TEACHING FOR CONCEPTUAL UNDERSTANDING: AN ANALYSIS OF SELECTED TEACHERS' PRACTICE

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ABSTRACT

The purpose of this study was to explore how teachers' practice either supports or constrains learners' conceptual understanding. The study is structured within an interpretive paradigm. The research takes the form of a case study and focused on the teaching practice of two purposefully selected teachers who had been identified as being effective/successful practitioners. The data was collected in two stages. In the first stage, qualitative data was collected by video recording six classroom lessons, three for each of the two participating teachers. In stage 2, participating teachers were individually interviewed. In these interviews the two participating teachers were asked to reflect on their classroom practice, through a process of stimulated recall, where their actions seemed to either support or constrain the development of learners' conceptual understanding. The study identified a number of elements of the two teachers' practice that related to the development of learners' conceptual understanding in the classroom. These include building on learners' prior knowledge, the use of concrete manipulatives, questioning that promotes critical thinking, and the use of multiple representations and connections. The study also identified elements of the two teachers' practice that had the potential to constrain the development of learners' conceptual understanding. These include the lack of opportunities for co-operative or peer-oriented learning, the absence of questioning that leads to discussion, and a scarcity of activities that build mathematical concepts through hands-on engagement. The study highlights the need for supporting teachers and helping them strengthen their practice with regard to those activities that support the development of conceptual understanding in their learners.

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DEDICATION

This thesis is dedicated to my wife Lahja and my daughter Grace for being patient, and for their constant support and encouragement throughout my study.

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ABBREVIATIONS

LCE	Learner-Centred Education
MBEC	Ministry of Basic Education and Culture
MEC	Ministry of Education and Culture

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CHAPTER ONE

INTRODUCTION OF THE STUDY

1.1 INTRODUCTION

The focus of this study was to explore how teachers' practice either supports or constrains learners' conceptual understanding. This chapter introduces the study by providing an overview of the contextual background, the research goals, and the research process itself. The chapter concludes by giving a brief overview of the structure of the thesis.

1.2 CONTEXT OF THE RESEARCH

In schools, different teachers prefer different teaching approaches. Some teachers emphasize learning for understanding while others by contrast tend to emphasize memorization. Within Kilpatrick, Swafford and Findell's (2001) strands of Mathematical Proficiency, learning with understanding is referred to as conceptual understanding while memorization of mathematical facts and procedures falls under the banner of procedural fluency. Conceptual understanding focuses on the understanding of mathematical concepts and relations, thereby helping learners to make connections between concepts and to relate them to one another. This also resonates with Hiebert and Lefevre (1986, pp. 3-4) who describe conceptual knowledge as "a connected web of knowledge, a network in which the linking relationships are as prominent as the discrete pieces of information".

In Namibia, the Ministry of Education has embraced Learner-Centred Education (LCE) as an approach for teaching and learning. LCE resonates strongly with the notion of conceptual understanding as it emphasizes learning with understanding. In learner-centred education the role of the teacher is to assist, motivate and facilitate learning, and learners are expected to take ownership of their learning. In addition, McLoughlin and Luca (2002) state that the main role of the teacher is to enable

“learners to take an active role in learning by initiating, managing, monitoring, reflecting and evaluating learning tasks and processes” (p. 574)

The notion of conceptual understanding also resonates very strongly with a constructivist epistemology (Piaget, 1971) since teaching for conceptual understanding emphasizes relating concepts and providing representations/ideas based on students’ prior knowledge or experiences. In addition, conceptual understanding and constructivist epistemology suggest that learners should interact with each other and with the teacher and be actively involved in the classroom. Stein et al. (1994) suggest that classrooms that are underpinned by a constructivist epistemology are characterised by learners being active rather than passive recipients, and teachers being “facilitators of learning rather than transmitters of knowledge” (p. 26).

Conceptual understanding, Learner-Centred Education and constructivist epistemology all resonate strongly with each other and all emphasize that classrooms that foster a spirit of developing learners’ conceptual understanding are characterised by, amongst other things, (i) a focus on *why* and *how* as opposed to *what*, (ii) multiple solution strategies, (iii) transferring concepts to novel contexts, (iv) an emphasis on connections, (v) the use of multiple representations or models, (vi) building on prior knowledge, (vii) connecting mathematics to the real world, and (viii) questioning that promotes critical thinking.

From my own teaching experience, I believe the way we teach has an important role to play in terms of constraining or supporting conceptual understanding. As Kilpatrick et al. (2001) remark, “the knowledge, beliefs, decisions, and actions of teachers affect what is taught and ultimately learned” (p. 313). With this in mind, my study is focused on how teachers’ practice supports/constrains the development learners’ conceptual understanding as characterised by Kilpatrick et al.’s (2001) strands of Mathematical Proficiency.

1.3 RESEARCH GOALS

The goal of this research was to explore how teachers' practice either supports or constrains learners' conceptual understanding. The study is framed by the following research question:

- How may teachers' practice support/constrain the development of learners' conceptual understanding?

1.4 RESEARCH DESIGN

This study is anchored within an interpretive paradigm. According to Cohen, Manion and Morrison (2011, p. 17) "the central endeavour in the context of the interpretive paradigm is to understand the subjective world of human experience". The interpretive paradigm is well suited to the study because it seeks to understand how teachers' practice supports or constrains conceptual understanding, and as such focuses on teachers' lived experience.

This research took the form of a case study and focused on the practice of two purposefully selected teachers from the Okahao Circuit of the Omusati Region of Namibia. The selection of the two teachers was based on their having been identified as being effective/successful teachers. In total, six Grade 10 lessons were observed – three for each of the participating teachers. The two participating teachers represent the case under scrutiny, and the unit of analysis is the teaching practice of the two teachers.

1.5 RESEARCH PROCESS

The data was collected in two stages using two methods – observation and stimulated recall interviews.

Stage 1

The first stage was to collect qualitative data by video recording six classroom lessons, three for each of the two participating teachers. The recorded videos were viewed repeatedly to help the researcher gain insight into the teachers' practice. In addition, vignettes from the recorded lessons were used as the basis of the stimulated recall interviews in Stage 2.

Stage 2

In stage 2, participating teachers were individually interviewed through a process of stimulated recall. Short vignettes were drawn from the lesson observation footage and were used as the basis of the interviews and discussion. During the interview, the participating teachers were asked to reflect on their classroom practice where their actions seemed to either support or constrain the development of learners' conceptual understanding. These interviews were audio recorded and subsequently transcribed.

1.6 OVERVIEW OF THE THESIS

The thesis consists of five chapters. A brief overview of each chapter is given below.

Chapter one

Chapter one introduces the study, contextualises the research, and provides a brief overview of the research goal, the research design and the research process.

Chapter two

Chapter two takes the form of a literature review and begins by reviewing the notion of Mathematical Proficiency with a particular focus on Conceptual Understanding. This leads to an overview of Constructivism as a theory of learning before looking at the relationship between Conceptual Understanding and Constructivism as well as

teaching practices that promote conceptual understanding in relation to a constructivist epistemology. The chapter concludes by characterising the Namibian context with particular reference to Learner-Centred Education and its impact on the teaching and learning of Mathematics.

Chapter three

This chapter provides an overview of the methods, techniques and procedures used to carry out the research.

Chapter four

Chapter four presents and discusses the data. The chapter is divided into two sections, corresponding to the two stages of the research process. Stage 1 focuses on the classroom observations while Stage 2 engages with the data from the stimulated recall interviews. The chapter concludes with a summary of the findings from these two stages.

Chapter five

This concluding chapter provides an overview of the research process and reflects on the findings of the study. The chapter also provides recommendations based on the findings, interrogates the limitations of the study and concludes with some suggestions for further study.

CHAPTER TWO
LITERATURE REVIEW

2.1 INTRODUCTION

This chapter begins by reviewing the notion of Mathematical Proficiency with a particular focus on Conceptual Understanding. This leads to an overview of Constructivism as a theory of learning before looking at the relationship between Conceptual Understanding and Constructivism as well as teaching practices that promote conceptual understanding in relation to a constructivist epistemology.

The chapter concludes by characterising the Namibian context with particular reference to Learner-Centred Education and its impact on the teaching and learning of Mathematics.

2.2 THE STRANDS OF MATHEMATICAL PROFICIENCY

Kilpatrick et al. (2001) highlight five important strands of mathematical proficiency based on the mathematical knowledge, understanding and skills that people need for successful mathematics learning. These five strands are conceptual understanding, procedural fluency, strategic competence, adaptive reasoning and productive disposition. These strands of mathematical proficiency are further explained below.

2.2.1 Conceptual Understanding

According to Kilpatrick et al. (2001), “conceptual understanding refers to an integrated and functional grasp of mathematical ideas” (p. 118). This supports the notion that learners need to learn mathematical ideas with understanding. Conceptual understanding also emphasises that learning should be connected to what learners already know.

2.2.2 Procedural Fluency

Procedural fluency relates to the carrying out of mathematical procedures. In addition, Kilpatrick et al. (2001) explain that procedural fluency relates to "knowledge of procedures, knowledge of when and how to use them appropriately, and skill in performing them flexibly, accurately, and efficiently" (p. 121).

2.2.3 Strategic Competence

Kilpatrick et al. (2001) characterise strategic competence as "the ability to formulate mathematical problems, represent them, and solve them" (p. 168). Strategic competence thus focuses more on problem solving and problem formulation.

2.2.4 Adaptive Reasoning

Adaptive reasoning focuses on logical explanations or proving of mathematical concepts and algorithms. "Adaptive reasoning refers to the capacity to think logically about the relationships among concepts and situations" (Kilpatrick et al., 2001, p. 129). Furthermore, adaptive reasoning focuses on the "capacity for logical thought, reflection, explanation, and justification" (Kilpatrick et al., 2001, p. 116).

2.2.5 Productive Disposition

This strand refers to how learners value mathematics as being useful in their lives. As stated by Kilpatrick et al. (2001):

> …productive disposition refers to the tendency to see sense in mathematics, to perceive it as both useful and worthwhile, to believe that steady effort in learning mathematics pays off, and to see oneself as an effective learner and doer of mathematics. (p. 131)

Teachers need to encourage learners during the teaching and learning process and create environments that help learners to see mathematics as worthwhile.

2.3 CONCEPTUAL AND THEORETICAL FRAMEWORKS

This study is framed by Kilpatrick et al.'s (2001) strands of Mathematical Proficiency, specifically the strand of *conceptual understanding*, as well as constructivism as it pertains to the teaching and learning of mathematics.

2.3.1 Conceptual Understanding

With respect to the notion of conceptual understanding, Kilpatrick et al. (2001) define conceptual knowledge as "an integrated and functional grasp of mathematical ideas" (p. 118). For Rittle-Johnson and Alibali (1999), conceptual knowledge is characterised by an "explicit or implicit understanding of the principles that govern a domain and of the interrelations between pieces of knowledge in a domain" (p. 175). Hiebert and Lefevre (1986, p. 4) posit that conceptual knowledge is achieved in two ways: by "the construction of relationships between pieces of information" or by the "creation of relationships between existing knowledge and new information that is just entering the system". In similar vein, Kilpatrick et al. (2001) emphasise that learners' organisation of their knowledge into a coherent whole enables them to learn new ideas by connecting those ideas to what they already know.

Kilpatrick et al. (2001, p. 116) describe conceptual understanding as a "comprehension of mathematical concepts, operations and relations". They further remark that because facts and methods learned with understanding are more likely to be connected, they should be easier to remember, use, and reconstruct when forgotten. This resonates with Hiebert and Lefevre (1986) who describe conceptual knowledge as knowledge that is rich in relationships. They further state that conceptual knowledge can be thought of as "a connected web of knowledge, a network in which the linking relationships are as prominent as the discrete pieces of information" (Hiebert & Lefevre, 1986, pp. 3-4).

Hiebert and Carpenter (1992) emphasise the importance of conceptual understanding by highlighting that even though conceptual understanding and procedural fluency are interwoven ideas, there seems to be a general consensus

amongst mathematics researchers that procedures learned through memorisation are easily forgotten while procedures learned with conceptual understanding are connected and promote the development of understanding. In support of this, Rittle-Johnson and Alibali (1999) report that learners whose instruction was more conceptually orientated were able to generate multiple solutions, and were able to adapt their solution methods to novel contexts. By contrast, “procedural instruction led to more modest gains in both understanding and problem-solving ability” (Rittle-Johnson & Alibali, 1999, p. 187).

Zerpa, Kajander and Van Barneveld (2009) believe that in order to teach meaningfully, teachers should have a deep conceptual understanding of the content they teach so as to be able to “illustrate to their students *why* [my emphasis] mathematical algorithms work and how these algorithms may be used to solve problems in real life situations” (p. 59). Teachers should also build on learners’ prior knowledge to generate new knowledge, and to use that new knowledge to solve problems.

In order for teaching and learning to be meaningful, Kazemi (1998) has identified four socio-mathematical norms that can guide students' mathematical activities and help promote conceptual thinking:

- Solutions to a problem should include explanations with arguments not simply the procedures of how to solve the problem.
- Errors should be viewed as an opportunity to re-explore a concept and find new ways to solve problems or to help learners.
- Mathematical thinking should require learners to represent mathematical concepts in different ways.
- Learners should work together and reach agreement through mathematical argumentation.

Conceptual understanding can also be developed through the use of multiple representations as a means to link different mathematical domains (Ainsworth, 2006). In addition, classrooms that foster a spirit of developing learners’ conceptual understanding are characterised by, amongst other things, (i) a focus on *why* and

how as opposed to *what*, (ii) multiple solution strategies, (iii) transferring concepts to novel contexts, (iv) an emphasis on connections, (v) the use of multiple representations or models, (vi) building on prior knowledge, (vii) connecting mathematics to the real world, and (viii) questioning that promotes critical thinking. These components that foster the development of conceptual understanding are further described below:

(i) a focus on *why* and *how* as opposed to *what*

Questions such as “why?” and “how?” promote the development of conceptual understanding because learners, when prompted with such questions, are required to elaborate and reflect on their answers and reasoning. By eliciting additional explanation one can more readily identify the understanding of the learners.

(ii) multiple solution strategies

It is by engaging with different solution strategies or approaches that a teacher can meaningfully assess learners’ understanding of concepts or problems. For example, simultaneous equations can be solved by the processes of elimination, substitution or graphical reasoning. A learner who is able to solve simultaneous equations in multiple ways is believed to have a deeper conceptual understanding.

(iii) transferring concepts to novel contexts

Learners are believed to conceptually understand a mathematical concept if they are able to transfer the concept to new contexts. Learners who can successfully do this are learners who are able to link their prior knowledge or experience to the new context. In addition, Stylianides and Stylianides (2007, p. 106) state that, “learning mathematics with understanding involves *making connections* among ideas; these connections are considered to facilitate the transfer of prior knowledge to novel situations”.

(iv) an emphasis on connections

Learners display conceptual understanding if they are able to make relationships between ideas or if they are able to link topics in mathematics. Learners with a deep conceptual knowledge should be able to relate mathematics to other subjects, mathematics topics to other mathematics topics, and apply their prior knowledge and experience to new knowledge. Furthermore, learners with different connections can effectively engage in problem solving activities.

(v) the use of multiple representations or models

For learners to develop conceptual understanding in a meaningful way, they need to understand how to represent information or data in different ways – e.g. numerically, graphically or diagrammatically.

(vi) building on prior knowledge

Learners' prior knowledge plays an important role in what they learn. Lessons that recognise the prior knowledge of learners and build on it are recognised as promoting conceptual understanding.

(vii) connecting mathematics to the real world

Learners should be able to connect mathematics to real world problems. This is very important because it also helps learners to identify real world problems and relate them to what they are studying in the classroom.

(viii) questioning that promotes critical thinking

Questions that focus on *how* and *why* promote critical thinking and reflection which has the potential to further develop conceptual understanding.

From my own teaching experience I have found that many learners seem to lack conceptual understanding of mathematical topics. The way we teach has an important role to play in terms of constraining or supporting conceptual understanding. As Kilpatrick et al. (2001) remark, “the knowledge, beliefs, decisions, and actions of teachers affect what is taught and ultimately learned” (p. 313). Kilpatrick et al. (2001) further state that the teaching of mathematics can be viewed as an interaction between the teacher, the learners and the subject (Mathematics). Furthermore, Simon (1995) posits that the teacher has the dual role of enhancing the development of conceptual understanding and of making sure learners share knowledge within the classroom community.

Constructivism as a theory of learning is a useful lens through which to interpret classroom practice in terms of teaching for conceptual understanding. With this in mind, the next section interrogates the notion of constructivist epistemology.

2.3.2 Constructivist Epistemology

Savery and Duffy (1995) see constructivism as “a philosophical view on how we come to understand or know” (p. 31). Constructivists believe that knowledge is constructed by learners as they engage in activities or in a process of learning. Loyens and Gijbels (2008) also suggest that one of the core elements of constructivism is that learners interpret new information with their prior knowledge and relate new knowledge to existing knowledge.

Fox (2001) describes the core characteristics of the constructivist view of learning as follows:

> (1) Learning is an active process.
> (2) Knowledge is constructed, rather than innate, or passively absorbed.
> (3) Knowledge is invented not discovered.
> (4a) All knowledge is personal and idiosyncratic.
> (4b) All knowledge is socially constructed.
> (5) Learning is essentially a process of making sense of the world.
> (6) Effective learning requires meaningful, open-ended, challenging problems for the learner to solve. (p. 24)

The above characterisation summarises aspects of constructivism in which the fundamental principle centres on knowledge construction. Fox (2001) also mentions that constructivism is essentially a theory of learning whereby learners use prior knowledge in the process of knowledge construction. However, knowledge construction is supported by the social set-up as well as prior knowledge.

Knowledge cannot simply be transferred from a teacher to a learner. Rather, teachers need to prepare activities and create environments that build on learners' experiences and prior knowledge. In addition, Simon (1995) adds that the role of the teacher is to create an environment in which learners learn best.

One of the fundamental tenets of constructivism is that learning occurs as learners are actively involved in a process of meaning making and knowledge construction rather than passively receiving information. Moreover, Fox (2001) also believes that "as a theory of learning, its central claim is that (human) knowledge is acquired through a process of active construction" (p. 24).

Most constructivists share two main ideas, namely that (i) learners are active in constructing their own knowledge and that (ii) social interactions are important to knowledge construction.

(i) Learners are active in constructing their own knowledge

Learners are the makers of meaning and knowledge. Savery and Duffy (1995) argue as follows:

> …we cannot talk about what is learned separately from how it is learned, as if a variety of experiences all lead to the same understanding, rather, what we understand is a function of the content, the context, the activity of the learner, and, perhaps most importantly, the goals of the learner. (p. 31)

In addition, the way teachers teach affects what is learned. This suggests that teachers need to plan activities that relate to learners' experience and prior knowledge. Savery and Duffy (1995) further explain that since understandings are

personally constructed, we cannot share understandings but rather we need to test the degree to which our individual understandings are well-suited. In addition, students should be encouraged, and indeed expected, to “think both critically and creatively and to monitor their own understanding i.e. function at a metacognitive level” (Savery & Duffy, 1995, p. 43).

(ii) Social interactions are important to knowledge construction.

The social environment is critical to the development of our individual understanding as well as to the development of knowledge. Savery and Duffy (1995, p. 32) indicate that we make use of our social environment to “seek propositions that are compatible with our individual constructions or understanding of the world”. Swan (2005) also comments that meanings are understood socially and then absorbed by individuals whereby these meanings will guide social interactions.

Phungphol (2005) remarks that:

> To provide effective social construction of knowledge, teachers [should] design sharing, caring, and nurturing classroom settings that promote social interactions, collaborations, cooperation, mutual respect, a sense of belonging, and tolerance for diversity that would lead to social and emotional competence and to the development of community of learning where every student enjoys and actively participate in the learning process. (p. 8)

Although constructivists have developed a learning framework to account for how learners learn mathematics, constructivism does not explicitly provide a means to make learners learn in a ‘constructivist way’. Rather, it is up to each teacher to find different ways to imbue their classroom with a constructivist pedagogy. Windschitl (2002) emphasises that:

> …if they [teachers] can get a sense of students' conceptions, frames of reference, and rules for organizing the world, teachers then must employ a range of facilitative strategies to support students' understandings as they engage in the problem-based activities that characterize constructivist classrooms. (p. 144)

2.3.3 Constructivist Pedagogy

Constructivist pedagogy refers to our way of teaching in relation to constructivist learning theory. Richardson (2003) describes constructivist pedagogy as

> …the creation of classroom environments, activities, and methods that are grounded in a constructivist theory of learning, with goals that focus on individual students developing deep understandings in the subject matter of interest and habits of mind that aid in future learning. (p. 1627)

The main emphasis is thus on teachers to adjust their activities, pedagogy and the learning environment to ones that support a constructivist learning theory. Another important aspect of constructivist pedagogy is that teaching should be connected to the prior knowledge and experience of the learners. Lattimore (1998) adds that "one of the best ways to improve performance is by connecting the pedagogy of mathematics to the lives and experiences of [the] students" (p. 52).

As Richardson (2003) states:

> …a constructivist classroom provides students with opportunities to develop deep understandings of the material, internalize it, understand the nature of knowledge development, and develop complex cognitive maps that connect together bodies of knowledge and understandings. (p. 1628)

The view is that learners in a constructivist classroom are exposed to connections between mathematical concepts for better understanding. Swan (2005) also states that meaning is constructed through communication, activities, and interactions with others (learners and teacher). Finally, Swan (2005) summarises constructivist pedagogy by highlighting that:

> …constructivism implies that learning is strengthened by environments which support and value the participation of all students, whose social norms encourage collaboration, the negotiation of meaning, and the search for understanding, and in which multiple perspectives are respected and incorporated into collective meaning making. (p. 9)

2.4 RELATIONSHIP BETWEEN CONCEPTUAL UNDERSTANDING AND CONSTRUCTIVISM

The notion of conceptual understanding resonates very strongly with a constructivist epistemology (Piaget, 1971) since conceptual teaching emphasises relating concepts and providing representations/ideas based on students' prior knowledge or experiences.

Most constructivists share two main ideas, namely that (i) learners are active in constructing their own knowledge, and (ii) that social interactions are important to knowledge construction. In addition, conceptual understanding and constructivist epistemology suggest that the construction of knowledge is shaped by the social environment and teachers need to structure their teaching on the interactions between learners. As Stein et al. (1994) point out, "in classrooms that are underpinned by constructivist epistemology, students are active rather than passive; teachers are facilitators of learning rather than transmitters of knowledge" (p. 26). Constructivism as a theory of learning is thus a useful lens through which to interpret classroom practice in terms of teaching for conceptual understanding.

Classrooms that support a constructivist view of learning incorporate multiple representations, consider learners' experience, focus on knowledge construction and create an environment that allows learners to engage with problems or activities. Taber (2011) points out that:

> …teaching is seldom about helping learners build up knowledge from nothing: indeed the constructivist approach suggests that would not be possible, as learning always builds upon, and with, the cognitive and conceptual resources already available. This leads to a number of key constructivist principles for teachers:
>
> - Teaching involves activating relevant ideas already available to learners to help construct new knowledge;
> - Students will build their new knowledge upon partial, incorrect, or apparently irrelevant existing knowledge unless carefully guided. (p. 48)

It is therefore important that teachers, as the facilitators of knowledge in the classroom, should help learners make connections between existing knowledge and learned knowledge. They can do so by guiding learners from what they currently know to what they are about to learn. Taber (2011, p. 49) also adds that from a constructivist position, “when teaching abstract concepts that cannot be directly shown or demonstrated to learners, the teacher needs to find ways to help students make connections with knowledge that could be relevant: using models, analogies and metaphors for example”. These are all components of teaching that have the potential to lead to conceptual understanding.

Furthermore, Taber (2011) suggests that:

> …effective constructivist teaching, whilst ‘student centred’ in terms of its focus on how knowledge building takes place in the mind of the learner, is very much ‘hands-on’ teaching where the teacher seeks to guide learning by supporting the knowledge-construction process. (p. 49)

Jones and Brader-Araje (2002, p. 6) also put an emphasis on “having students working together while sharing ideas and challenging each other's perspectives” as a constructivist approach which can promote conceptual understanding. Jones and Brader-Araje (2002) also note that learners do not enter classrooms as blank slates but posses a wealth of pre-knowledge and experience. They further view constructivist pedagogy as “an active process, taking students prior knowledge into consideration, building on preconceptions, and eliciting cognitive conflict” (p. 4).

There is also an important synergy between constructivism and conceptual understanding in relation to assessment practice. Given that constructivists view knowledge as “complex mental structures” (Swan, 2005, p. 8), a constructivist pedagogy should see assessment as emphasizing learning with understanding rather than “the memorization of isolated facts and procedures’’ (Swan, 2005, p. 8). Moreover, teachers can assess conceptual understanding by asking questions such as “*why?”* and *“how?”*, asking learners to solve and represent mathematical problems in different ways, or asking questions that require critical thinking.

Alonso-Tapia (2002) believes the following characteristics are most likely to promote conceptual understanding and change:

- Most suitable tasks: those demanding the *application and use* of knowledge for solving problems implying some degree of novelty (*analogous* and *transfer tasks*).
- Teachers make explicit for what goals understanding of particular content is relevant.
- Tasks designed to allow teachers to identify specific factors in students that hinder conceptual change.
- The assessment process covers the different nodes and links of the conceptual network students are supposed to construct.
- Teachers give specific help based on assessment, whether this takes place before, during or after instruction.
- Teachers avoid messages and classroom practices stressing the relevance of assessment for goals extrinsic to understanding. (p. 395)

In addition, Alonso-Tapia (2002) suggests that teachers can create assessment contexts that can affect the level to which students strive for understanding, and as such it is necessary to consider the characteristics of such assessment tasks. As Samuelsson (2010) remarks, “problem-based learning is significantly better for improving students’ performances in conceptual understanding” (p. 71). It is of vital importance for teachers to incorporate problem solving into their teaching in order for them to improve their conceptual understanding. Samuelsson (2010, p. 71) further adds that “students who worked in problem-solving classes were exposed to a higher level of reasoning, and that they accept this reasoning as valid”. Classrooms that incorporate problem solving promote conceptual understanding in learners because learners are involved in high levels of reasoning and critical thinking.

2.5 LEARNER-CENTRED EDUCATION

In many countries, the notion of learner-centred education has been of central importance. In learner-centred education the role of the teacher is to guide, help and facilitate learning. The emphasis of the learner-centred approach is on learners taking control of their learning. By doing so, they are expected to engage fully in the

lessons by asking questions and sharing ideas. Schweisfurth (2013) also indicates that, "...learners not only have more control over what they learn and the process of learning, but are encouraged to question critically canons of received knowledge and the unequal structures of society which they support" (p. 2).

The teachers' role is critical in ensuring the success of a learner-centred approach. As further elaborated by McLoughlin and Luca (2002), the main role of the teacher is to enable "learners to take an active role in learning by initiating, managing, monitoring, reflecting and evaluating learning tasks and processes" (p. 574).

2.5.1. Learner-Centred Education in the Namibian Context

Learner-centred education (LCE) was chosen as an approach for teaching and learning for Namibia after independence.

The Namibian Ministry of Basic Education and Culture [MBEC] (1999) describes LCE as:

> …an approach that means that teachers put the needs of the learner at the centre of what they do in the classroom, rather than the learner being made to fit whatever needs the teacher has decided upon. This means that activities which put the learner at the centre of teaching and learning must begin by using or finding out the learners' existing knowledge, skills and understanding of the topic. The teacher is responsible for developing different activities to find out what the learners already know about the topic. Then teachers develop more activities that build on and extend the learners' knowledge. (p. 5)

Based on this definition, a learner-centred approach strives for the teacher to place a critical emphasis on the needs of each learner by finding out what learners already know about a given topic. The teacher should also prepare activities that prompt learners' experience and help them to construct knowledge. In addition to this, the Namibian Ministry of Education and Culture (MEC) also highlights that, "it is by reflecting on what we have experienced that we internalise the outer world and activity into inner understanding" (Namibia. MEC, 2003, p. 9).

Importantly, in a learner-centred approach, activities should be arranged in such a way that every learner has a chance to engage with hands-on activities and thereby become actively involved in the learning process. In relation to this, the MEC (Namibia. MEC, 2003) adds that a basic principle of learner-centred education is the creation of an environment in which each and every learner learns to the best of his or her ability.

Furthermore, the MEC (Namibia. MEC, 2003) also adds that a learner-centred approach emphasises that if learners are taught in a way which builds on what they already know and have experienced, learning is more likely to be meaningful. It is also believed that the learner-centred approach increases understanding because learners learn best through hands-on engagement or when they share ideas in groups.

Learner-centred education also encourages teachers to use different representations to link learners' experience to new knowledge. Swan (2005) remarks:

> …learner-centred teaching thus recognizes the importance of building on the conceptual and cultural knowledge that students bring with them to the learning experience, of linking learning to students' experiences, and of accepting and exploring multiple perspectives and divergent understandings. (p. 6).

The MBEC (Namibia. MBEC, 1999) urges that teaching that supports learner-centred education involves interacting with learners and creating an environment where teachers recognise the prior knowledge of their learners. Teaching which ignores and does not build on learners' prior experience and learning will limit learners' thinking as they are less likely to see the connection between the world outside school and what is taught and learnt in the school. Learner-centredness also requires learners to be motivated for them to fully take part in teaching and learning activities.

Communication is essential in learner-centred education. For learners to engage, to share ideas and to participate fully, they need to communicate with each other or with the teacher. Windschitl (2002) believes that learning happens when individuals

express themselves and when they negotiate with other individuals. The MEC (Namibia. MEC, 2003) also adds that listening skills are an essential requirement for communication, and it is important to ensure that learners listen to each other as well as the teacher in order to explore and share knowledge. Classrooms should create a learning environment whereby learners are given a chance to talk about a problem and communicate it to each other, to ask questions, and to discuss problems in groups and as a whole class. The MEC (Namibia. MEC, 2003, p. 9) further comments that, "through communication with others, playing, experimenting, experiencing things, and by reflecting on them, the child learns".

The MBEC (Namibia. MBEC, 1999) has identified the following as the main indicators of LCE:

- The starting point is the learners' existing knowledge, skills, interests and understanding, derived from previous experience in and out of school;
- the natural curiosity and eagerness of all young people to learn to investigate and to make sense of a widening world must be nourished and encouraged by challenging and meaningful tasks;
- the learners' perspective needs to be appreciated and considered in the work of the school;
- Learners should be empowered to think and take responsibility not only for their own, but for another's learning and total development;
- Learners should be involved as partners in, rather than receivers of educational growth. (p. 5)

2.6 THE RELATIONSHIP BETWEEN LCE, CONSTRUCTIVISM AND CONCEPTUAL UNDERSTANDING

Learner-centred education, constructivism and conceptual understanding are intimately related. Classrooms that promote a learner-centred approach, that are imbued with a constructivist pedagogy, and which place an emphasis on conceptual understanding can be characterised by the following overarching features:

(a) A focus on prior knowledge and experience

One of the focal points of a constructivist pedagogy, LCE and conceptual understanding is that learning should be built on learners' prior knowledge and experience. It is this prior knowledge and experience that helps learners to build new knowledge on their existing knowledge.

As Simon (1995) comments, "…we construct our knowledge of our world from our perceptions and experiences, which are themselves mediated through our previous knowledge" (p.115). The notion of prior knowledge is also highlighted by Kilpatrick et al. (2001) when they remark that learners with conceptual understanding are better able to learn new knowledge since they are able to relate new knowledge to the knowledge they have already acquired. Therefore, learners' prior knowledge and experience helps teachers to teach for conceptual understanding, and to teach with a learner-centred approach through a constructivist pedagogy.

(b) A focus on knowledge construction

Constructivism as a theory of learning has as its central claim "…that (human) knowledge is acquired through a process of active construction" (Fox, 2001, p. 24). Learning occurs when learners construct knowledge as opposed to learners receiving information from the teacher. The construction of knowledge promotes critical thinking and helps learners to learn independently.

LCE and notions of conceptual understanding also place emphasis on knowledge construction, as they require learners to be at the centre of learning. Group work and leading learners into discussions and debates are some aspects of a learner-centred approach that can promote conceptual understanding through knowledge construction.

(c) The use of multiple presentations and connections

Multiple representations serve as a way of solving mathematical problems, and thinking about mathematical concepts, in different ways. Learners should be able to connect different mathematical concepts and represent them in different ways. An ability to form such connections and to see relationships between different mathematical ideas is indicative of a deep conceptual understanding (McCormick, 1997). This resonates with a constructivist pedagogy in which students need different tools to make representations and explore ideas (Noddings, 1990).

(d) The arrangement of the physical and social environment of the classroom

Swan (2005) remarks that environments that are learner-centred accept a constructivist philosophy that individuals bring unique knowledge, skills, attitudes, and beliefs to the learning experience, and that teachers should find different ways to structure these experiences during teaching and learning. Swan's remark resonates with notions of conceptual understanding. Teachers should create an appropriate physical and social environment in the classroom by allowing learners to engage with hands-on activities rather than sitting or doing individual work, and by encouraging learners to ask questions and interact with each other or with the teacher.

(e) Teacher-learner and learner-learner interaction

Effective teacher-learner and learner-learner interaction supports conceptual understanding, LCE and a constructivist pedagogy since such interactions all call for the sharing of ideas and the helping of each other, as opposed to the teacher being the only source of information.

(f) Authentic tasks

Constructivist pedagogy, a learner-centred approach and notions of conceptual understanding rely on activities and the building of mathematical concepts through

hands-on activities. Windschitl (2002) also believes that learners should be given opportunities to engage in tasks that are situated to the learners' context and experience.

2.7 CONCLUSION

The purpose of this chapter was to provide a contextual and theoretical background to the study. The literature review focused on teaching for conceptual understanding with the focus on constructivist epistemology as a theory of education that underpins the study. The chapter also looked at the relationship between conceptual understanding and constructivism and how they inform teaching and learning.

The chapter also looked at the Namibian context with reference to Learner-Centred Education and its impact on the teaching and learning of Mathematics. The relationship between constructivism, conceptual understanding and learner-centred education was also interrogated.

CHAPTER THREE
METHODOLOGY

3.1 INTRODUCTION

The purpose of this chapter is to provide a clear overview of the methods, techniques and procedures used to carry out the research.

3.2 RESEARCH GOALS

The goal of this research was to find out how teachers' practice either supported or constrained learners' conceptual understanding. This was done with the help of the following research question:

- How may teachers' practice support/constrain the development of learners' conceptual understanding?

3.3 RESEARCH ORIENTATION

This study is anchored within an interpretive paradigm. As stated by Cohen et al. (2011, p. 17) "the central endeavour in the context of the interpretive paradigm is to understand the subjective world of human experience". The interpretive paradigm is well suited to the study because it seeks to understand how teachers' practice supports or constrains conceptual understanding, and as such focuses on teachers' lived experience.

3.4 RESEARCH METHODOLOGY

This research took the form of a case study. The two participating teachers represent the case under scrutiny, and the unit of analysis is the teaching practice of the two teachers. Leedy and Ormrod (2010) highlight the importance of the case study methodology in that it promotes understanding of a specific situation under study and is useful for investigating focused instances of human interaction.

“Case studies investigate and report the real-life, complex dynamic and unfolding interactions of events” (Cohen et al., 2011, p. 289). The case study methodology is thus appropriate for my research since its focus is on specific aspects of two teachers’ teaching practice as well as related teacher-learner interactions. Kane and Brún (2001) remark that in a case study the researcher is able to obtain a better understanding of how things work in relation to attitudes, behaviours, and the environment in a natural setting.

The case study methodology helped me to understand the teachers’ practice in relation to the teacher-learner interaction, teaching methods and other aspects that supported or constrained conceptual understanding.

3.5 RESEARCH DESIGN

The research made use of two different data collection methods – observation and stimulated recall interviews. Using different data collection methods is useful in qualitative research because it helps the researcher to collect more data than would have been possible using a single research method. Kane and Brún (2001) also support the use of multiple methods since it provides “’stronger’ information than using a single technique” (p.108).

Furthermore, using different data collection methods – particularly the use of interviewing – also helped me to obtain greater understanding of particular episodes that were noted during the lesson observations. During the interviews I was able to ask the teachers to expand on these incidents thereby gaining a more nuanced understanding of what I was able to extract from the lesson observation.

The research was carried out in two stages.

Stage 1

The first stage was to collect qualitative data by video recording six classroom lessons, three for each of the two participating teachers. Creswell (2008) states that

the advantages of observation include “the opportunity to record information as it occurs in a setting, to study actual behaviour” (p. 222). The recorded videos helped me to review the teachers’ practice through multiple viewings and thus to understand their practice better.

Three Grade 10 lessons for each of the two teachers were audio-visually recorded. In addition to collecting data with respect to how teachers’ practice supported or constrained the development of learners’ conceptual understanding, vignettes from the recorded lessons were used as the basis of the stimulated recall interviews in Stage 2.

Stage 2

Upon conclusion of the lesson observation sessions, teachers were individually interviewed. These interviews took the form of a stimulated recall interview. Short vignettes were drawn from the lesson observation footage and played back during the interview. These vignettes captured interesting classroom episodes where each teacher’s actions seemed to either support or constrain the development of learners’ conceptual understanding.

The two teachers were asked to reflect on their classroom practice as evidenced in the chosen vignettes. This then led into a semi-structured discussion around issues pertaining to their classroom practice that either support or constrain learners’ development of conceptual understanding. These interviews were audio recorded and subsequently transcribed.

3.6 DATA COLLECTION METHODS

Two different data collection methods were used – observation and stimulated recall interviews.

3.6.1 Observation

According to Cohen et al. (2011, p. 456), “the distinctive feature of observation as a research process is that it offers an investigator the opportunity to gather ‘live’ data from naturally occurring social situations”.

The observed lessons were audio-visually recorded and were later analysed using an observation schedule (see Table 3.1 in Section 3.8).

3.6.2 Stimulated recall interviews

After observing the teachers, the second stage was to carry out stimulated-recall interviews relating to themes or interesting episodes that emerged from the recorded lessons. These interviews were very important because they allowed me to delve deeper into particular issues or themes that emerged from the lesson observation process. As Gay and Airasian (2003) remark, “interviews permit researchers to obtain important data they cannot acquire from observation” (p. 209).

During the interviews, the researcher also asked open-ended questions to allow interviewees to express their views on particular aspects of the lessons as well as common themes emerging from the lessons. Each teacher was interviewed individually.

3.7 RESEARCH SITE AND PARTICIPANTS

The research took place in the Okahao Circuit of the Omusati Region of Namibia. The selection of the two teachers was based on their being identified as effective/successful teachers. These two teachers achieved the best learner results in Mathematics in the Grade 10 final examination of 2012 in the Okahao Circuit. I specifically chose to work with these two teachers because I wanted to explore how successful teachers’ practice supports/constrains conceptual understanding. The sampling technique employed was thus purposeful sampling (Cohen et al., 2011).

3.8 DATA ANALYSIS

The data gathered during the lesson observations and interview sessions was analysed with respect to two different aspects:

- actions that support the development of conceptual understanding
- actions that potentially constrain the development of conceptual understanding

3.8.1 Classroom observation

Classroom observations were analysed in terms of an observation schedule. The observation schedule was based on the two key theoretical ideas, namely (i) conceptual understanding as an element of Kilpatrick et al.'s (2001) strands of mathematical proficiency, and (ii) constructivist epistemology. The framework includes aspects such as:

- The interaction between teacher and learners.
- Teaching based on knowledge construction and critical thinking.
- The nature of discussions and prompting of questions.
- Use of multiple representations by the teacher.
- Peer-oriented learning.
- Acknowledgement of learners' prior knowledge.
- Emphasis on connection making.

This framework was developed by drawing on appropriate literature relating to notions of conceptual understanding and constructivist epistemology.

The lessons were observed using the observation schedule shown in Table 3.1.

Observation Schedule

Table 3.1 Observation Schedule

Observation Criteria	**Rating**		
	0	**1**	**2**
Introduction			
The teacher discusses the homework with the learners and asks questions like “how did you get the answer?” or “why did you do it this way?”			
The teacher considers what the learners know already (pre-knowledge) by asking questions related to the lesson topic when introducing the lesson.			
Teaching and Learning			
The classroom is structured for co-operative learning.			
The teacher builds teacher-learner and learner-learner interaction.			
The teacher leads learners into discussions.			
The teacher prompts learners to ask questions.			
Teaching and learning involve the use of concrete materials or manipulatives.			
The activities are focused on building mathematical concepts through hands-on activities.			
The learners are actively involved.			
The questions are focused on knowledge construction and critical thinking.			
The teacher asks “why” and “how” questions.			
The teacher engages the learners in peer-oriented learning (e.g. pair work, group work, debate).			
The teacher uses multiple representations of mathematical concepts.			
The teacher monitors the activities and assists where possible.			
The learners are assessed through student work, observations and points of view.			
The teacher motivates learners.			
The teacher analyzes the performance of the learners.			
The teacher provides feedback and advice on learners’ performance.			
Conclusion			
The teacher gives homework.			

Explanation of the grading system

The grading criteria range from 0 to 2, with 0 being the weakest and 2 being the strongest**.** A tick was placed at a rating (0 – 2) according to the extent of the evidence shown.

Table 3.2 The grading criteria

Rating	Numeric Rating	Description of the rating
Evident	2	There is strong evidence of all or almost all components of an observed criterion.
Partially evident	1	There is only partial evidence of the observed criteria.
Not evident	0	There is no evidence of the observed criteria.

3.8.2 Stimulated recall interviews

The stimulated recall interviews were used to deepen the analysis of the classroom observations using the criteria in the observation schedule. The data was further analysed in terms of emerging themes. These themes were developed through repeated engagement with the interview data with the help of the observation schedule.

3.9 SUMMARY OF THE DESIGN AND TOOLS

Table 3.3 Summary of the research process

Phase	Tools/Techniques	Aim	Data	Analysis
1	Piloting	• To assess the effectiveness of the observation instruments (video recording machines). • To test the observation schedule	- Qualitative	Analysis of effectiveness of observation instruments and schedule.
2	Classroom Observation	• To observe teachers' practice.	- Audio-visual recordings	Observation schedule.
3	Stimulated-recall interview with individual teachers	• To engage with the teachers on emerging themes.	- Interview transcripts	Emerging themes. Analysis with participants

3.10 VALIDITY

Validity refers to whether the data collected and analysed is trustworthy. Cryer (2000, p. 76) describes a piece of research as being valid if it “does what it is intended to do”. Moore (1998, p. 163) describes validity as “the degree to which an evaluative device measures what it is supposed to measure”. In terms of validity, I piloted my observation schedule and made necessary adjustments to it prior to commencing the study. In addition, during the interviews I engaged the teachers in a discussion related to aspects of their classroom practice. This allowed me to seek clarity on particular classroom episodes where observations were insufficient or ambiguous. The stimulated recall interviews in part thus represent a form of member checking.

3.11 ETHICAL CONSIDERATION

The anonymity of all research participants was ensured throughout the research process and pseudonyms are used in this written thesis. Prior to commencement of the study, formal consent was obtained from all participants (teachers) as well as the principals of the schools where the research took place. Permission to carry out the research was also obtained from the Circuit Inspector.

The Circuit Inspector, the principals of the two schools, the two teachers and the learners were informed about the purpose of the study. They were also informed that their names would be kept anonymous. All the participants took part in the research through voluntary informed consent.

Learners involved in the videos were also informed that the videos would only be used for the purposes of the research study.

3.12 CHALLENGES

There were a number of initial challenges related to the data collection process, mainly in terms of technology. However, these issues were resolved through the piloting process.

There were also a number of challenges in terms of the data collection. There was a lot of rescheduling of observation and interview times due to changes in the teachers' timetables and teachers being absent from school, and this added to time pressures in terms of the data analysis.

3.13 CONCLUSION

It was the purpose of this chapter to describe the design of the data collection and analysis process. The next chapter presents and discusses the generated data.

CHAPTER FOUR
RESULTS, ANALYSIS AND DISCUSSION

4.1 INTRODUCTION

This chapter presents, analyses and discusses the data. The chapter is divided into two sections, corresponding to the two stages of the research process. Stage 1 focuses on the classroom observations. Six lessons, three for each of the two participating teachers (Samuel and Titus) were video recorded. These lesson observations were analysed and are discussed through the use of the previously described observation schedule. Stage 2 took a form of stimulated-recall interviews which were analysed based on emerging themes derived from the classroom observation. The chapter concludes with a summary of the findings from these two stages.

4.2 STAGE 1

In this section I present and discuss the data emanating from the classroom observations.

4.2.1 Findings from Observation

The classroom observation schedule was used for each observed lesson – three lessons for each of the two participants. Tables 4.1 and 4.2 represent the combined observation schedules for Titus and Samuel respectively. The lessons are then described in relation to the categories in the observation schedule.

4.2.1.1 Findings from Titus

<u>Overall Observation Schedule</u>

In Table 4.1 the grading criteria range from 0 to 2, with 0 being the weakest and 2 being the strongest**.**

Table 4.1 Observation Schedule - Titus

Observation Criteria	**Rating**		
	Lesson 1	**Lesson 2**	**Lesson 3**
Introduction			
The teacher discusses the homework with the learners and asks questions like “how did you get the answer?” or “why did you do it this way?”	0	0	0
The teacher considers what the learners know already (pre-knowledge) by asking questions related to the lesson topic when introducing the lesson.	2	2	0
Teaching and Learning			
The classroom is structured for co-operative learning.	0	0	1
The teacher builds teacher-learner and learner-learner interaction.	2	1	2
The teacher leads learners into discussions.	0	0	2
The teacher prompts learners to ask questions.	2	0	2
Teaching and learning involve the use of concrete materials or manipulatives.	2	0	0
The activities are focused on building mathematical concepts through hands-on engagement.	2	0	0
The learners are actively involved.	2	1	2
The questions are focused on knowledge construction and critical thinking.	2	2	2
The teacher asks “why” and “how” questions.	1	1	1
The teacher engages the learners in peer-oriented learning (e.g. pair work, group work, debate).	0	0	1
The teacher uses multiple representations of mathematical concepts.	0	1	2
The teacher monitors the activities and assists where possible.	0	2	2
The learners are assessed through student work, observations and points of view.	1	0	2
The teacher motivates learners.	1	1	1
The teacher provides feedback and advice on learners’ performance.	1	1	2
Conclusion			
The teacher gives homework.	2	0	2

Observation from lesson 1

The topic for the first lesson was locus. The lesson covered four types of locus: fixed distance from one point, fixed distance from one line, equidistant from two points, and equidistant from two intersecting straight lines. The teacher gave one example of each type of locus after which learners were given class work.

When beginning the lesson, Titus considered the prior knowledge of the learners by asking them questions on locus before introducing the lesson. Titus started the lesson by saying, *"This is a line. I want you to draw for me the sets of points which are 2cm from this line. How are you going to draw them? What are you going to do?"* By asking these questions, Titus wanted to assess what learners already knew about the concept of locus.

The classroom was not structured for cooperative learning. Learners were not seated in small groups where they could share ideas and solve problems together. Rather, each learner was seated on his or her own.

There was good interaction between the teacher and the learners, as well as between the learners themselves. Some learners were working on the chalkboard together with the teacher while other learners, who were not at the chalkboard, called the teacher for help when they needed it. The teacher mostly took on the role of observing and assisting where possible.

Even though there was good interaction in the classroom, the teacher did not lead learners into discussions. Other than the learners at the chalkboard, the learners were not arranged in groups to discuss the class work. One of the learners at the chalkboard was given a chance to explain the work to the others.

Although Titus did not lead learners into discussions, he prompted learners to ask questions after every explanation. Most of the learners asked questions and this helped the teacher to assess their understanding and to know when to move on with a new concept or when further explanation was necessary. Learners not only asked

questions of the teacher, but of each other as well – e.g. when a fellow student was explaining on the chalkboard.

The teaching involved the use of concrete materials and manipulatives. During the lesson, the teacher and learners used compasses and rulers to construct locuses. Learners practised using the pair of compasses and the ruler on the chalkboard. Learners who were not at the chalkboard practised in their book.

The compasses and the rulers helped learners to build mathematical concepts through hands-on engagement. Some learners used a sheet of paper with two correctly spaced holes to draw the locus of points equidistant from a given point. This hands-on approach helped them build the mathematical concept of locus.

The learners in this lesson were actively involved with every learner wanting to do something on the chalkboard. Learners were asking questions, answering questions from the teacher and from their fellow learners, and were contributing towards learning.

The teacher asked questions during the lesson with the focus on knowledge construction and critical thinking. He asked questions like "*How do you do this?"* and "*Why do you do it that way?"* The "why?" and "how?" questions encouraged learners to think critically, and required them to justify their answers.

The lesson was not prepared so as to engage learners in peer-oriented learning. However, a few learners were given the chance to do the class work on the chalkboard while others observed.

The teacher did not represent locus in different ways and only used one method for finding the locus. Nonetheless, some learners devised their own means of drawing the locus of points equidistant from a given point. These learners used a sheet of paper in which they made two correctly spaced holes. One hole was then placed at the centre point with a pen in it to hold it in place while a pencil was placed in the other hole. The pen was then kept fixed at the point while the pencil was rotated to

draw a circle – i.e. the desired locus of points equidistant from a given point. Titus could have capitalised on this by asking the learners to demonstrate their own particular solution to the problem.

The teacher did not monitor how well the activity was being done in the class. He focused mainly on what the learners on the chalkboard were doing. Although some of the seated learners called the teacher for help, many who didn't still seemed to have a problem in finding the locus. The teacher did not monitor how learners were progressing individually.

Titus motivated the learners who were doing the class work on the chalkboard, for example by praising with encouraging words such as "well done" and "that is good", but did not encourage the other learners who were seated at their desks.

The teacher provided feedback to the learners at the end of the lesson on the main points of the lesson. Homework was set.

Observation from lesson 2

Scale Drawing was the topic for the second lesson. During the introduction of the lesson, the teacher asked questions to test the learners' understanding. For example, the teacher began the lesson by saying, *"the height of this door is 1.7 metres. Then I say draw it in your book. Can that diagram fit in your book?"* The answers from the learners was NO because 1.7 metres is too big to fit onto a sheet of paper in their books. With this simple example, the teacher introduced scale drawing. After further examples, a class work activity was set.

The classroom was not structured for cooperative learning, nor was the lesson itself. Learners were seated at their individual desks and just listened to the teacher.

The classroom environment was quiet and there was little interaction between the teacher and the learners and between learners. The teacher did most of the calculations on the chalkboard and the learners were given little work to do.

The teacher did little in leading learners into discussions. Learners were not given the opportunity to discuss their scale drawing with their colleagues.

In this lesson, the teacher did not prompt learners to ask questions. Instead, the lesson was dominated by the teacher who did most of the calculations.

No concrete materials or manipulatives were used in this lesson. All the work was based on calculations done on the chalkboard.

The activity that was given by the teacher required learners to calculate, but did not build mathematical concepts through hands-on activities.

Many learners were not actively involved. This was perhaps a result of the teacher doing most of the work on the chalkboard. Only a few learners were involved in doing the class work on the chalkboard. Although some of the seated learners did the class work individually, many others were disconnected from the lesson.

Despite the fact that Titus was doing most of the work, he nonetheless asked questions that focused on knowledge construction and critical thinking. The teacher asked the meaning of “NOT TO SCALE” which was next to the shape he had drawn. One learner answered that “*it means you do not need to measure”.* Titus further asked “*why are you saying it means you do not need to measure?”* He wanted learners to explain what they were saying in order for him to assess whether the learners really understood what they were saying.

The teacher did not engage the learners in peer-oriented learning. The activity that was given focused on individual work, although some learners discussed things with each other. The teacher did not arrange learners in groups or in pairs for them to tackle the class work exercise.

Scale drawing was represented in different ways, and the teacher related scale drawing done in the Mathematics class to the scales given on maps as experienced in Geography.

The teacher spent only a small amount of time moving around the class monitoring the class work and assisting the learners where possible. The teacher also monitored and assisted those learners who were doing the class work on the chalkboard.

Feedback was provided after the class work was completed. No homework was given.

Observation from lesson 3

The topic for lesson 3 was the continuation of scale drawing. The teacher started the lesson by asking questions for the learners to recall what they were taught during the previous lesson. After that, the teacher did one example on the chalkboard on how to calculate the length, area and volume using a given scale (1:50). The last part of the lesson was given over to revising an unrelated topic – that of simultaneous equations. Learners solved simultaneous equations on the chalkboard and the teacher assisted them.

In this lesson, no homework was discussed since none was given in the preceding lesson. The teacher started the lesson by asking questions in order for the learners to recall what they remembered from the previous lesson.

The classroom was partially structured for co-operative learning because some learners were seated in pairs and discussed the class work together.

The teacher-learner and learner-learner interaction was excellent. Learners were answering the given problems on the chalkboard and discussing them. The learners were also writing the problems they considered to be challenging on the chalkboard for others to solve in order to learn from each other. The teacher took the role of

facilitator, with most of the work being done by the learners themselves. The teacher's role was to assist and offer guidance where necessary.

The teacher led learners into discussions. The teacher gave learners a chance to talk to each other about the problems on the chalkboard. He also allowed free discussions between the learners who were solving problems on the chalkboard and the learners seated in the class.

The learners were encouraged to ask questions where they did not understand. Some learners asked questions by writing problems on the chalkboard while others asked questions related to the problems presented on the chalkboard. These questions helped learners to learn more – both from the teacher's explanation as well as from contributions from other learners.

The lesson did not involve the use of concrete materials or manipulatives. Teaching and learning was based on the calculations on the chalkboard.

The activities of this lesson did not involve using concrete materials to build mathematical concepts.

The learners were actively involved. They took control of the class by doing most of the work on the chalkboard. Learners were solving problems on the chalkboard, they were writing problems on the chalkboard and solving them, and they were also explaining and discussing problems on the chalkboard. The learners who were seated solved the problems on their own and contributed during the explanations. Some learners discussed the problems in pairs. The teacher was a facilitator.

The teacher asked questions that focused on knowledge construction and critical thinking. For example, the teacher drew a map on the chalkboard and asked learners to find the distance from Okahao to Windhoek. He further asked questions that focused on knowledge construction and critical thinking like "*what are you going to do?"* Some learners were able to think that they needed to use the scale to find

out the real distance between Okahao and Windhoek. These types of questions helped learners to think logically and critically.

The seating arrangement in this class did not fully support peer-oriented learning. Some learners were seated in pairs and in small groups of three, but others were seated individually. Although the teacher emphasised that learners should discuss the problems and solve them together, only those learners in pairs or in small groups managed to engage in peer-oriented learning. The rest of the learners were working individually.

On the revision part (simultaneous equations), the teacher represented mathematical concepts in different ways, using the different solution methods of elimination and substitution.

The teacher motivated the learners and provided feedback by highlighting the main things learners should know when solving these problems. The teacher then gave homework.

4.2.1.2 Findings from Samuel

Overall Observation Schedule

The grading criteria range from 0 to 2, with 0 being the weakest and 2 being the strongest**.**

Table 4.2 Observation Schedule - Samuel

Observation Criteria	**Rating**		
	Lesson 1	**Lesson 2**	**Lesson 3**
Introduction			
The teacher discusses the homework with the learners and asks questions like “how did you get the answer?” or “why did you do it this way?”	2	0	0
The teacher considers what the learners know already (pre-knowledge) by asking questions related to the lesson topic when introducing the lesson.	1	2	1
Teaching and Learning			
The classroom is structured for co-operative learning.	0	0	0
The teacher builds teacher-learner and learner-learner interaction.	2	2	2
The teacher leads learners into discussions.	1	1	0
The teacher prompts learners to ask questions.	2	2	2
Teaching and learning involve the use of concrete materials or manipulatives.	0	2	2
The activities are focused on building mathematical concepts through hands-on engagement.	0	2	0
The learners are actively involved.	2	2	2
The questions are focused on knowledge construction and critical thinking.	2	1	2
The teacher asks “why” and “how” questions.	0	1	2
The teacher engages the learners in peer-oriented learning (e.g. pair work, group work, debate).	1	0	1
The teacher uses multiple representations of mathematical concepts.	2	0	0
The teacher monitors the activities and assists where possible.	2	2	2
The learners are assessed through student work, observations and points of view.	1	2	2
The teacher motivates learners.	1	1	1
The teacher provides feedback and advice on learners’ performance.	2	2	2
Conclusion			
The teacher gives homework.	2	2	2

Observation from lesson 1

The topic for this lesson was “division by a monomial”. Samuel started the lesson by monitoring homework. He then asked a number of questions about monomials as a starting point, as well as to assess learners’ background understanding of monomials. The teacher did some examples on the chalkboard and then gave the class work to do. This was done by some learners on the chalkboard and by the rest of the class individually in their seats. Learners who did the class work on the chalkboard were asked to explain to the other learners. The teacher assisted the learners by explaining and correcting the class work.

The teacher started the lesson by monitoring homework at random. The teacher monitored a number of books and asked learners questions like “how did you get the answer?” However, the teacher did not put much emphasis on the responses from the learners. The teacher’s main aim was to check whether the learners had done the homework. After the homework check Samuel asked two learners to do the homework on the chalkboard, the focus here being on how to get the correct answer. After the two learners gave the answers, Samuel praised them while pointing out any mistakes they had made. However, there was no emphasis on *how* the learners got the answer or if other learners had *different* ways of getting to the answer.

The classroom was not arranged for co-operative learning. Each learner was seated at his or her own desk. It appeared that Samuel did enough to build teacher-learner and learner-learner interaction. During class activities, he asked learners to do the work on the chalkboard. While some learners were doing the work on the chalkboard, the rest did it individually at their desks. The teacher moved around the class to assist learners, with most learners calling for assistance. Besides assisting individual learners, the teacher also asked questions and assisted the learners working on the chalkboard. The teacher also asked the learners who were working on the chalkboard to explain the solutions to the others. In addition to that, Samuel asked learners to assist one another when a learner was unable to give a correct answer or was unable to explain a concept.

Although the teacher asked learners to do the work on the chalkboard, little was done by the teacher to lead learners into discussions.

In this lesson, teaching and learning did not involve the use of concrete materials or manipulatives. The work focused on doing calculations – either on the chalkboard or individually.

Learners were actively involved in this lesson. Most of them were eager to do the class work on the chalkboard and some volunteered answers when the teacher asked them. The learners were also free to help each other, which many of them did. The teacher did not ask any “why?” or “how?” questions during this lesson, other than superficially doing so when checking homework. The teacher asked learners to give the answers but did not attempt to ask *how* the learners got the answer or *why* they had approached it in a particular way.

Learners were not engaged in peer-oriented learning (e.g. pair work, group work, debate) in this lesson. The activity given was done on the chalkboard by some learners and the rest of the learners carried out the activity individually.

The teacher did little to motivate learners. Even though he praised the learners by saying “good answer” or “excellent answer”, he did not encourage learners to put more effort into their work, especially those who did not do well in their homework.

Although the teacher did not analyse the performance of the learners in this lesson, he did give feedback related to the activities. The teacher explained all the steps to get the answer and also gave alternative ways of getting the answer (multiple representations). Learners thus had the freedom to use the method which made the most sense for them.

Homework was given and learners were encouraged to help one another.

Observation from lesson 2

Translation was the topic for lesson 2. The lesson content focused on how to translate a figure and how to describe the transformation. The teacher asked a few questions on translation and did a few examples on the chalkboard and on the whiteboard. After the teacher gave a few examples, a number of learners were asked to translate figures drawn on the whiteboard with the assistance of the teacher. The teacher explained more on how to translate figures and then moved on to how to describe the transformation (translation). He concluded the lesson by giving homework as well as a short summary on how to describe translations.

In this lesson, the teacher did not discuss the homework given in the previous lesson. The teacher started the lesson by asking learners to explain the term “translation” The teacher followed this introduction by explaining the term and giving a few examples.

The classroom was not structured for co-operative learning. Learners sat at their individual desks.

There was good interaction between the teacher and the learners as well as between learners. The learners were involved in doing the class work on the chalkboard together with the teacher. Learners were also helping each other.

There was very little discussion in the classroom. Those learners who were doing the work on the chalkboard were more involved than those learners working individually. Learners were not given a chance to discuss either the class work or their answers.
The teacher gave learners a chance to ask questions after every explanation, although only a few learners asked questions - most of them were quiet.

In this lesson the teacher did not make use of concrete materials or manipulatives. The teacher only translated different figures that were drawn on a whiteboard.

The activities that were given did not help learners to build mathematical concepts through hands-on engagement because learners were not given any concrete materials to translate. Learners were only given a chance to translate the figures drawn on the whiteboard.

The classroom environment was relaxed and quiet, and learners were actively involved with the work, translating different figures according to given vectors.

The questions asked by the teacher did not focus on knowledge construction and critical thinking. Rather than asking “why?” and “how?” questions for learners to justify their answers, the teacher focused more on process and procedure.

The activities given were done on the chalkboard by a few learners. No pair work or group work took place. Learners were learning from the learners doing the class work on the chalkboard, from the explanations from the teacher and by asking questions.

Even though learners seemed to master the method used by the teacher to translate a given figure, the teacher did not use different approaches to translating the figures. The teacher did not ask learners to explore if there were different ways of translating a figure.

Samuel did a lot to assist learners. He helped learners to translate figures and also helped learners explain to others in cases where questions arose. The teacher also made use of “code switching” to help learners where he thought they needed more clarity.

The learners’ contributions (either giving answers or asking questions) were recognised and praised by the teacher. The teacher also directed questions to learners who were not participating in order to encourage them to take part. Even though the teacher recognised the contributions of the learners, Samuel did not do more to motivate the learners and to encourage them to ask questions. Homework was given for the learners to practice.

Observation from lesson 3

In this lesson, the topic was “Rotation”. The lesson content focused on how to rotate a figure through 90°, 180° and 270° clockwise or anticlockwise. The teacher showed a number of examples on the whiteboard and gave learners a chance to rotate drawn figures on the whiteboard. Class work was then set and the teacher asked some of the learners to come to the board to do the class work.

The teacher did not discuss the homework given in the previous lesson. During the introduction of the lesson, the teacher asked a few questions like; in which direction will the figure move if rotated 90° clockwise about the origin?

The arrangement of the classroom did not support co-operative learning. The learners were seated individually rather than in small groups. The initial activity was done by one learner on the whiteboard rather than learners discussing the activity in pairs or in small groups.

There was good interaction in the class. When the learners were doing the class work on the whiteboard, other learners were assisting. Learners were also responding to questions from the teacher, asking questions, contributing and assisting the teacher to rotate the figures on the whiteboard.

After the teacher explained a concept or made a correction on the whiteboard, he always gave a chance for learners to ask questions.

During teaching and learning, the teacher made use of a white board and white board markers as teaching aids to help him and the learners who were doing the class work to rotate different figures. It appeared that learners who were doing the class work on the whiteboard found it useful to use these teaching aids to rotate the figures according to the angle of rotation given.

Hands-on activities that could help learners build their mathematical concepts – e.g. the use of physical objects that could be rotated – were not used.

Learners in this class were actively involved in the lesson. Learners were participating by giving answers and assisting the learners who were rotating figures on the whiteboard.

The teacher asked a lot of “why?” and “how?” questions. The teacher wanted to find out if the learners knew what they were doing. The teacher asked questions like “*why do you move the figure to the right but not to the left?”* These questions focused on knowledge construction and critical thinking and made learners explain their actions and justify their decisions.

The arrangement of the classroom did not allow the teacher to engage learners in peer-oriented learning. Each learner was seated on his or her own.

Samuel did not represent how to rotate figures in different ways. He also did not give learners a chance to rotate figures in different ways. An approach the teacher could have used to rotate a figure in a different way is by using tracing paper.

The teacher assisted learners when they were rotating the figures on the whiteboard. The teacher asked questions and assisted them when he found that they needed help.

The teacher concluded the lesson by asking questions at random to assess whether the learners had mastered the learning objectives. Learners who seemed not to have mastered the learning objectives were not motivated, but the teacher praised those learners who gave correct answers.

The teacher gave feedback on the mistakes made by learners on conclusion of each piece of class work. The teacher also gave a worksheet on rotation as homework.

4.3 STAGE 2

Stage 2 discusses themes that emerged from the classroom observations. The researcher discussed these emerging themes with the two participating teachers through the use of stimulated recall interviews, using vignettes of activity from each lesson as a catalyst for discussion.

4.3.1 The teacher discusses the homework with the learners and asks questions like "how did you get the answer?" or "why did you do it this way?"

An important component of teaching and learning is homework. Homework not only helps learners to practice the work covered, but it provides a valuable opportunity for the teacher to assess whether learners have understood the previous topic. As Titus explains, the importance of homework is "*to find out whether the learners understand the previous topic before we move on, otherwise if they could not understand then I could re-teach on the things they didn't understand".* There is great value in discussing homework at the beginning of each lesson to monitor how the learners are progressing. By asking questions like "how did you get the answer?" or "why did you do it this way?" the teacher will gain insight into whether the learners have mastered the learning objectives.

The purpose of homework is not only to allow learners to practice after school but also to help learners identify what they do not understand. Kilpatrick et al. (2001) add that "several useful purposes that homework can serve have been identified, including providing practice, preparing students for the next class, fostering traits such as responsibility and independence, and communicating with the home" (p. 352).

Questions such as "how did you get the answer?" or "why did you do it this way?" are useful in bringing to the fore different approaches to solving a problem which can then be shared with the class. Sometimes teachers feel there is no need to ask "how did you get the answer?" or "why did you do it this way?" According to Samuel,

"when learners get confused or do not understand you can just tell from their response, their facial expression..." Therefore, he did not ask any "why?" or "how?" questions. Nonetheless, by asking these sorts of questions the teacher has a powerful means of gaining access to any underlying misconceptions that a learner might have. Titus also said he does not ask such questions when discussing homework because *"homework in a classroom is more on giving correct answers. So, … we left out the "how" and "why" questions just to save time. That one gave us enough time to proceed with the next topic for the day."* For Titus, one way to save time and yet still be able to discuss the homework with the learners is to have several learners on the chalkboard solving different problems at the same time. After they have solved the problems on the chalkboard, they are then given a chance to explain to the other learners, with the teacher guiding and correcting where necessary. This may help other learners to identify where they made mistakes, and thus saves time. It is also a good platform for the learners to ask questions of the teacher if they do not understand something, rather than simply receiving marked work from the teacher with no explanation as to where a learner made their mistakes.

4.3.2 The teacher considers what the learners know already (pre-knowledge) by asking questions related to the lesson topic when introducing the lesson.

Learners come to school with prior knowledge and experience. Jones and Brader-Araje (2002) note that learners do not enter classrooms as blank slates but that they possess a wealth of pre-knowledge and experience. Teachers should assist learners to build on their prior knowledge when generating new understandings.

Constructivist epistemology and the importance of developing conceptual understanding both emphasise that teachers should consider the prior knowledge of their learners during teaching and learning. It is this prior knowledge that helps teachers to establish new knowledge by building on what learners already know. Loyens and Gijbels (2008) suggest that one of the core elements of constructivism is that learners interpret new information with their prior knowledge and relate new

knowledge to existing knowledge. Both participants in this study acknowledged the importance of prior knowledge during teaching and learning. Samuel stated that, "*I have first to know what learners have in their minds, what learners are assuming about that particular content for me to build on that. I have to start from where learners are. I have now to find out as to whether they have got something concerning that particular topic or I have to start now from scratch...."* Constructivist pedagogy, LCE and conceptual understanding emphasise that learning should be built on learners' prior knowledge and experience. It is this prior knowledge and experience that helps learners to build new knowledge on their existing knowledge.

Learners' prior knowledge plays a vital role in what and how they learn. The Namibian Ministry of Basic Education and Culture [MBEC] (1999, p. 5) indicate that "... teaching and learning must begin by using or finding out the learners' existing knowledge, skills and understanding of the topic". The notion of prior knowledge is also highlighted by Kilpatrick et al. (2001) when they remark that learners with conceptual understanding are better able to learn new knowledge since they are able to relate new knowledge to the knowledge they have already acquired. With reference to his lesson on locus, Titus remarked "*I try to find out the gap they are having, you see, you try to find out whether they know the definition of Locus from different perspective so that you will be able to differentiate from what they know if it is different from what you are introducing".*

Both participants found it important to start the lesson by asking questions related to the lesson topic in order to assess learners' prior knowledge. Samuel stated that he asked questions for the learners to show him "*what they have concerning that particular learning content".*

It is believed that if learners are able to transfer their prior knowledge and experience to new concepts, they are believed to conceptually understand a mathematical concept. For this to be successful, teachers need to prepare activities and create environments that build on learners' experiences and prior knowledge. Understanding learners' prior knowledge and experience helps teachers to teach for conceptual understanding.

4.3.3 The classroom is structured for co-operative learning.

Co-operative learning in a classroom involves learners working in small groups to complete or discuss a given task. In co-operative learning, learners work together in small groups in which they share ideas on a certain problem. Guskey (1990) describes co-operative learning as “an instructional format in which students work in small heterogeneous groups of two to six students on learning tasks assigned by the teacher” (p. 34).

Co-operative learning is important as it allows an opportunity for learners to learn from each other, and it builds meaningful interaction between the learners. Samuel remarked that, *“co-operative learning enhances learning, as we all know that learners learn best from each other, and as they are communicating so towards finding solutions to questions or problems this is through which learners learn best.”* In addition, some learners learn better from each other through co-operative learning.

One of the methods teachers can use to encourage all learners to be involved and to contribute to the class work is to structure their classroom for co-operative learning. The teacher’s role in such an environment is to move around the class to assist groups and to monitor whether all members of the groups are contributing. The other important aspect of learning together is that contributions from different people have the potential to make learning more powerful.

However, some teachers do not see co-operative learning as an effective learning situation. Samuel explained why the constraints of his classroom prevented him from using co-operative learning as a teaching strategy: “*that very small classroom is too overcrowded, we are talking about a number of 47 learners in maybe a 10 by 7 metres classroom, so now grouping them that one, you will not even have space to walk around the classroom from one group to another because now here co-operative learning you mean learners taking on tasks collectively like in pairs or in groups, small groups so now if you happen even to put them in pairs, how many pairs are you going to touch within 40 minutes? …So, this will leave some learners*

like feeling left out because you won't get time to reach them." Although space constraints prevented Samuel from making use of co-operative learning, he nonetheless employed what he considered a variation on the idea: *"what we try to do is call a learner from a group of those 47 learners to come to a chalkboard and show others how to do that and discussion also sometimes comes about."*

Titus also felt that the co-operative learning approach was not appropriate for him. *"Co-operative learning mostly requires learners to share the ideas on different questions and different topics for the day. Therefore to save time on that one again because time is not enough I only have 45 minutes. We wanted to save time for that one so that because not all the learners can get the chance to share their ideas and their knowledge on any question because of time."* Time constraints were thus given as the reason for Samuel not employing co-operative learning.

4.3.4 The teacher builds teacher-learner and learner-learner interaction.

Learner-Centred Education, constructivist epistemology and conceptual understanding all call for effective teacher-learner and learner-learner interaction. They all emphasise that the interactions should call for the sharing of ideas and the helping of each other, as opposed to the teacher being the only source of knowledge.

As a strategy for developing teacher-learner interaction in the classroom, Titus often makes jokes in the class. He mentioned that, *"jokes actually catch the attention of the learners. A certain learner might be concentrating on other things but sometimes when you bring up a related joke, the learner might be, you know, start concentrating. Jokes also refresh the minds of the learners, and they also create free environment in the classroom. Teacher and learners relationship* [interaction] *will be connected."* He added that interaction in the class also helps learners not to be *"afraid of asking questions, learners not afraid of coming up with different examples and so on."* It is also believed that during classroom interaction, learners learn from each other.

When there is good interaction in the class, learners are free to ask questions in order to understand concepts better. In most cases, good classroom interaction promotes a feeling in learners that they are part of the teaching and learning process or that they are taking ownership of their learning, and this promotes the development of conceptual understanding.

In addition, conceptual understanding and constructivist epistemology suggest that teachers need to structure their teaching on the interactions between teacher and learners and between learners themselves. Swan (2005) states that meaning is constructed through interactions with others (learners and teacher).

4.3.5 The teacher leads learners into discussions

Leading learners into discussions is one of the aspects of a learner-centred approach that can promote conceptual understanding through knowledge construction. The role of the teacher in this context is to lead learners into discussion as opposed to the teacher doing all the talking. Titus commented that *"when the learners are discussing they tend to learn from each other. Some learners are better teachers than others. So, some learners learn well through social learning, discussion creates a good environment in the classroom. So teachers can also learn from the learners."*

Samuel also stated that discussion is important during teaching and learning because *"when learners are discussing or when learners are justifying their decisions, that also gives the teacher a clear view of the level of learning that learners have acquired or the information that learners have acquired. That is when you tell as to whether learners really understand … the content or the concept."* Titus added that a *"free environment in the classroom can also be created through discussions."*

Even though Titus and Samuel value the importance of leading learners into discussions, in most of the observed lessons they did not lead learners into discussion. As Samuel explained, in some instances this was due to the particular

topic they were exploring: *“discussion here in Transformation was not really an approach because transformation is too practical … Learners have to be working than talking that is why we did not do a lot of discussions there..”*

4.3.6 The teacher prompts learners to ask questions

Teachers need to monitor the understanding of their learners during teaching and learning. This can be achieved by encouraging learners to ask questions. Titus finds it important to prompt learners to ask question by stating that, “*the teacher wants to find out whether learners understand or whether the teaching was clear to them”.* Samuel, in his view, stated that, “*I ask them to ask questions, for me to be clear on what has been happening in the class as to whether everybody in the class has understood what has been learned at that particular time”.*

Both participants believe promoting the asking of questions is vital for monitoring the progress of the learners. If learners are encouraged to ask questions, this helps the teacher to identify areas that the learners are still struggling to understand. As a result, questions from learners help a teacher in finding different teaching methods or strategies to help the learners.

Questions also serve as an important means of communication between a teacher and the learners. Therefore, teachers should encourage learners to ask questions and interact with each other and with the teacher.

Using the principles of conceptual understanding and constructivist learning theory, Samuel has built a learning environment in which learners were given a chance to ask questions when they do not understand. Asking questions helps the teacher to find out if the learners understand or not. Samuel also states that *“when they don’t understand they ask questions”*. This helps to promote deep and lasting learning.

4.3.7 Teaching and learning involve the use of concrete materials or manipulatives

Concrete materials or manipulatives were used in most of the observed lessons as teaching aids. Titus asked the learners to use concrete materials "to draw a line that is equidistant from A and B". He stated that he *"wanted to find out whether the learners really knew how to use their equipment. You could see that we were having a lot of teaching and learning equipment such as the protractors, the rulers, the chalks. So, I am trying to find out whether the learner could use her mind and hands to find that line."*

Learners also used the concrete materials or manipulatives for practice. Learners learn better and improve understanding when they practice or play around with manipulatives. Kilpatrick et al. (2001) also remark that, manipulatives "enable teachers and students to have a conversation that is grounded in a common referential medium, and they can provide material on which students can act productively provided they reflect on their actions in relation to the mathematics being taught" (p. 354).

Concrete materials or manipulatives also help with the explanation of concepts. According to Titus, concrete materials and manipulatives are useful during teaching and learning in the sense that they *"help the learners to remember things well and also to think very well. So, when you are using concrete materials, learners most of the time are encouraged to think in a correct way."*

4.3.8 The activities are focused on building mathematical concepts through hands-on engagement

It is important for a teacher to prepare activities that are focused on building mathematical concepts through hands-on engagement. Titus notes that as learners are involved, learning tends to take place *"because they really enjoying creating things up for instance when they are building different triangles and patterns in the sequence and so on."*

When learners are actively involved there is a better chance for them to learn. Taber (2011) suggests that hands-on activities support the knowledge construction process. The teacher's role is to guide and assist the learners. Furthermore, in a learner-centred approach, activities should be arranged in such a way that every learner has a chance to engage with hands-on activities and thereby become actively involved in the learning process. This resonates well with Titus who believes that building mathematical concepts through hands-on activities is important because *"learners are helped to think constructively."*

Constructivist pedagogy, a learner-centred approach and notions of conceptual understanding rely on activities and the building of mathematical concepts through hands-on activities. Moreover, it is also believed that the learner-centred approach promotes conceptual understanding because learners learn best when they are engaged with hands-on activities or when they share ideas in groups.

However, building mathematical concepts through hands-on activities is not always easy. Samuel remarked, in response to a specific lesson of his, that *"I could not devise any platform whereby learners are going to be engaged in these hands-on activities."* In addition, not all topics necessarily lend themselves to the use of hands-on engagement - Titus for example remarked that he *"didn't focus on that for the day because the topic was not focussing on, was not able to focus on that one."*

4.3.9 The learners are actively involved

A learning environment in which the teacher does all the talking while the learners simply listen does not support constructivist pedagogy or a learner-centred approach. Learners need to be involved in teaching and learning by actively participating, asking questions and contributing to the lesson. Titus comments that, *"involving learners in teaching and learning ... creates a free environment in the classroom. The learners will also feel involved in the teaching and learning [and] all the learners will always concentrate".*

In relation to the literature, one of the fundamental tenets of constructivism is that learning occurs as learners are actively involved in a process of meaning and knowledge construction rather than passively receiving information. Titus further adds that with active involvement learners *"are also getting the ownership of their own subject and the classroom."*

However, even if learners are actively involved, there is no guarantee that learning is taking place. Learners can be actively involved but they may not necessarily learn anything. For the teacher to monitor if learners are actively involved in a meaningful way, they need to ask learners to talk about what they are doing or to apply what they have learned. This will help teachers to assess if learning has taken place.

4.3.10 The questions are focused on knowledge construction and critical thinking

Knowledge construction and critical thinking are fundamental in the process of teaching and learning. Teachers should ask questions that are focused on knowledge construction and critical thinking. During teaching, Samuel asked learners questions like "what does it mean?" He explained the reason for asking those types of questions by saying, *"I really want to find out as to whether that learner understands what he or she is talking about."*

Similarly, Samuel remarked that questions focusing on knowledge construction and critical thinking are very important because *"sometimes learners are not clear ... when they are making their contributions, when they are expressing themselves, so now you have to ask a question like: what does that mean?, for them to elaborate more and you will find out, you as a teacher will now find out as to whether this learner understands what he or she is talking about."* On the same note, Titus also believes that questions that are focused on knowledge construction and critical thinking help learners to understand better as he states that he emphasises *"learning with understanding."*

4.3.11 Teacher asks “why” and “how” questions

Samuel and Titus see “why?” and “how?” questions as a means of monitoring the understanding of the learners. Specifically, Titus stated that learners *“need to answer all this “what” and “why” and “how” questions for you to find out whether they really understand what they are doing…. You need to find out whether the learners know how to do things.”*

In his lesson on transformation, Samuel asked learners if the transformation shown was an enlargement, rotation or reflection. The answer from the learners was “*NO, none of the three”*. Samuel further asked *“why is it not an enlargement, why is it not rotation and why is it not reflection?”* He stated that the focus of these questions related to learning for understanding*. “If a learner understands what they are doing, they must also be able to justify their decisions. Therefore if they are saying NO, it is none of the three types of transformation that I have mentioned, then they must justify their reasons…. I want those reasons because in the reasons they are going to give me, they are going to give me the properties or the information concerning what translation is. You see, then from there I can deduce that these learners understand what translation is. They can recognise when a figure has been translated, they can recognise when the figure is being enlarged or rotated or reflected. And at the end of the day, I can also prove that learners understand really what transformation is*.”

Titus further added that *“the “what” and “why” questions actually help the teacher to find out whether the learners understand different concept of the topic.”* Questions such as “why?” and “how?” promote the development of conceptual understanding because learners, when prompted with such questions, are required to elaborate and justify their answers. This resonates strongly with the responses of the two research participants.

On the other hand, Titus stated that he sometimes doesn’t use “why?” and “how?” questions in his teaching in order *“to save time.”*

4.3.12 Teacher engages the learners in peer-oriented learning (e.g. pair work, group work, debate)

As it is emphasised in co-operative learning, classrooms that promote conceptual understanding create a learning environment whereby learners are given a chance to communicate with each other and discuss problems in groups and as a whole class.

Samuel did not engage learners in peer-oriented learning because he felt that "*during the lesson that could not happen because of the timeframe"*. Titus also did not engage learners in peer-oriented learning, stating that *"the lesson we had was not a double lesson, we only had 45 minutes. We wanted to save time, I only gave them homework to go and discuss outside."*

Even though these teachers did not engage learners in peer-oriented learning, they both acknowledged that it is an important and effective teaching and learning approach. Titus indicated that peer-oriented learning is important because *"learners tend to learn from each other through peer learning."* Furthermore, group work and debates are some of the aspects of the learner-centred approach that can promote conceptual understanding. Samuel, like Titus, also comments that *"peer oriented learning is an effective learning approach because learning from peers or learners consulting themselves, debate and discover things, they even feel proud of themselves that they have even worked together and found out things there, and they build also this social or interpersonal skills and social skills they turn into very positive people and learning happens effectively when people are positive or learners are positive."*

Samuel suggested that one of the reasons why peer-oriented learning is potentially effective is that *"learners learn best from themselves than from the teacher because they are [more] open towards each other than towards a teacher."*

4.3.13 The teacher uses multiple representations of mathematical concepts.

Multiple representations of mathematical concepts are vital in Mathematics, especially in relation to problem solving. Multiple representations help learners to develop conceptual understanding in a meaningful way and to develop links between different mathematical ideas. It is important that learners are able to represent information or data in different ways – e.g. numerically, graphically or diagrammatically. Samuel highlighted his appreciation for the use of multiple representations as follows: *"how can you just teach learners like solving linear simultaneous equations by elimination method only? There is also substitution method, there is also using a graph. Give learners all those methods and then they will choose the one that suits them best."* Titus also strongly supports the use of multiple representations in the classroom. Similarly to Samuel he states that "*different learners like using different methods. Every learner will be helped to use the best method she understands."*

Classrooms that support a constructivist view of learning also incorporate multiple representations. Teachers should consider preparing problems or activities that allow for an engagement with multiple representations. As Samuel indicated, *"we prefer different things. Things work better with us differently."* Multiple representations are important in teaching and learning because they serve as a way of solving mathematical problems, and thinking about mathematical concepts, in different ways. Samuel stressed that *"using different concepts or different methods to take on concepts, it is very much important because learners learn differently and they may understand the content through different ways."*

One of the importances of using multiple representations is that it promotes flexible learning. If learners have different ways of solving a problem, they can draw on these different approaches when solving other problems.

Apart from multiple representations being an efficient approach, it is also an effective and accurate approach. It is accurate in the sense that learners can use one method to solve a problem and then use a different method to check if the answer is correct.

In addition, multiple representations are effective when used during teaching and learning because they tend to promote conceptual understanding and the understanding of concepts in different ways.

Learner-centred education also encourages teachers to use different representations. Learners should be able to connect different mathematical concepts and represent them in different ways. It is important for learners to choose the method that suits them best. Samuel also stated that "*people learn differently",* therefore, "*presenting mathematical concepts or approaching them differently, that is something important when it comes to learning because, a learner should approach that learning content the way that learner can understand it best".*

4.3.14 The teacher monitors the activities and assists where possible

Both Samuel and Titus monitored the learners' activities in the classroom. Both teachers walked around their classrooms monitoring how learners were doing the activities. The teachers also assisted learners who had specific difficulties. McLoughlin and Luca (2002) suggest that one of the main roles of the teacher is to monitor the learning tasks and processes.

4.3.15 The learners are assessed through student work, observations and points of view

During teaching and learning, Samuel and Titus managed to assess their learners by marking their activities and homework, and asking questions such as "how?" and "why?". The two teachers also moved around their classes to monitor how learners were doing their class work individually.

4.3.16 The teacher motivates learners

Learner-Centred Education requires learners to be motivated for them to fully take part in teaching and learning activities. The teacher should ensure that learners are motivated. Learners need a driving force in the form of motivation for them to learn.

Samuel commented that *"without that drive, or that momentum, I want to say a driving force, for them to take on a certain task ... they won't learn".* In Samuel's view it is vital to motivate the learners and to encourage them to work hard in order for them to perform well.

There are many important reasons for motivating learners. Some of the importances of motivation are mentioned by Titus: *"motivating learners encourages learners to study well. …Motivation also enables learners to realise their carriers - for instance if you are presenting the topic and you happen to motivate them in a certain way or the other, this topic is so important in your life in this way, they are more likely to be motivated to study hard because they know this topic will help them in future when they go for such careers."*

Even though these teachers indicated the importance of motivation, Samuel did little to motivate his learners. Samuel stated that *"most of the learners are motivated already."*

4.3.17 The teacher provides feedback and advice on learners' performance

The two teachers provided feedback when discussing homework with their learners. In most cases, these teachers also provided feedback on the conclusion of class work. Samuel commented that feedback *"is of importance because it makes learners aware of what was expected of them to do in the homework or in that given task."*

4.3.18 The teacher gives homework

In general, both Samuel and Titus gave homework at the end of their lessons. They also usually discussed the homework of the previous lesson with the learners before they started with the day's lesson topic. Both teachers recognised the importance of giving homework. Titus stated that *"homework helps the learners to practice more. Learners are helped to improve on their weaknesses. The teacher is also able to find out what the learners know and what they do not know. It also exposes different questions, different tests and exam questions to the learners. It keeps the learners in*

touch with the subject, you know if you give homework, the learners are more likely to develop this kind of relationship with the subject. The learners also help to remember on what they were taught in the class."

Samuel also added that homework "*gives ... a picture as to how these learners are going to perform maybe in the examinations".* It is important for teachers to encourage learners to do homework because there is not enough time to do practice in the class. Therefore, learners should do more practice after school in order for them to master the lesson objectives. Homework also requires learners to consult each other and to search for information. Samuel mentioned that *"I usually encourage consultations between themselves to consult each other and work out problems that are given to them as homework."*

4.4 CONCLUSION

This chapter presented and discussed the findings of the study. Stage 1 focused on classroom observation through the use of an observation schedule while Stage 2 took a form of stimulated-recall interviews which were analysed based on emerging themes derived from the classroom observation. The next chapter consolidates the findings of this study in relation to the original research question.

CHAPTER FIVE
FINDINGS AND CONCLUSION

5.1 INTRODUCTION

This chapter provides an overview of the research process and reflects on the findings of the study. The chapter also provides recommendations based on the findings, interrogates the limitations of the study and concludes with some suggestions for further study.

5.2 REVIEW OF THE OBJECTIVES

The goal of this study was to investigate how teachers' practice supports or constrains the development of learners' conceptual understanding. The study was guided by the following research question:

- How may teachers' practice support/constrain the development of learners' conceptual understanding?

5.3 OVERVIEW OF THE CONTEXT

One of Kilpatrick et al.'s (2001) strands of mathematical proficiency is conceptual understanding. Kilpatrick et al. (2001) define conceptual understanding as "an integrated and functional grasp of mathematical ideas" (p. 118). Conceptual understanding emphasises that learners should learn with understanding. In Namibia, the notion of conceptual understanding resonates with the learner-centred approach in which learners play an active role in their own learning. The development of conceptual understanding is also underpinned by a constructivist epistemology which resonates strongly with both conceptual understanding and LCE by emphasising that learning should be connected to what learners already know.

In addition, notions of conceptual understanding and constructivist epistemology suggest that the construction of knowledge is shaped by the social environment and teachers need to structure their teaching with this in mind.

5.4 OVERVIEW OF THE RESEARCH PROCESS

This study is anchored within an interpretive paradigm. The study focused on two teachers' lived experience in the classroom as a means to gaining insight into how their practice either supports or constrains the development of conceptual understanding of their learners.

The first stage of the study aimed at collecting qualitative data by video recording six classroom lessons, three for each of the two participating teachers. The second stage took the form of stimulated-recall interviews where individual teachers discussed issues pertaining to their classroom practice based on vignettes extracted from the video recordings.

5.5 FINDINGS OF THE STUDY

The findings of this study are summarised around critical aspects related to the development of learners' conceptual understanding in the classroom.

5.5.1 Building on prior knowledge

Learners' prior knowledge plays an important role in teaching and learning. In schools, some teachers take learners' prior knowledge into consideration because they believe it helps in connecting what learners already know to what they are currently learning. Lessons that recognise the prior knowledge of learners, and build on it, are recognised as promoting conceptual understanding.

The findings of this study show that the two participating teachers understand the importance of building their teaching on learners' prior knowledge. The data analysis revealed that the participants asked questions related to the lesson topic at the

beginning of the lesson in order to assess what learners already know about the lesson topic.

5.5.2 The classroom is structured for co-operative learning

Co-operative learning in a classroom involves learners working in small groups in which they share ideas to complete a given task. Structuring a classroom for co-operative learning is important in teaching and learning because it creates an opportunity for learners to learn from each other.

From the analysed data, it is clear that the two participating teachers do not arrange their classrooms for co-operative learning. The two participants cited time constraints and overcrowding as reasons for not incorporating co-operative learning strategies into their teaching. If co-operative learning is not employed at least to some extent in the classroom, it could possibly constrain the development of learners' conceptual understanding.

5.5.3 The teacher leads learners into discussions

Leading learners into discussions is another aspect that can potentially promote conceptual understanding. Even though Titus and Samuel both value the importance of learner discussion, in the lessons analysed in this study neither participant explicitly led learners into discussions, although this may well have been a result of the particular topics taught in the observed lessons.

5.5.4 Teacher engages the learners in peer-oriented learning (e.g. pair work, group work, debate)

Peer-oriented learning emphasises the engagement of learners in pair work, group work or in debates. An important aspect of classroom practice that has the potential to promote conceptual understanding relates to creating a learning environment where learners are given the opportunity to complete tasks in groups or in pairs.

The study revealed that the two participating teachers do not engage learners in peer-oriented learning because of reasons related to time constraints. Nonetheless, the two teachers acknowledged that peer-oriented learning is an important and effective teaching and learning approach. This was indicated by Titus when he stated that *"learners tend to learn from each other through peer learning."*

5.5.5 Teaching and learning involve the use of concrete materials or manipulatives

Both Samuel and Titus incorporated the use of concrete materials and manipulatives into the teaching and learning process. The concrete materials used included protractors, rulers and compasses. The use of concrete materials and manipulatives helped learners to engage with the mathematics being taught and this supports the development of conceptual understanding. The participants saw the use of concrete materials and manipulatives as being helpful with regard to the explanation of concepts.

5.5.6 The activities are focused on building mathematical concepts through hands-on engagement

Another teaching approach that promotes the development of conceptual understanding is for learners to be engaged in hands-on activities. In the lessons observed, Titus and Samuel were not always able to prepare activities that focused on building mathematical concepts through hands-on engagement. Samuel remarked, in response to one of his lessons, that *"I could not devise any platform whereby learners are going to be engaged in these hands-on activities."* Insufficient hands-on engagement could potentially constrain the conceptual development of some learners as it is generally accepted that learners learn best when they are engaged in meaningful hands-on activities.

5.5.7 Questions that promote critical thinking

Questions such as “why?” and “how?” promote critical thinking and the development of conceptual understanding because learners are challenged to elaborate and justify their answers. The two teachers were found to place importance on “why?” and “how?” questions during their teaching. The importance of asking learners such questions is captured by Titus as follows: *“[Learners] need to answer all these “what” and “why” and “how” questions for you to find out whether they really understand what they are doing.”* For Samuel, the importance of asking “why?” and “how?” questions relates to their relevance with regard to “*learning for understanding”.*

5.5.8 The use of multiple representations and connections

For learners to develop conceptual understanding in a meaningful way, they need to understand how to make connections and represent mathematical concepts in different ways. Exposure to different solution strategies also relates to the notion of multiple representations.

The study revealed that both Titus and Samuel used multiple representations of mathematical concepts during their teaching to promote the conceptual understanding of their learners. In the words of Samuel: *“using ... different methods to take on concepts, it is very much important because learners learn differently and they may understand the content through different ways.”* Furthermore, learners who are able to represent mathematical concepts in multiple ways are believed to have a deeper conceptual understanding.

In addition, evidence from the study shows that the participating teachers also made connections between subjects or between topics in Mathematics. For example, Titus related scale drawing in Mathematics to maps in Geography.

5.6 CHALLENGES AND LIMITATIONS OF THE STUDY

The biggest limitation of this case study is that it focused on only two teachers, and for each teacher only three lessons were analysed. As such, the findings of the study cannot be generalised to Namibia as a whole, but they nonetheless provide a valuable snapshot of the terrain.

Another limitation of this study relates to the video recording of classroom lessons. Only a single video camera was used in these recordings, and as such it was not possible to capture all the activity in the classroom.

There were also a number of challenges related to the data processing, mainly in terms of the transcription process. It was difficult to transcribe some words because they were either not spoken clearly or were not spoken loudly enough.

Rescheduling of observation and interview times was a challenge during the data collection. These challenges arose due to changes in the teachers' timetables and teachers being absent from school. Although this added to time pressures in terms of the data analysis process, these challenges were largely overcome.

5.7 SIGNIFICANCE OF THE STUDY

The main purpose of this study was to gain insight into how teachers' practice either supports or constrains the development of conceptual understanding. This study provides data that could be workshopped with mathematics educators to help them structure their teaching for conceptual understanding.

5.8 RECOMMENDATIONS AND SUGGESTIONS FOR FURTHER STUDY

Based on the results of this study, I would like to make the following recommendations:

The Ministry of Education should be encouraged to provide workshops to teachers on how to teach for conceptual understanding with special reference to aspects that support conceptual understanding, such as:

- Building on prior knowledge
- Peer-oriented and co-operative learning (e.g. pair work, group work)
- The use of concrete materials and manipulatives
- Questions that promote critical thinking
- The use of multiple representations and connections

Furthermore, institutions of higher learning responsible for training teachers should emphasise the importance of teaching for conceptual understanding, and should explicitly train teachers in potential techniques to achieve this.

I believe it would also be worthwhile for the research to be carried out in different regions and to compare the data on how teachers' practice supports or constrains the development of conceptual understanding. This could be used to identify pockets of best practice.

5.9 CONCLUSION

This study was of significance to me in many ways. The study represents a small window into the lived experience of two teachers, and how their classroom teaching practice supports or constrains the development of conceptual understanding in their learners. The study allowed me to critically reflect on my own practice and how best to assist other teachers. It is hoped that this study adds in some small way to opening up the discourse around teaching for conceptual understanding within the Namibian educational landscape.

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APPENDICES

Appendix A – Consent forms from the Inspector, Principals and teachers.

RHODES UNIVERSITY
Grahamstown • 6140 • South Africa

CONSENT FORM

I [redacted] in my capacity as the Inspector of Education of Okahao Circuit hereby give written consent for Andreas Akwenye Kashima, in his capacity as a Master of Education student at Rhodes University, to conduct research in Okahao Circuit as outlined in the above document.

SIGNED: _____

DATE: 14/01/2014

RHODES UNIVERSITY
Grahamstown • 6140 • South Africa

CONSENT FORM

I [redacted] in my capacity as Principal of [redacted] hereby give written consent for Andreas Akwenye Kashima, in his capacity as a Master of Education student at Rhodes University, to conduct research at [redacted] as outlined in the above document.

SIGNED: _____

DATE: 25/01/2014

MINISTRY OF EDUCATION
[redacted]
2014 -01- 2 0
PRIVATE BAG 503
OKAHAO
TEL./FAX: 065-252003

RHODES UNIVERSITY
Grahamstown • 6140 • South Africa

CONSENT FORM

I [redacted] in my capacity as Principal of [redacted] hereby give written consent for Andreas Akwenye Kashima, in his capacity as a Master of Education student at Rhodes University, to conduct research at Shaanika Nashilongo Secondary School as outlined in the above document.

MINISTRY OF EDUCATION
The Principal
Oshikoto Region
OFFICIAL
2014 -01- 20
P/Bag 501 Okahao
Tel/Fax: 065-252250
Email: shaanikass@hotmail.com

SIGNED: [redacted]

DATE: 20/01/2014

RHODES UNIVERSITY
Grahamstown • 6140 • South Africa

CONSENT FORM

I [redacted] in my capacity as a research participant hereby give written consent for Andreas A. Kashima, in his capacity as a Master of Education student at Rhodes University, to conduct research as stipulated in the letter. I understand what will be required of me in the role of research participant.

SIGNED: _____

DATE: 20/01/2014

RHODES UNIVERSITY
Grahamstown • 6140 • South Africa

CONSENT FORM

I [redacted] in my capacity as a research participant hereby give written consent for Andreas A. Kashima, in his capacity as a Master of Education student at Rhodes University, to conduct research as stipulated in the letter. I understand what will be required of me in the role of research participant.

SIGNED: _____

DATE: 20/01/2014