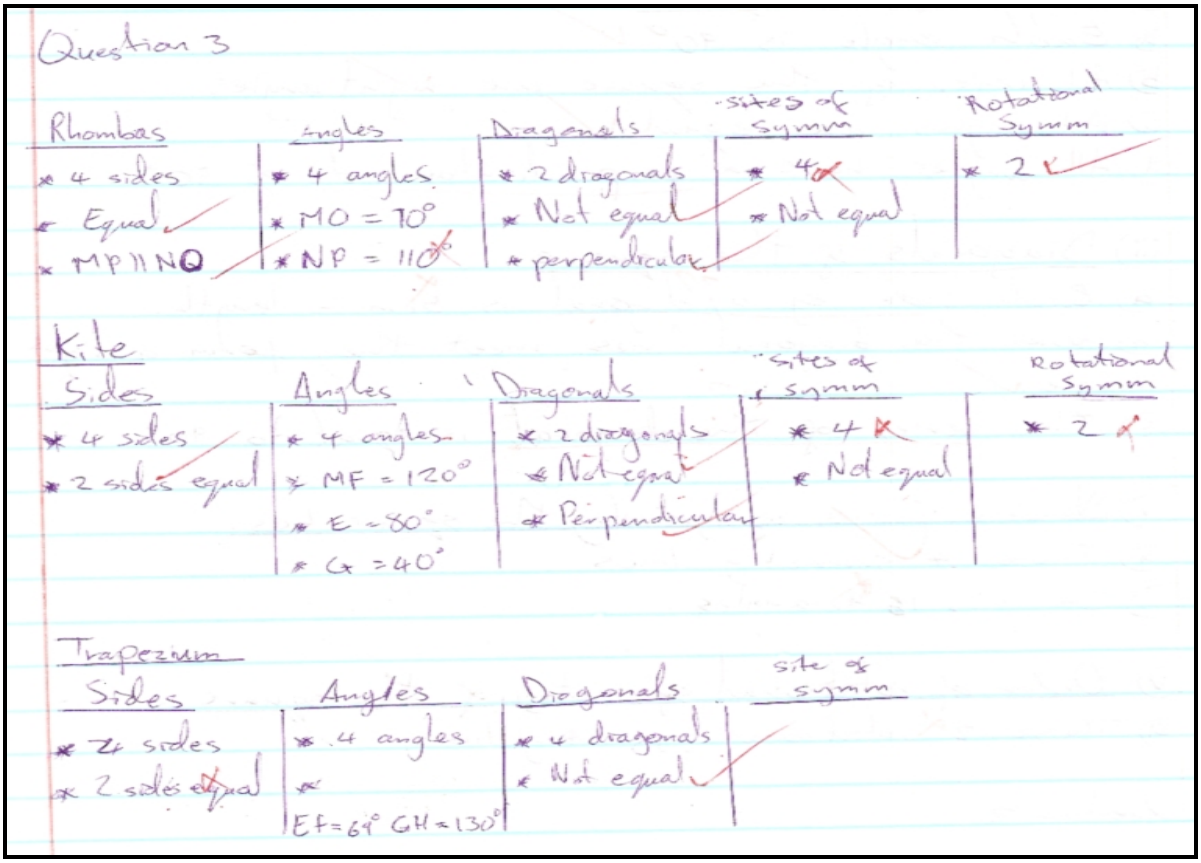


Figure 4.3 Steven's Tables

Steven is one of the learners who decided to use tables for collecting his data. Although his recording has not captured useful information in some aspects, it is evident that information is much easier to access when recorded on a table. There are learners who did not use tables but still collected valuable information for each area of interest. Their information is not as easily accessible as when it is on a table. Moseti's information can be seen in fig 4.1 and he makes his summaries next to the diagram he drew. It is not so clear what the summaries are, hence it shows that information is not easily accessible.

iii) ***Language***

Appropriate mathematical language in the classroom needs to be fostered at all times. It is important that learners develop accurate ways of communicating mathematically. Besides incidents where I have already discussed that learners used dictionaries to find words which they

did not find familiar, there are cases where learners used mathematical terms either correctly or incorrectly and I will show these examples. In the extract below, learners had to mention how they can tell that two lines are parallel. We were discussing the properties of a rhombus at this stage.

Teacher: ... How can you conclude that they are parallel then, Katlego?
Katlego: Inaudible
Teacher: M and N as well? Do after measuring as well, what did you say, that they are parallel? These angles are equal, all of them M,N,O and P.
(Tumisang inaudible)
Teacher: M and O are? They are going to the same direction, in what sense?
Tumisang: Inaudible
Teacher: They are equal and, what do you mean they are going in the same direction?
Tumisang: The lines
Teacher: Ok, which lines?

Although learners were not audible on the video recorder, since I was repeating their answers, it is understandable that in this incidence Katlego was saying that lines M and O (incorrect use of notation for naming sides) are going in the same direction (the learner could also be using direction because of the notation of arrows used to show parallel lines) because I even asked "in what sense?". When the discussion continued later on, the learner corrected himself by saying 'the lines'. It can be assumed here that the learner used M and O as symbols for lines whereas they represent angles. It therefore indicates that at the point in time I might not have understood the reason for the learner mentioning that 'they are going to the same direction' was referring to the lines not the angles and while the learner was thinking correctly, he expressed himself incorrectly. It is evident therefore that I missed the opportunity to close the gap of using symbols appropriately. As shown in the extract above, there were other incidents where learners used some words inappropriately and having conversations helped learners to listen to proper ways of communicating mathematically and have the opportunity to refine their use of language. Since listening to peers falls under the same mathematical process with the use of suitable language I

included it in Table 4.1 but will not comment on it as most of the learner conversations were not audible on the tape.

From the analysis done on the investigations, I found that in all the three mathematical processes identified during the discussions, learners acquired some skills. In the process of systematic exploration, learners explored with the dictionary and made mistakes, but feedback assisted them to correct their mistakes. In systematic recording of data, learners started recording the answers very briefly and only after feedback some learners measured and/or recorded data that could assist with understanding the properties of the given shapes. With the last mathematical process, the use of suitable language and listening to peers, learners were using mathematical language inappropriately but after feedback there were changes and learners could even correct themselves when using incorrect language. After analyzing the investigation, I analyzed my giving feedback on the work learners did.

4.3 FEEDBACK

There are two types of elaboration feedback I discussed in chapter 2. These are directive feedback and facilitative feedback. Directive feedback addresses the topic, responses and discussions and in facilitative feedback worked examples and guidance are given and information on misconceptions is also given Shute (2008). I coded all areas where I identified directive feedback and facilitative feedback. There were seventeen occurrences of directive feedback and eight occurrences of facilitative feedback.

As I interacted with my learners, I would realize gaps that hindered learners to progress in their learning and as this happened, I would have to present information addressing a certain concept or skill that learners needed (Shute, 2008). For example, in a case where learners had to give the property of the diagonals of a rhombus at the point of intersection, learners could not respond so I had to explain the concept of lines that bisect each other and are also perpendicular. These are concepts that they needed to use for every shape and be familiar with at all times. My explanation here is only targeting these concepts, therefore feedback in this case is directive.

Directive feedback sometimes focuses on the response of the learner indicating why an answer is incorrect or correct. In one instance learners debated a lot on the number of axes of symmetry in a rhombus, after a number of attempts by different learners trying to demonstrate how to find the axes of symmetry, I finally resolved to show them by folding the square once more and drawing on the board the axis of symmetry and then showed them how they should find the axis of symmetry of a rhombus. Some of the mistakes that learners made were to fold on the same folding by just reversing the sides. I then had to explain to them that the same fold only counts as one axis of symmetry.

There are times when I avoided explicitly giving directive feedback. In such instances I would guide the learners to give the correct answer through some guidance. Shute (2008) refers to this kind of feedback as facilitative feedback. It also gives information about learners' misconceptions. There was an instance where learners had differing views about whether the diagonals of a rhombus were equal or not. The learner who insisted that the diagonals are not equal was a very shy and quiet learner and others were vocal about diagonals being equal. I then asked them to measure the diagonals and they realized that they were incorrect. So they got to the correct answer without having to be given the answer but they found the correct answer by themselves. Another way of giving feedback is to give a hint or some guidance, for example, there was an incident where learners had to find properties of a square relating to its diagonals. When asking them to tell what they found about diagonals, there was no immediate response. I drew a square on the chalkboard and labeled it ABCD and asked them to indicate the diagonal. The learners mentioned that AC and BD are diagonals. My observation here is that sometimes even when the learners know a concept, they struggled to explain it, hence the use of a diagram to assist them to respond to my question. In this way learners are given some guidance.

In other instances where learners had misconceptions, feedback would give information about those misconceptions. There was a time when Kedibone repeated a misconception about angles. In the first instance she said "each angle is about 7cm" as indicated in the extract discussed earlier. In the second instance, when illustrating on the board that the angles of a parallelogram are all obtuse, she pointed to a side AD. I had to indicate to her that an angle lies between two lines and is not a line as she was indicating. What is interesting is that the learner understands the

meaning of obtuse but describes it as from one point to another. This shows that the learner had a misconception about what an angle is and I reminded her of the earlier instance and what I said but also showed on the diagram the amount of turn representing an angle.

The incidents mentioned above show that feedback given to learners can either give information that explains a certain concept that addresses the topic or addresses the response of a learner which is directive feedback. Feedback can also give a hint or address a particular misconception, this kind of feedback is facilitative. I have shown that I used more directive feedback than facilitative feedback. This might have been caused by the fact that learners had many gaps in this particular topic and many concepts that were necessary had to be either re-taught or learners had to search for the meanings of the concepts. Facilitative feedback takes a similar description of "facilitator" where Staples (2007:6) describes facilitator as having an image of reform teaching where teachers avoid 'telling'. The problem of 'not telling', as she points out, is that teachers may lose out on developing 'inquiry mathematics'.

4.4 MISCONCEPTIONS

There were a few misconceptions that were elicited as learners gave their contributions. I take it to be an opportunity for a teacher when misconceptions arise because they can be dealt with. In my teaching I realized that I did not treat the opportunities in the same way. There were times when I addressed the misconception and there were times even when I thought I addressed them, and during coding I realized that I did not do it in ways that would assist learners. In the following section, I will discuss how I coded the misconceptions and what I found out about the manner in which I treated them.

4.4.1 Seized and Missed Opportunities

The categories I used for misconceptions that surfaced in the investigation were based on how I responded to them since my main focus was on giving feedback. As I identified the misconceptions, I realized that there were times where an opportunity arose for me to address the misconception. I then coded my responses as either missing the opportunity (**MO**) or seizing the opportunity (**SO**). There is still another issue to deal with; this is how I respond to the

misconceptions. I did this by supporting learners to reflect on their thinking with the hope that the misconceptions will be refined and ultimately transformed. In this way I gave facilitative feedback. Seven misconceptions arose during the six lessons conducted. Table 4.2 below shows the misconceptions that arose, how I dealt with them and whether they are missed opportunities (MO) or seized opportunities (SO). The first four are the MO's and then follow the SO's.

Misconception	Method of dealing with it	Finding facts	Deduction
1. Sides of a square are equal because they add up to 10cm	Finding out what the learner really meant by asking questions	The learner did not add at all	Not clear why the learner mentioned adding. Did not try to find out why she mentioned addition (MO)
2. Angle of intersection of diagonals is 5cm	Try to find out if learners measured	The learner might not have measured but assumed that it is 5cm since the sides are 10cm	The learner could have been asked to explain where he got the 5 from (MO)
3. Co-interior angles are $90°$	Proceeded to the issue of transversal line	Learners led to the answer by reminding them about co-interior angles	Learners could have been asked to work out the sum of their co-interior angles (MO)
4. Angles are perpendicular	Clarification of the question was made	The learner might still not understand perpendicular lines	Learners could have been asked to draw two perpendicular lines (MO)
5. Axis of symmetry...each angle is about 7cm ,… the distance of the angles	Try to find which angles by asking questions	The learner lacks the concept of what an angle is	Explained what an angle is (SO)
6. 7's are degrees	Questioning what instrument is used for measuring angles	The learner lacks the concept of what an angle is	The difference between angle and length given (SO)
7. Parallel lines are equal	Two lines not parallel and other two parallel ones are drawn to show the difference	The learner then says they are not parallel because they meet	The illustration seems to have worked, the issue of equal distances is emphasized (SO)

Table 4.2 Elicited Misconceptions

It can be noted from the information above that there were four MO's and three SO's. I first discuss the MO's. In the first misconception, I still have a question as to why the learner spoke of adding the sides initially and even after some probing she still talked about adding, which shows that it was not just a mistake. I still think if I asked the question 'why did you say you added?' then I could have understood the learner better. I have a suspicion that there could be something going on in the learner's mind such that the questions asked may have not been elicited. It may also be an indication of an underlying misconception which might persist as time goes on. This is the reason why I classified this as a MO. Although I failed to adequately deal with the

misconception, I would say that the learner was given a chance to reflect on her own thinking to some extent because finally she mentioned that she did not add.

In the second misconception, the learner did not only give an incorrect answer but is also using inappropriate language. But I assume that the learner mentioned 5 cm because we were talking about the diagonals of a square whose sides were 10 cm. The learner might have then thought that if the length is 10cm, then half of the diagonal will be 5 cm. It would have been an opportunity to ask learners to use Pythagoras theorem to find the length of the diagonal so that learners can make connections with other sections already learned. Learners would not only realize through calculation the length of the diagonal but they would also measure the diagonal to confirm their answer. Kedibone wrote half of the diagonal as 7cm whereas some learners wrote 5 cm. By using Pythagoras they would find that $\sqrt{r^2} = 10^2 + 10^2 = \sqrt{200} \approx 14cm$. Learners who wrote 5cm as half of the diagonal could have recognized their mistake and also learned different ways of checking their accuracy.

In the third misconception, the learner talked about perpendicular angles instead of co-interior angles. I just told the learner to remember what perpendicular means and proceeded to inquire about co-interior angles. Had I drawn the rhombus and showed them the co-interior angles and asked them to add them, learners could have had a much better understanding, not only of the co-interior angles, but would also make connections with concepts done earlier. The fourth misconception is related with the third one, in that the learner talked about the perpendicular angles. When asked about co-interior angles, I have already shown that I did not attend to the learner adequately. What I could have done could be to ask learners to draw two perpendicular lines or even use the square and the rectangle to identify perpendicular lines. Learners would then have an opportunity to realize that lines can be perpendicular not angles. The aspect of perpendicular could be highlighted even further when dealing with other shapes.

Misconception five from the table shows the incident discussed in the first extract where Kedibone has a misconception about an angle. This was classified as a seized opportunity because I explained what an angle is and asked learners to say what is used to measure an angle

so that they can realize that length and angle are two different measurements. Although I classified misconception five under SO because the misconception was addressed, it is evident that the learner's misconception was not adequately dealt with as it persisted. The question I asked myself is why the misconception persisted. Smith et al. (1993) alluded to the fact that if only a correct answer is given, then the misconception is simply pushed underground. An appropriate intervention could have been used but it shows that I did not practice what I knew. This is proof that one does not always do what they necessarily know when teaching (McKinney, 2005).

The next misconception is also related to the fifth one in that she still confuses length with angles. My intervention here was to remind the learner of the instruments that measure both the length and the distance by asking her to mention them. I then later gave the difference between the length and the angle. The last misconception was a SO because I drew two pairs of lines, one pair with lines that were not parallel and the other pair with lines that were parallel. In our discussion, learners had to identify which pair is parallel and find out how it differs from the one that is not.

In their definition, Smith et al. (1993) point out that misconceptions arise from prior knowledge. It is true that to deal with misconceptions completely, is a process. Nonetheless, if appropriate interventions are taken, then there is hope that learners will ultimately reach conceptual change. It is well and good for these misconceptions to be elicited, but if appropriate ways of dealing with them are not implemented, there is little hope for learners' misconceptions to be corrected.

The teacher needs to be equipped at all times to deal with misconceptions in ways that will assist learners to rethink how they understand certain concepts. Sometimes one can be caught unsuspecting as in my case when I found that the learner understood an angle in a different way, and in such cases it is important to assist learners to reflect on their thinking as suggested in the literature. As we discussed the concept of an angle, the other learners could also be given an opportunity to contribute by the teacher redirecting the question. This did not happen in my lesson. It again shows that one should be prepared at all times to come up with innovative ways

to deal with misconceptions successfully and that a lot of practice in doing this is required for teachers.

4.4.2 Interventions dealing with misconceptions

There are interventions suggested by different authors with respect to dealing with misconceptions. These interventions were discussed in depth in chapter 2. The table below shows evidence of these interventions during the six lessons conducted.

Misconceptions	Discussing misconceptions (Swan, 2001)	Learners' reflective thoughts (Van de Walle, 1991)
1. Sides of a square are equal because they add up to 10cm (MO)	"Did you add anything?"	"No, each side, we found that each side is 10cm, so they are equal "
2. Angle of intersection of diagonals is 5cm (by another learner not Morena) (MO)	"Did you try to measure angles where they cut, Morena? (response over looked)	Learner could not reflect because he was not asked what he meant
3. Co-interior angles are $90°$ (MO)	"What do we call angles in these positions?"	"Co-interior angles" response by another learner
4. Angles are Perpendicular (MO)	"What do we call angles in this position?"	I explained what I am referring to and did not address perpendicular lines
5. Axis of symmetry...each angle is about 7cm ,… the distance of the angles (SO)	"What is the axis of symmetry?"	After explanations learner was not asked a related question
6. 7's are degrees (SO)	Those 7's are what?	After explanations learner was not asked a related question
7. Parallel lines are equal (SO)	"How do we check that two lines are parallel"	"I think parallel lines is having a line on top and the second line..."(she makes gestures with her hands)

Table 4.3 Interventions

I start firstly by discussing misconceptions that were not adequately addressed (Dark shading) and these are the second and the seventh misconceptions. In these cases, it is difficult to tell whether learners' 'flawed conceptions' (Smith et al.; 1993) have been dealt with as not enough

time was given to address the misconception. When considering the second misconception and analysing learners' work, I found that Moseti was the only learner who recorded measurements on his shapes, there are a few learners who did not submit their shapes and I am not sure if they recorded measurements in those shapes. Some learners showed measurements on their work given in response to questions that required them to measure the sides of the shapes. Learners simply gave the lengths of the sides of the shapes. These answers may indicate that learners did not understand the concept of diagonal lines properly. Even the fact that some learners found the diagonals of the rhombus not to be equal but failed to strongly stand their ground when others stated otherwise indicates that they were not yet confident with their answer. Another conclusion I could make is that learners still need time to develop the mathematical process of collecting data that is adequate for them to make conclusions.

Task 1, question 4b) requires learners to decide whether diagonals are perpendicular or not. When focussing on the second misconception the issue of intersecting lines was not sufficiently addressed. Angles at a point of intersection are very important for this particular topic. Due to the fact that it was not addressed adequately, it may be difficult for learners to form relevant concepts as the instruction progresses. Two learners correctly identified all the shapes where diagonals are perpendicular. Three identified the square and the rhombus and not the kite. The rest of the learners either showed all diagonals of the shapes being perpendicular or incorrectly identified the rectangle or the parallelogram or both as having their diagonals perpendicular. From this breakdown, it is evident that learners had no clear understanding of perpendicular lines and I missed the opportunity to deal with it even when their misconception was elicited. It is crucial therefore to note that it is not enough only to welcome learners' misconceptions but they need to be addressed.

The seventh misconception was also not adequately addressed and it involved perpendicular lines. The learner in this instance refers to "perpendicular angle". Had this misconception been dealt with, it would have not only unravelled the issue of "perpendicular angle" but the concept of angle would have been addressed. Misconceptions two, four and six, show that learners are still grappling with the concept of angle. The way in which they interpreted an angle is consistent

throughout the lessons. Learners perceive an angle as length. Even after an explanation of what an angle is was given, it did not make any difference to the learners.

The persistence of the misconceptions confirm what Smith et al. (1993) highlighted, that merely explaining a concept does not always deal with a misconception but may simply push it underground. In the first and sixth misconceptions where less than two minutes was spent in discussing the misconceptions, my interpretation would be that learners might have made mistakes more that having misconception because firstly, it did not take too long for the learners to provide positive responses but their responses reflected the fact that they realized the correct answer.

With misconception five and seven where more time for discussion was given, learners gave appropriate responses and this carried on even later during the subsequent lessons. The results in the table below indicate the performance of learners when answering question 1b) iv), 2b) iv) and 3b) iv) about finding the number of axis of symmetry for each shape (misconception 5).

Shape	**Correct responses**	**%**	**Incorrect Responses**	**%**	**No Response Given**	**%**
Square	11	48	12	52	0	0
Rectangle	9	39	11	48	3	13
Rhombus	11	48	11	48	1	4
Parallelogram	17	74	1	4	5	22
Kite	15	65	7	30	1	4
Trapezium	4	17	16	70	3	13
Average	**11**	**49**	**10**	**42**	**2**	**9**

Table 4.4 Responses for finding the number of axes of symmetry for the six shapes

As I continued analyzing learners work, I was interested to find out how learners performed in cases where a misconception arose and I adequately dealt with it. From the table above it can be

noted that “correct” responses are slightly lower than the “incorrect” and “no response” combined. There is no definite conclusion I can make from these results as the differences between “correct” and “incorrect and no response” is not significant. However, the fact that almost 50% of the responses were accurate, points out that there was a satisfactory development of the concept of symmetry as compared to when learners started working on the concept. I would hope that with time learners’ understanding would improve even further.

In this section I discussed different responses to misconceptions: seized opportunities and missed opportunities. I firstly discussed MO and then came to SO. I realized that there were interventions I could have implemented after the misconception was elicited but instead I either asked questions which ultimately did not address the misconception or I just moved on to something else. These responses from my side indicate that when a misconception is elicited it takes skill and quick thinking to treat the misconception appropriately. I hope with time, now that I have discovered my weakness in this area, I will pay more attention to it.

With SO’s, I also realized that although learners’ misconceptions were dealt with, there is no immediate change in terms of how the learners interact with a particular concept. Nevertheless, in addition to applying strategies such as discussing the misconception or asking learners to reflect on their thoughts it may take some time for learners to formulate new concepts (Swan, 2001). When discussing interventions dealing with misconceptions, I analyzed the manner in which learners answered questions 1b) iv), 2b) iv) and 3b) iv). My observation was that 49% of the learners responded accurately to the questions. The reason I focused on this misconception was that more time was taken in dealing with the misconception. Swan (2001) argues that teachers are at times reluctant to discuss misconceptions for fear of waste of time. The results obtained above may be an indication of hope that the time taken to discuss the misconception may ultimately pay off when the chances of the same misconception recurring over and over are reduced. Although generalizations cannot be made due to the scale of this research and the limited number of subjects involved, there are aspects that indicate reason for change of behaviour in dealing with misconceptions.

4.5 CATEGORIES OF CONVERSATIONS

In this section, I discuss the four components of conversations that were presented in chapter 2 (Hufferd-Ackles et al., 2004). These components are evident in a class where math-talk is practiced as Hufferd-Ackles et al. (2004) indicate. I discuss questioning, and then explaining mathematical thinking followed by sources of mathematical ideas and lastly the responsibility for learning. Each component has been graded into four levels starting with the lowest level, zero and the highest being three. I will give brief descriptions of the levels and examples that I took from my lessons.

4.5.1 Questioning

Firstly, I coded all questions so that I could identify the levels of questioning which would then determine the extent to which learners' thinking was encouraged. The table below indicates the number of questions asked in each lesson and the level at which the questions were asked as classified in the framework. In the component of questioning, Level 0 represents answers made in one or few words or the teachers give answers to their own questions. In level 1 the teacher begins to ask the "why" and "how" questions. For example, in lesson 4, I asked a question, "Monare can you show us how you are doing your axis of symmetry?" The question in this case was rated level 1. Another example of level one is where learners were asked why a decision was made that lines are parallel. Level 0 is represented by questions such as "Which ones are parallel?" and "what is a diagonal line?"

	Total No. Of Question	Level 0	Level 1	Level 2	Level 3
Lesson 1	5	4	1		
Lesson 2	28	27	1		
Lesson 3	0				
Lesson 4	23	16	7		
Lesson 5	3	3			
Lesson 6	0				
Total	**59**	**50**	**9**		

Table 4.5 Levels of questions asked in different lessons.

As I explained earlier, every second lesson was planned for whole-class discussions and this is where most of the questions were asked. In lesson 3 and 6, learners spent the whole period working hence there were no questions asked except in the small groups which are not analyzed here. It is clear that in the first whole-class discussion, learners were not yet familiar with the topic so the questions were answered in one word or at times the teacher had to answer them, as is usually the case in level 0.

In lesson 4, there was a greater percentage of questions in level 1 and this indicates that learners could interact at a slightly higher level as they became more familiar with the topic. The percentage of questions asked at level 1 in all the lessons was 15% whereas it was almost double that percentage in lesson 4. In lesson 4, the focus was on the properties of the rhombus, and the parallelogram. Learners at this stage had had some time discussing properties of the square and the rectangle. It shows then that they could engage more in this lesson through the scaffolding received in lesson 2. Although the "how" question was asked, the learners did not necessarily address it, which indicates that although the level of questioning is at level 1, the learners' responses are not yet there. It was noted that learners only spoke in response to the questions asked. There was no initiation of math-talk by the learners. Learners did not reach the level where they asked questions, indicating that the classroom math-talk never reached level 2 and 3 of questioning.

4.5.2 Explaining Mathematical Thinking

In this component, at level 0, learners are uncomfortable to express their thinking to the whole class. In level 1, other learners start to support those that are explaining their thoughts. In level 2 of the explaining component, the teacher uses learners' explanations even those with mistakes and there are disagreements which enhance learning. When analyzing the lessons I realized that in most cases learners' voices were inaudible and where they were audible, the learners' responses were very short except in one instance where learners were disagreeing about the number of axes of symmetry of a rhombus. A number of learners were willing to demonstrate how they found their answer and there was a lot of disagreement which indicates level 2. As a learner shows others how they found the number of axes of symmetry, more disagreements came from classmates, a member of the learner's group offered to help, and another member took the shape and tried to demonstrate. The rest of the class argued that the learner was repeating the lines of symmetry.

There were more disagreements until I decided to show them what we did with the square and how it should be done with the rhombus. It is clear at this stage that learners were confident to show their own strategies even though they differed from those of the majority signifying that most learners were actively involved in the learning of the concept of symmetry. Since this incident is one out of all the lessons that were observed, the learners might have felt more confident to participate as they did not have to explain their understanding using language but rather they just had to demonstrate without saying much. It is quite common in class that even if learners have to demonstrate a problem on the board, they would rather just write it and not explain. The indication here is that there might be a lot of thinking that goes on in learners which may not be displayed if that can only be done through speech. If this is the case, learners should be encouraged to demonstrate their thinking in other ways other than through explaining. Explanation of mathematical ideas did not reach level 3.

4.5.3 Source of Mathematical Ideas

In the third component where the focus was on the source of mathematical ideas, the main issue was to find whether the teacher was the main source of ideas or learners also contributed to mathematical ideas shared in the classroom. In level 0 I looked for incidents where the ideas came from the teacher. In level 1, the teacher's interest was to elicit the learners' ideas so that their prior learning and misconceptions can be identified. Open-ended questions were asked in level 2 and learners voluntarily began to explain certain mathematical ideas. The table below shows the number of incidents for each level. The columns represent levels 0-3 where **ST** is an abbreviation for ideas who's source was the teacher, **SL** represents ideas who's source is the learner, **OEQ** is representing open ended questions asked by the teacher and finally, **LVE** stands for learner's voluntary explanations.

	Total No. Of Maths Ideas	**Level 0** **ST**	**Level 1** **SL**	**Level 2** **OEQ**	**Level 3** **LVE**
Lesson 1	2	1	1		
Lesson 2	24	8	16	2	
Lesson 3	0				
Lesson 4	42	15	27	4	
Lesson 5					
Lesson 6					
Total	**68**	**24**	**44**	**6**	

Table 4.6 Source of mathematical ideas identified in all the lessons.

In the table above it is evident that there were more mathematical ideas in lesson 4 than in lesson 2. The reason could be that learners were more familiar with the topic in lesson four than in lesson 2. In lesson 2, the learners' ideas are slightly less than double the number of the teacher's ideas. The learners' ideas are slightly less than half in lesson 4. It should be noted however that amongst the mathematical ideas given by learners, some were incorrect and others were misconceptions. This component is one of the important ones in this research as learners'

contribution indicates their thinking capabilities. When I am knowledgeable of the learner's thinking, I am in a better position to give feedback that will address the ideas expressed by learners more appropriately. There were 14 sections during lesson 4 where learners were inaudible. It is possible then that there were more ideas elicited by learners.

Of all the mathematical ideas contributed, 65% of them were contributed by learners demonstrating that learners' were actively engaged. This percentage does not necessarily represent participation of learners in all the lessons but mainly lesson 4 as the percentages of ST, SL and OEQ in lesson 4 is 61%, 63% and 67% respectively. In level 3 learners voluntarily explain and since this did not happen, this component did not reach level 3, and was mainly in level 1.

4.5.4 Responsibility for Learning

The last component dealing with responsibility for learning shows that at level 0, the teacher tends to repeat learners' responses and the consequences are that some learners may not bother to listen attentively to other learners because they know that the teacher will repeat the responses. At level 1, learners are supposed to ask questions and at level 2 they explain their thoughts on what they have learned or how they understood a certain concept at level 2.When analysing, there were 18 incidents (not recorded in the table) where I repeated learners' responses indicating that responsibility for learning is at level 0. Level 1 was not identified during whole-class discussions. There were a few incidents where learners asked me questions as they worked in groups. The questions were about the definition of the axis of symmetry and in another instances they asked for clarity of what was in the task. The questions asked therefore were not necessarily to assist them in understanding mathematical concepts relating to what we were dealing with (properties of quadrilaterals). This is symptomatic of the fact that they were not yet supported in taking responsibility to learn.

According to table 4.7 above, there were 44 ideas whose source was the learners. In these cases, learners would give short answers and be prompted to explain further. The fact that there were 44 incidents where learners expressed their own ideas, shows that they reached level 2 of source of mathematical ideas. With regard to learners expressing their ideas, out of the 26 learners in the classroom, 7 learners (not shown in the table) gave a response more than once during all the six

lessons. The indication here is that only 27% of learners participated in the discussions in an ongoing way. Usually at this level, learners explain their thoughts at the board. Kedibone was requested to illustrate what she meant about obtuse angles and she did. It was the only time that a learner explained their idea on the board. The indication here is that this component did not reach level 3. At level 3 learners help those that are struggling and there are more people taking part in the discussions.

Conversations are important for my study as I give feedback to learners and they express their thoughts to me. These interactions are vital in that through feedback, learners alter their knowledge and misconceptions are dealt with. I also benefit in that as learners make contributions, I learn more about their shortcomings and that assists me in altering my teaching and planning for better strategies in subsequent lessons. As I draw conclusions from my findings, I realize that the components: explaining, source of mathematical idea and responsibility for learning reached level 2, questioning only reached level 1.When taking into consideration that none of the components reached level 3, the indication is that I need more development in conducting discussions that are worthwhile in my classroom. It is important to also mention that the creation of a culture that enables learners to freely express themselves takes time. As I mentioned in chapter 3, I had not been with the learners for adequate time to allow for the creation of the culture.

Questioning is the component that reached the lowest level and this indicates that during planning, I need to think of questions that I will ask in class especially the open-ended ones. But most importantly I need to encourage the learners to ask each other and me questions so that this component can shift to higher levels. Although the quality of recording was poor and I can not give a conclusive report about the source of mathematical ideas, it can be seen that there is need for learners to give contributions that add value to their learning rather than them getting ideas mainly from the teacher. The quality of ideas here is also important because the more learners' ideas are accurate, the more the discussions shift to a deeper level. At this stage it is evident that learners did not take responsibility for their learning to a satisfactory level as this component remained at level 2. It would be more fulfilling for me and the learners if I can reach a stage

where learners voluntarily assist those that are struggling and more learners take part in the lesson.

CHAPTER 5

CONCLUSION

5.1 INTRODUCTION

This chapter forms a consolidation of all the findings of the research. I need to first of all state the limitations of the research to clarify all that this research may not be able to address. Then the findings of the research will be discussed and the implication of the findings will emanate from that discussion. I will also reflect on the proceedings of the study. Finally, I will express the conclusions of the whole research.

This study was concerned with investigating my giving feedback to Grade 10 learners in an investigative task. My task was to develop an investigation that would be given to Grade 10 learners and as they worked on it, I had to give feedback to the learners on their work. Feedback was mainly given during whole-class discussions. During the discussions, I picked up a number of misconceptions as learners made contributions. The misconceptions created an opportunity for me to address the issues that still needed attention. It became clear that I was not always able to pick up on misconceptions or address them properly when I did and the implications of this are also discussed.

5.2 LIMITATIONS

The study being action research meant that I was a participant and a researcher at the same time. The implication here is that I had to develop a task and administer it myself and also teach and reflect on my own teaching. In this way I cannot make generalizations that can be used as rules to guide teaching practice as a whole (Cohen, Manion & Morrison, 2000). According to what Cohen et al. (2000) explains as emancipator action research, my study fails to meet the criteria as the findings may not "change the system" or bring improvement to the system. My study would therefore be more inclined to the views of reflective practitioners whose focus is on improvement in the classroom as opposed to critical theorists who view action research for the purpose of changing education, schools and the broader society (Cohen et al., 2000).

Lampert (2001:51) talks about "building a classroom culture" and she says it should begin on the very first day of the year and be maintained until the end of the year. She continues to mention that it was important for her to establish a relationship with her learners that would create an environment that would enhance productive learning. Nesher (1987:38) and Swan (2001) echo the issue of creating a conducive environment for learning by highlighting one moment in a class observed where the teacher emphasized to learners that they learn from mistakes. Learners were encouraged to make their mistakes public without feeling bad about them. The author claims that these environments are "feedback systems" which enables learners to explore their own ideas and receive feedback on these ideas. Because I was on leave just before conducting this study, I was allocated a new class when I came back. Although I tried to create this culture with my new class, it took them time to get used to it and I realized that most learners were not free to publicly express their ideas. It took a considerable amount of time to get learners to respond and this can be rather frustrating when under time constraints. In some instances I would respond to my own questions which illustrated lack of patience on my part. To capture learners' conversations for me was very important as this would help me to identify areas I needed to focus on and give support during whole-class interaction.

I intended capturing learners' conversations by focusing on one group that seemed to be engaging actively with one another. I decided together with the person taking the video to focus on a particular group. Unfortunately, the voices were not audible from the video recording. Even during whole class discussions, many of the learners' responses were not audible because I did not have extra microphones or tape recorders to record the voices. Failure to capture learners' interactions effectively has affected my data to some extent. Since the video was on the right hand side of the classrooms, it was difficult to pick-up voices of learners who were seated on the left hand side of the classroom. As I explained earlier, the six lessons were planned such that I would alternate between learners working in groups and whole class discussions. It was mainly from the whole-class discussions where I was able to gather most of my data on conversations and these were from the 2nd and the 4th lesson.

I had hoped to also look at learners work everyday but I managed to do this only on day one. On successive days I would find that learners had to take their work home because they did not finish their work and had to finish it off at home. There were times when I would have an opportunity to look at some of the learners' work in class and then I would discover that some of the areas needing attention could not be addressed immediately with the whole class as learners were busy with another question. Feedback for such areas was therefore not given during discussion but would be in the learners' written work. If time was not a constraint, the ideal would be to mark learners every time they wrote and immediately discuss their responses in the successive lesson.

5.3 FINDINGS

There are issues of focus I needed to attend to in this chapter. They are guided by the research questions stated in chapter one which are:

1. How do Grade 10 learners respond to investigative assessment tasks?
2. What kinds of feedback assist learners in engaging with investigative tasks?
3. How are investigations useful in teaching?

QUESTION 1: How do Grade 10 learners respond to investigative tasks?

This study indicated that the investigation offered opportunities for mathematical processes such as using systematic exploration, the use of systematic recording of data and the use of suitable language.

i) Exploration

There were seven incidences of exploration shown in Table 4.1. Duminy and Steyn (1985) stated that the kind of teaching that places a learner at a central point tends to be inclined to an inductive approach of teaching. An inductive approach "proceeds from particular cases to the general rule" (Duminy and Steyn, 1985:77). This kind of approach guides learners to eventually develop new knowledge. The investigation that I used gave learners an opportunity to measure sides and angles of shapes so that they could draw conjectures from the results they found. Learners used their results to understand the polygons better. The first task was more guided so

that learners could become familiar with the process of exploration. The purpose of exploring nonetheless is to enable learners to later on make generalizations about what they explored. In this investigation, processes that enabled exploration were evident but there was no question that allowed learners to generalize or draw conclusions.

The response of learners to the explorations was enabled by the use of investigations as shown in table 4.1. Learners explored based on the instructions that were given on the question paper. However, there was not much initiative from learners to take the investigation further, William (1980) suggests eight ways that learners can demonstrate higher order thinking. They are fluency, flexibility, originality, elaboration, risk taking, complexity, curiosity and imagination. Although this study does not allow enough space to discuss these behaviors in depth, they give guidance in determining whether learners practiced higher order thinking or not. When taking elaboration for instance, William (1980:197) shows that learners demonstrating this behavior would "stretch, expand, or embellish ideas". Learners in this study simply answered in one word, phrase or short sentence. They did not expand on their ideas. It was only when I gave feedback on recording data that some started adding more information and using tables. It shows that there was little originality or risk taking. Originality of the learners will have to be developed and hopefully feedback given will support learners in ways that they will develop in this area. My study suggests that developing William's eight aspects of higher order thinking will take a long time.

ii) Systematic recording of data

Only two learners recorded their measurements on their diagrams as shown in Figure 4.1, and Figure 4.3. These learners were able to state a number of things about the properties of the shapes. For the rest of the learners, all I could see was folding where they were looking for lines of symmetry. Although the rubric showed that they needed to measure, they did not record the measurements. This indicates that learners did not exhibit complexity in their work. Killen (2000) explains complexity as bringing order where there is chaos. Raw data is mostly messy, but it takes skill to arrange and organize that data in ways that can be easily interpreted. The table shown in Figure 4.3, indicates that there were at least two learners who had acquired some

skill of organizing data in ways that it can be easily accessible. The number of learners who changed behavior after feedback was only two. This indicated that acquisition of these skills is a process.

iii) Language

Killen (2000) argues that a problem solving strategy should be used when one seeks to develop learners' thinking skills through sharing of ideas with others. The investigation enabled learners to develop language skills related to polygons. Although most of the time the language used was not appropriate, learners had an opportunity to express themselves and were corrected where they made mistakes or were asked to explain themselves in cases where I suspected that the statement made originated from a misconception.

Other tasks could still achieve this goal but investigations are different in that learners talk about what they did and the results they derived from their activities. This makes communication much easier than where learners would have to talk about concepts they may not even understand. With investigations, communication may begin at a very basic level but the teacher can deepen it as learners become more familiar with the concepts used.

In this topic of polygons, there were concepts such as "bisecting lines, perpendicular lines, transversal line etc." where learners exhibited lack of understanding. Paper charts showing these types of lines could have been used and learners referred to them as they were working with the concepts. It was not helpful at that stage to be explaining these terms as learners needed to be reminded in a pictorial representation what the lines look like. Swan (2001:152) suggests that a teacher's main task is to assist learners in interpreting "mathematical representations" which will lead to a creation of conceptual framework. This shows that resources needed for the lesson were not anticipated. Well planned resources involve the inclusion of those materials that take into consideration prior knowledge and concepts that the teacher anticipates would elicit misconceptions.

QUESTION 2: What kinds of feedback assist learners in engaging with investigative tasks?

To answer this question, I need to take into account the types of feedback that I used in my teaching. There were two types of feedback that were evident: facilitative feedback and directive feedback.

i) Feedback

Maoto and Wallace (2006) made an illustration of teachers not taking time to wait for learners to respond. In cases where this happens often, learners usually tend to keep quiet because they know that the teacher will finally give an explanation. I have shown in Chapter 4 that there were seventeen cases of direct feedback as opposed to eight of facilitative feedback. Facilitative feedback requires that the teacher waits for learners to give their own responses after the teacher has given a clue or some guidance. But as shown by Maoto and Wallace (2006), it is much easier for teachers to give an explanation. This explains the reason why there are more cases of directive feedback as opposed to facilitative feedback.

It was stated in chapter 2 that directive feedback is usually given at the beginning of the topic. Since learners were still struggling with most concepts, it might have been more appropriate to give directive feedback as learners still needed scaffolding. Facilitative feedback would have been more acceptable in cases where learners were showing more competence in the topic.

ii) Misconceptions

In the analysis I have shown that some misconceptions were addressed (SO) whereas some were not addressed (MO). A misconception is addressed by asking questions that finally elicit the underlying problem. According to Boaler and Brodie (2004:692), a more appropriate type of question to elicit misconception would be "probing, getting students to explain their thinking". An opportunity would also be seized by explaining the concept in different ways, for example, giving an illustration or giving examples. In this study, there were no cases where probing that led to learners "clarifying ideas" is used. Ideas were either explained or an illustration given.

It has been shown that in some cases, although a follow-up on the misconception was made, I did not ask questions that really elicited the misconception. Questions were more of the type that Boaler and Brodie (2004:692) termed "gathering information, leading students through a method". In such cases, the teacher asks questions that do not require learners to reflect on their thinking. An example of this is shown in the first misconception where the learner said "sides of the square are equal because they add up to 10cm". The learner kept answering my questions which were not necessarily helping her to think about what she had just said. Ultimately, when asked whether she added anything she said "no". When questions of this nature are asked, an opportunity to discover the underlying misconception of the learner is missed. An opportunity is also missed when a learner's response is not followed-up. There were no questions asked to understand why the learner gave a particular response. This means that the misconception was just left hanging. So this study shows that even though I intended to work with learner misconceptions, I struggled to ask the right kind of questions.

iii) Conversations

In the four components of conversations discussed in Chapter 4, I found that although I asked questions that are classified to be at level two (the "how" and "why" questions), learners gave short answers which are said to be in level one. The answers would be either one word or a phrase. Learners were not giving explanations responding to the "how" or "why" questions. I therefore concluded that this component of questioning only reached level one. Explaining reached level two because there was an instance where learners had different ways of finding the axes of symmetry and learners disagreed with one another. Learners who would normally not volunteer to answer in class were willing to show how they found their axes of symmetry which I found quite impressive except that they did not explain their thinking but demonstrated it. This is an indication that learners' confidence had reached high levels but not high enough to talk. I also used learners' explanations with mistakes which are also classified at level two. This gives an opportunity for further learning. An example of this occurred where Kedibone went to the board to explain obtuse angles. Instead of showing an angle, she pointed to the side. I then used that misconception to explain the concept of angle. In level two of sources of mathematical

ideas, where I looked at where mathematical ideas came from, I found that there were a substantial number of learners' contributions. I concluded that level two was reached because I found that in all the lessons combined learners' contributions amounted to 65%. Responsibility for learning reached level two as there was evidence of learners explaining their thoughts.

In answering the question, it is not easy to simply say this feedback or that feedback assisted learners as I realized that directive feedback is helpful at the beginning of the lesson when learners still need a lot of support in understanding new concepts being introduced to them. Facilitative feedback is more useful when learners are expected to further develop knowledge that they have acquired and use it publicly so that it can be refined. In relation to misconceptions it is clear that mastery of questioning is crucial if learners' misconceptions are to be dealt with appropriately. Black (1998) states the importance of open ended questions when giving feedback. The issue of questioning is confirmed again in the component of questioning under conversations. This component reached level one whereas the other components reached level two. It is quite evident that I need to improve in handling conversations but questioning needs even more attention.

QUESTION 3: How are investigations helpful in teaching?

I would have answered this question satisfactorily if I can show the mathematical processes and knowledge learners acquired as they worked on the investigative task. Learners' work as shown in their answer books and the interactions that we had in class will adequately show this. In answering Question 1, I gave clearly the mathematical processes that learners gained when working with the investigative task. There are three mathematical processes that learners demonstrated out of fourteen processes mentioned by Laridon et al. (2005). The fact that there were few mathematical processes evident in the lesson is not the main issue. What is important is to find out the number of processes the task could possibly enhance and whether those processes were enhanced in the learners. I will give an example with two mathematical processes that were not evident in the lesson.

If we consider identification of patterns and relationships, chances of learners identifying patterns were there but since they were not explicitly requested to give patterns that they recognized, learners would need to go out of their way to identify them. For example, as we discussed, learners were already realizing that all the shapes have four sides, four angles and the sum of their interior angles was 360°. They should have been given the opportunity in the task to make generalizations from such patterns. When considering relationships, learners should have been afforded opportunities to classify shapes that are related in terms of sides, angles or other properties so that they could even realize that a square is also a rectangle which learners fail to accept in most cases because they have not been exposed to these relationships.

It is clear that the investigative task can only elicit what it was intended to elicit. The implication is that in designing investigative tasks, it is the teacher's task to find as many mathematical processes to elicit as possible. As it has been shown earlier, only three mathematical processes were evident and that is because of the extent to which the task was designed to elicit from learners.

On the analysis I made on learners' answers on axes of symmetry of shapes in table 4.4, it was shown that there was 49% correct responses from learners. The shape that was correctly answered more than others (74%) was the parallelogram which has no axis of symmetry. The least correctly answered is the trapezium (17%). This analysis gives an indication that the investigative task enhanced the learning of symmetry as it was evident at the beginning that learners did not understand the concept of symmetry well. In conclusion my answer to question 3 is that investigative tasks are useful in teaching because many concepts can be treated at the same time hence making it possible for connection of ideas, but they must be phrased in ways that support the full range of mathematical processes.

5.4 RECOMMENDATIONS

In this section I will discuss the recommendations based on the findings. Recommendations made will be in relation to investigations, feedback, misconceptions and then conversations. The recommendations will address the questions that guided this research.

Responding to the question on how learners respond to investigative assessment task, the finding is that the learners were engaged and participated at all times. Learners had fruitful interactions during whole-class discussions. The implication here is that investigative tasks can work well when opportunities for whole-class discussion are created. A number of these types of tasks need to be given to learners as instructional tasks. At this point in time, only two investigations can be written as compulsory for formative assessment. Teachers should not be confined to these only as I have found that there are a number of skills that can be gained by learners through these tasks. Language skills, use of mathematical dictionary, measuring, organizing data and interpreting it are just some of them.

Learners responded well to directive feedback when the topic or task is still new. Facilitative feedback could yield good results when learners are used to a topic or task. The findings in this research do not point to a specific kind of feedback as being preferable, but that the two types discussed should be used at certain times. It maybe found that as learners are exposed more to investigative tasks, feedback will be more facilitative. This is what further research may investigate.

The last question seeks to find the usefulness of investigations in teaching. I have already alluded to the fact that investigations should be used as instructional tasks. When this happens, a more inductive approach to teaching will be used where learners will be enabled to discover certain rules for themselves. When learners are exposed to these ways of teaching, they develop better thinking skills and they will ultimately become better learners.

This study has highlighted important lessons for me. Firstly, I have learned that when creating investigative tasks, I need to identify mathematical processes that I would like learners to acquire

for a particular topic, then I can ask questions that will enable learners to demonstrate these processes. I also found out that facilitative feedback is good when learners are familiar with the mathematical language used in a topic. This feedback simply guides learners to reflect on their thoughts and does not explicitly give the correct answers. Directive feedback assisted where learners' concept development is still immature and further support is needed.

When asking questions during whole class discussions, it is important to anticipate questions that I need to ask in case a certain misconception arises. I have learned that even if learners' misconceptions are elicited, it does not help if they cannot be dealt with appropriately by using different mathematical representations that help learners form their own conceptual frameworks. With regard to conversations, I have learned that I need to develop in all the four components of conversations so that I can reach level 3 in all of them. My assumption is that this level can be reached with time and it may not be the same with every class as some learners are more conversant than others. However, if efforts are made to develop in this area, it will not be difficult to support learners to make their contributions without fear of intimidation or ridicule.

Lastly, if I were to conduct action research again, I would ensure that there is a team of teachers or researchers I work with in the place where research takes place. There is great importance in having people who can give ongoing and immediate feedback about what is going on constructively. When one conducts research individually, there is not absolute objectivity and for one to improve remarkably, critical feedback is essential.

5.5 CONCLUSION

The study conducted here focuses on investigative tasks, how these tasks can be used to enhance feedback and how they can be used in teaching. From the findings, I have shown that investigative tasks are not only good in teaching but they can expose learners to a number of skills while they also assist teachers to give feedback which will enable them to elicit misconceptions that can so easily be pushed under by further teaching. With investigations, as teachers acquire more skills in developing the tasks, they can plan in ways that will cater for anticipated misconceptions and when the misconceptions surface, instead of re-teaching, they

can provide resources that will enable learners to find information for themselves rather than being told one thing over and over.

The purpose of action research is for one to improve their practice. Having conducted this study helped me to find better ways of developing investigations not only for formative assessment but also to develop them as instructional tasks that will enable learners to develop a number of skills in mathematics such as communication, measuring, use of a mathematical dictionary. Mathematical processes are also developed and learners possessing such processes, will have better opportunities of making sense of mathematics, hence developing mathematical proficiency.

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APPENDIX A

Investigative Task

Shape in the round Grade 10 2008-08-04

Examiner: L.J. Mathenjwa	**Time**: 1hr 40
Moderator: N. Madubedube	**Marks**: 45
Learning Outcome: 3	
Assessment Standard: 10.3.2	

AS: 10.3.2 Investigation of polygons, using any logical method (Eucledian, co-ordinate and/or transformation).

INSTRUCTIONS:

- This task will be done in small groups of four learners each.
- Every member of the group has to participate and submit their own work.
- You will need protractors and compasses for some of the activities.
- Each person should complete and submit their answer sheet on time.
- More marks will be awarded for extra work.

TASK 1

QUESTION 1

Use the copies of the figures provided.

a) Draw a square such as ABCD, with length of side 10cm. Cut the square out.

b) Use the cut-out square to investigate as many of the properties of the square as possible. Measure lengths and angles or fold the cut-out shapes as you may decide. Write down what you find out about:

(i) the sides of the square

(ii) the angles of the square

(iii) the diagonals of the square

(iv) the number of axes of symmetry the square has

(v) the order of rotational symmetry of the square.

QUESTION 2

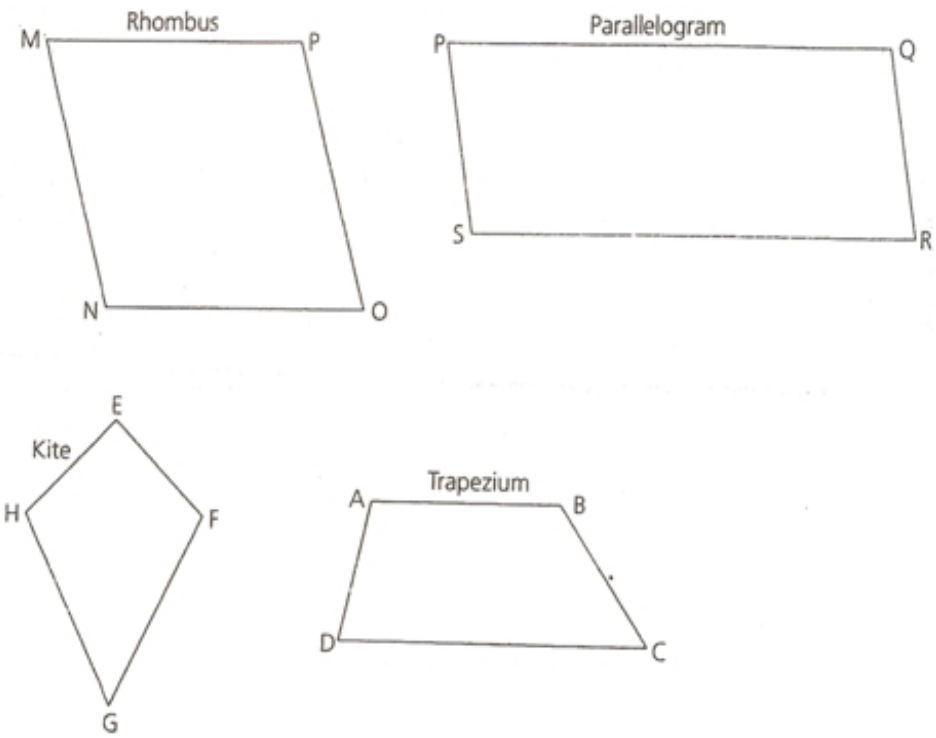
a) Draw a rectangle such as EFGH with one pair of sides 10cm in length and the other pair 7cm in length. Cut the rectangle out.

b) Use the cut-out rectangle to investigate as many of the properties of the rectangle as possible.

c) Write down what you find out about:
   (i) The sides of the rectangle
   (ii) The angles of the rectangle
   (iii) The diagonals of the rectangle
   (iv) The number of axes of symmetry of the rectangle
   (v) The order of rotational symmetry of the rectangle

QUESTION 3

a) Draw larger versions of the special quadrilaterals given in figure 2. Cut them out and investigate their properties in the same way you did for the square and the rectangle in question 1 and 2.



b)

No.	Property	Square	Rectangle	Rhombus	Parallelogram	Kite	Trapezium
1	All sides are equal						
2	At least two pairs of adjacent sides are equal						
3	Both pairs of opposite sides are equal						
4	At least one pair of opposite side is parallel						
5	Both pairs of opposite sides are parallel						
6	Interior angles sum to 360°						
7	All angles are right angles						
8	At least one pair of opposite angles is equal						
9	Both pairs of opposite angles are equal						
10	Diagonals bisect each other						
11	At least one diagonal is bisected at right angles						
12	Both diagonals are bisected at right angles						
13	Diagonals are equal in length						
14	Diagonals bisect at least one pair of opposite interior angles						
15	Diagonals bisect both pairs of opposite interior angles						
16	All angles between diagonals and sides are 45°						
17	Number of axes of symmetry						
18	Order of rotational symmetry						

Some language for the next questions.

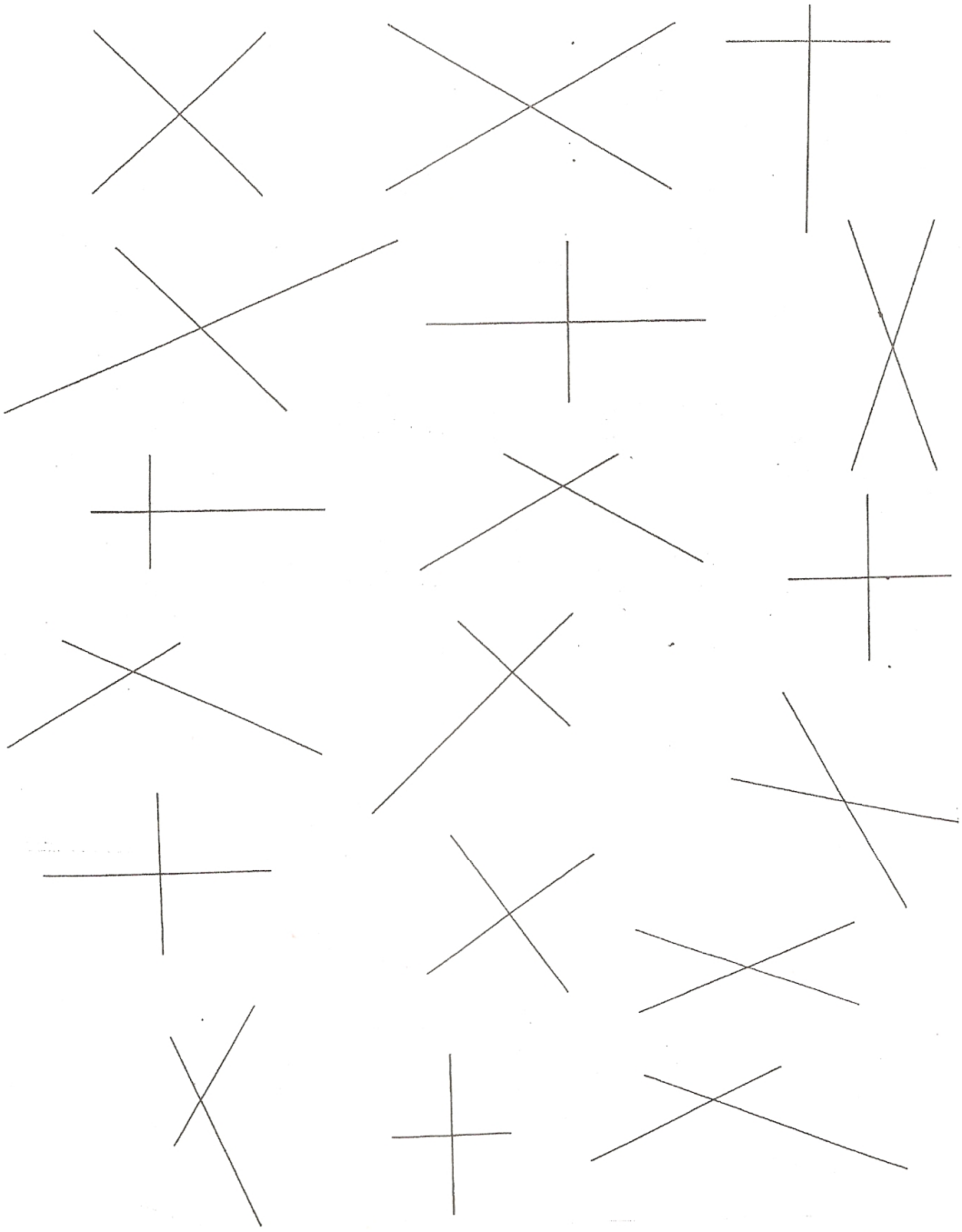
"At least" means that there could be more than this number. So, if both pairs of opposite sides are parallel, this still qualifies for at least one pair being parallel.

In the table of properties given:

a) Tick the properties from 1 to 16 that apply to all the shapes you have investigated. (You may need to do further measurements in some cases.)
b) Fill in the number of lines of symmetry the shapes have for property 17.
c) Fill in the order of rotational symmetry of the shapes for 18.

QUESTION 4

a) Draw quadrilaterals around the following pairs of diagonals.



b) As you have seen in part (a), all quadrilaterals have two diagonals that intersect each other. The two diagonals can have three characteristics:

1) they are equal in length

2) the intersect at right angles

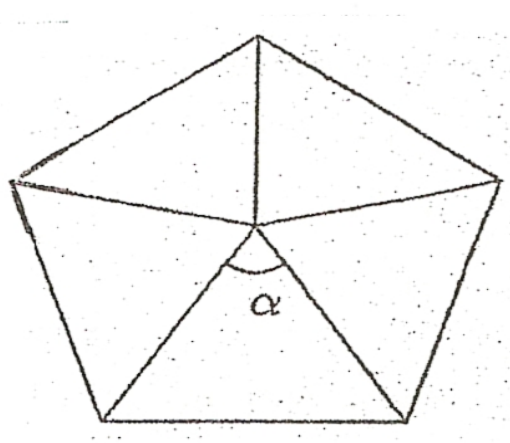
3) they bisect each other

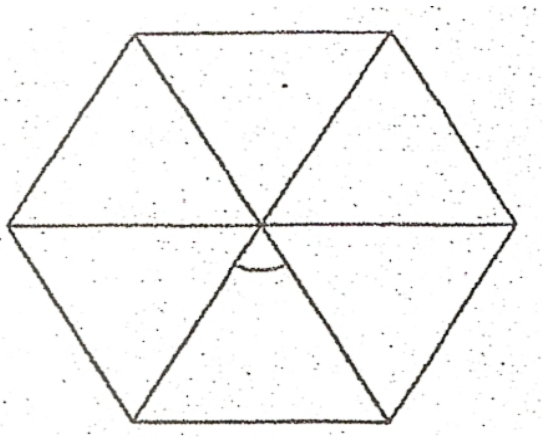
Based on your drawings in part (a), fill the table below.

	DIAGONALS		
	Equal in length	**Intersect at right angles**	**Bisect each other**
Square			
Rectangle			
Rhombus			
Kite			
Parallelogram			

TASK 2

These investigations should be done individually.

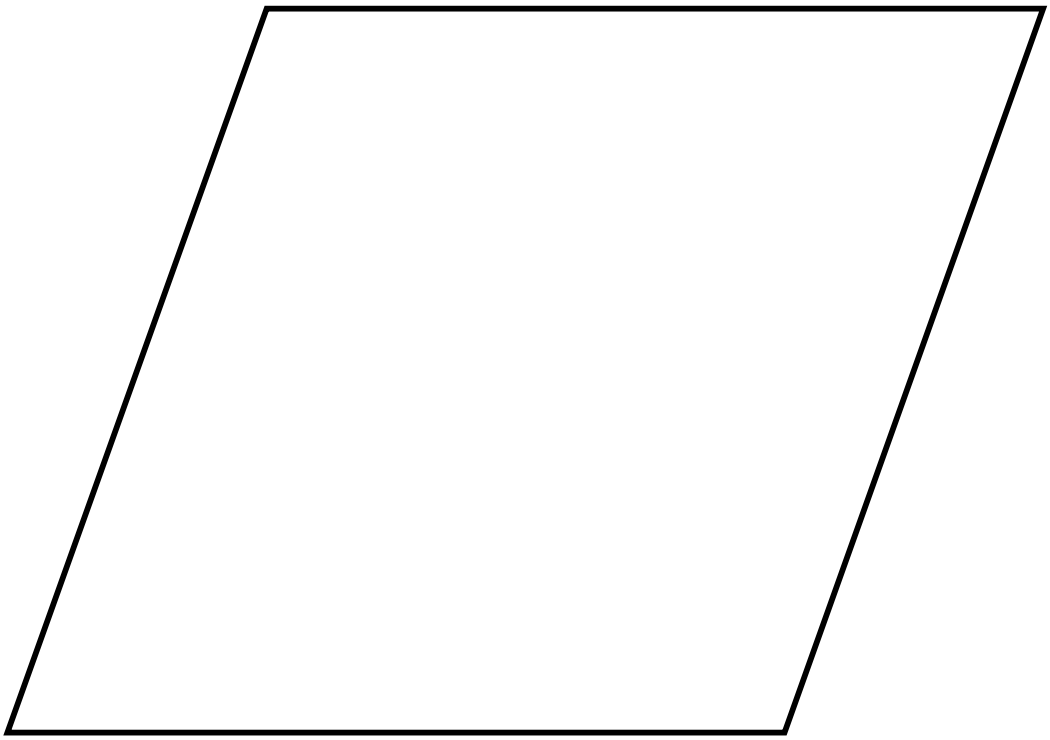


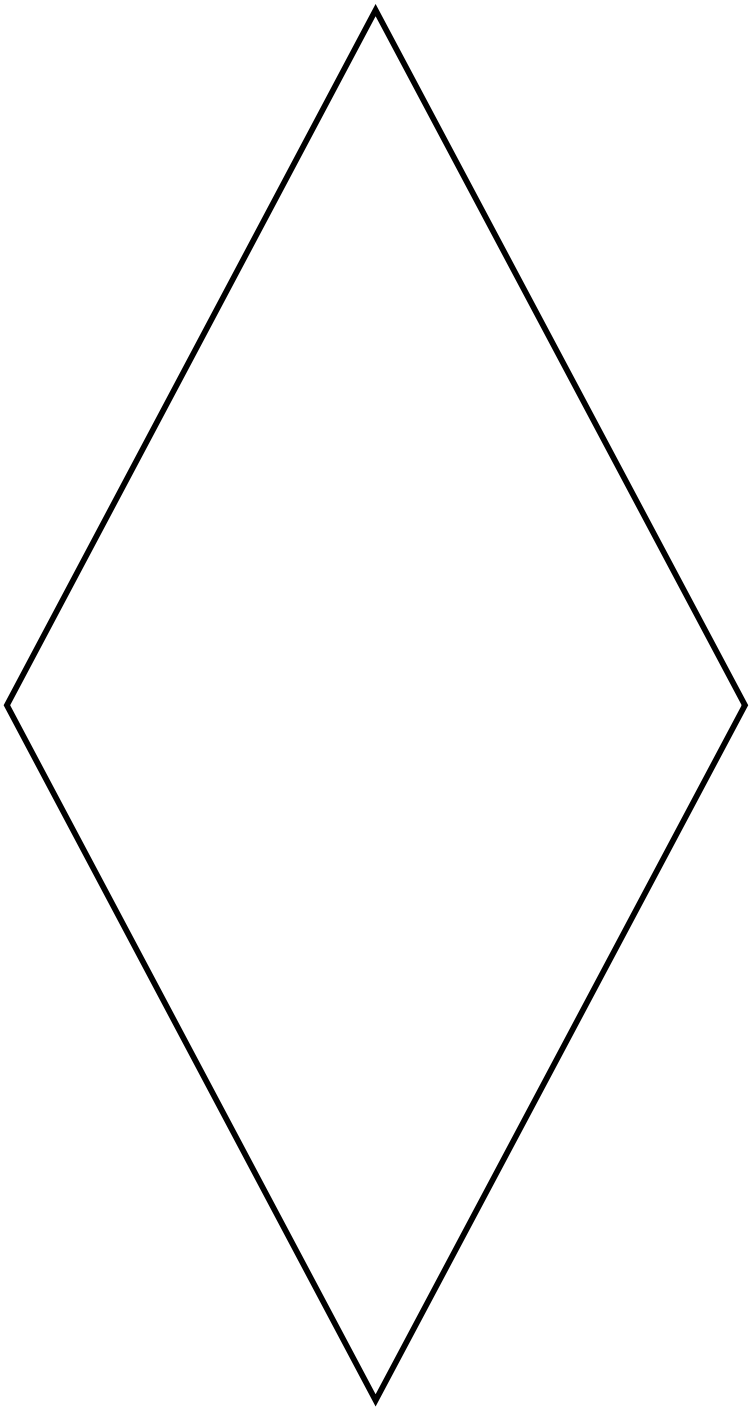


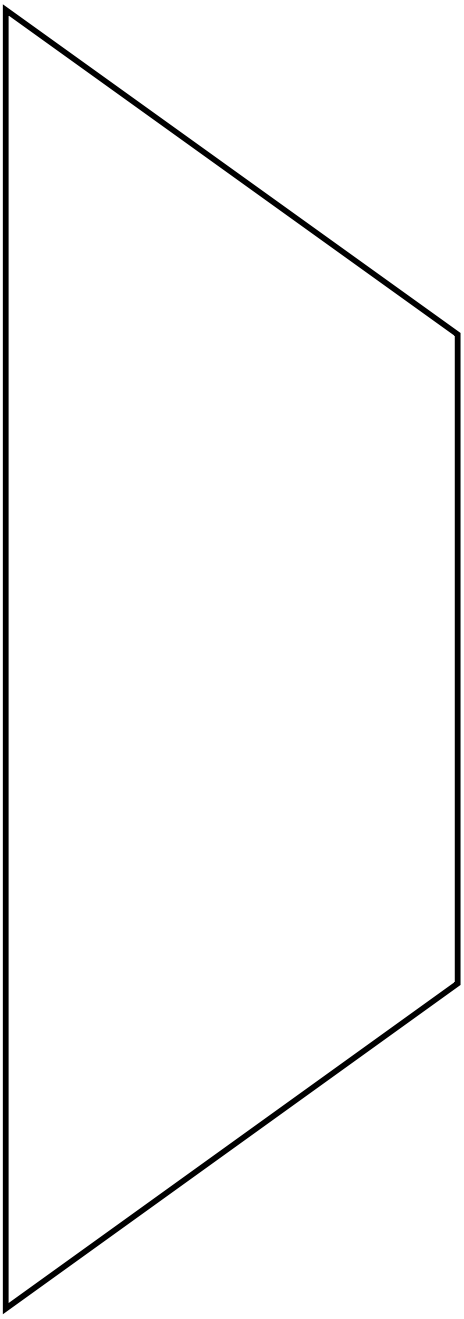
1. All regular polygons can be constructed by rotating an isosceles triangle of correct apex angle (a), about the apex. Find:
   a) The apex angle for constructing:
      (ii) a regular pentagon (ii) a regular hexagon.
   b) The apex angle for an *n* sided regular polygon in terms of *n.*
2. Investigate which regular polygons can form tessellations.

APPENDIX B









APPENDIX C

UMnyango WezeMfundo
Department of Education

Lefapha la Thuto
Departement van Onderwys

Enquiries : Shadrack Phele MIRMSA

Tel. No. : [+2711] 355 0285

Wednesday, 20 August 2008

Mrs. Mathenjwa Lerato Josephine
99 Six Avenue
Roodepoort North
Johannesburg
1724

Dear Mrs. Mathenjwa Lerato Josephine

PERMISSION TO CONDUCT RESEARCH: PROJECT

The Gauteng Department of Education hereby grants permission to conduct research in its institutions as per application.

Topic of research : "Giving feedback in investigative tasks in Grade 10".

Nature of project : Master in Science Education

Name of university : University of the Witwatersrand.

Upon completion of the research project the researcher is obliged to furnish the Department with copy of the research report (electronic or hard copy).

The Department wishes you success in your academic pursuit.

Yours in Tirisano,

p.p. Shadrack Phele [MIRMSA]
TOM WASPE
CHIEF INFORMATION OFFICER
Gauteng Department of Education

Office of the DDG: IS & KM (CIO)
Room 1807, 111 Commissioner Street, Johannesburg, 2001 P.O.Box 7710, Johannesburg, 2000
Tel: (011) 355-1514/1507 Fax: (011) 355-0734/0833 E-mail: tomw@gpg.gov.za or elridar@gpg.gov.za

APPENDIX D

UNIVERSITY OF THE WITWATERSRAND: MATHEMATICS RESEARCH PROJECT

Dear Parent / Guardian

My name is Lerato Mathenjwa, your mathematics teacher. I am currently doing my MSc degree in Mathematics Education. As part of my studies, I am doing a research on giving feedback for investigative task in Grade 10. I hope that the findings of this study will assist in giving feedback in ways that will enhance learners understanding.

The child's principal (Mrs. Mohapi) has given me permission to send you this letter to invite your child to participate in this research project. Please note that your child's participation is voluntary. After reading this letter, you can decide whether you want him/her to participate or not. You are encouraged to talk to your child about it.

Children whose parents do not agree that they should be video-recorded, will not be video recorded; they will be kept away from the focus of the video recorder. If the face is shown, it will be hidden from public view.

I will protect your child's anonymity and confidentiality. Their real names will not be used in the final report. I will remove any reference to their personal information that might allow someone to guess their identity. In case I need to use the information in the video recording for conference or for teaching purposes, their faces will be hidden from public viewing and permission from you will first be requested.

Remember that your child is not obliged to participate and can withdraw at any stage during the study. Should you require any further information, do not hesitate to contact me- the school telephone number is provided below.

If you agree that your child be part of this research project, please complete the consent form on the next page and sign in the space provided.

Lerato Mathenjwa
(011)410 2190

CONSENT (Parent/Guardian)

I give consent for my child to participate in the study:

_____ Yes

_____ No

I give consent for my child to be videotaped in his/her maths classes:

_____ Yes

_____ No

I give consent for video tapes with my child in them resulting from this study to be shown at academic conferences

_____ Yes

_____ No

I give consent for video tapes with my child in them resulting from this study to be used for teaching purposes, in teacher education programmes

_____ Yes

_____ No

Learner's name: _____

Parent/Guardian's name: _____

Signature: _____

Date: _____

UNIVERSITY OF THE WITWATERSRAND: MATHEMATICS RESEARCH PROJECT

Dear Learner

My name is Lerato Mathenjwa, your mathematics teacher. I am currently doing my MSc degree in Mathematics Education. As part of my studies, I am doing research on giving feedback for investigative task in Grade 10. I hope that the findings of this study will assist in giving feedback in ways that will enhance learners understanding of mathematics.

The principal (Mrs. Mohapi) has given me permission to send you this letter to invite you to participate in this research project. Please note that your participation is voluntary. After reading this letter, you can decide whether you want to participate or not. You are also allowed to withdraw from the study at anytime. You are encouraged to talk to your parent about it.

If you agree to participate in this study, the class will be video- recorded for about a week in the month of August. The focus in the video-recordings and lesson observations will be how I give feedback and deal with misconceptions and ideas you raise during feedback.

I will protect your anonymity and confidentiality. Your real names will not be used in the final report. I will remove any reference to your personal information that might allow someone to guess your identity.

Remember that you are not obliged to participate and can withdraw at any stage during the study. Your participation, nonparticipation or withdrawal will not affect your learning, your marks or your relationship with me. If you wish not to be video recorded, you will be kept away from the focus of the video recorder. If your face is shown, it will be hidden from public view. Should you require any further information, do not hesitate to contact me-the school telephone number is provided below.

If you agree to take part in this research project please complete the consent form on the next page and sign in the space provided.

Lerato Mathenjwa
(011) 410 2190

CONSENT (Learner)

I am willing to participate in the study:

_____ Yes

_____ No

I am willing to be videotaped in my maths class:

_____ Yes

_____ No

I give consent for video tapes with me in them resulting from this study to be shown at academic conferences

_____ Yes

_____ No

I give consent for video tapes with me in them resulting from this study to be used for teaching purposes, in teacher education programmes

_____ Yes

_____ No

Learner's name: _____

Signature: _____

Date: _____

Wits School of Education

27 St Andrews Road, Parktown, Johannesburg, 2193 • Private Bag 3, Wits 2050, South Africa
Tel: +27 11 717-3007 • Fax: +27 11 717-3009 • E-mail: enquiries@educ.wits.ac.za • Website: www.wits.ac.za

STUDENT NUMBER: 051611F
Protocol: 2008ECE231

22 August 2008

Mrs. Lerato Mathenjwa
99Sixth Avenue
ROODERPORT NORTH
1724

Dear Mrs. Mathenjwa

Application for Ethics Clearance: Master of Science

I have a pleasure in advising you that the Ethics Committee in Education of the Faculty of Humanities, acting on behalf of the Senate has agreed to approve your application for ethics clearance submitted for your proposal entitled:

Giving feedback in investigative tasks in Grade 10: misconceptions that may arise between teacher and learner.

Recommendation:

Ethics clearance is granted

Yours sincerely

MMabeta
Matsie Mabeta
Wits School of Education

Cc Supervisor: Prof. K Brodie (via email)