CHALLENGING STUDENTS THROUGH MATHEMATICS: A CULTURALLY RELEVANT PROBLEM SOLVING

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
the Degree Doctor of Philosophy in the Graduate School of The Ohio State University

By

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2004

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ABSTRACT

According to the Human Science Research Council of South Africa’s (2002) analysis of the Third International Mathematics and Science Study-Repeat, reveals that low achievement was related to: (1) low socioeconomic status, (2) fairly low parental educational level, and (3) lack of fluency in the language of testing. This last factor implies difficulty in communication. Only about a quarter (26%) of the participants had the language of the test as their first language and these scored better in mathematics and science. The current study investigated the effect and role that culturally relevant problem solving in the language of their choice may have on learning mathematics. It explored students’ thinking and recorded any emerging mathematics concepts during culturally relevant mathematics problem solving while using any language of their choice. The investigation started with six South African grade 10 students. One participant withdrew from the study while two volunteered, thus ending with seven participants. They were selected from two schools whose only common denominator was that they are from previously disadvantaged communities and use English as the medium of instruction.

Data were collected from whole class observations, participants’ journals, transcripts of audio taped interviews, and participants’ written work. The majority of the seven participants, preferred to communicate their mathematics thoughts in a mixture of English and their first language. It also emerged from the data that they solved problems
they could not solve before using own strategies. These strategies differed from person to
person. The data also revealed that culture had an influence on the type of strategy to be
used and the solution of the problem.
DEDICATION

I dedicate this to my high school mathematics and science teachers, my mentor teachers, and all my past students.
ACKNOWLEDGEMENTS

I express my sincere gratitude and appreciation to Professor Patricia A. Brosnan who provided expectations, guidance, insight and encouragement. Thanks also go to Professor Douglas T. Owens for his guidance, assistance and comments. I am also indebted to Professor Michael L. Scott for his encouragement and insight, particularly on diversity issues. Professors M.W. Legotlo and R. Gunther thank you, your support has been immeasurable. Thank you, Bishop Markus M. Ditlhale for providing spiritual support and guidance during dark moments. To my brothers, Bishop C. M. Molefe, Asiel D. Molefe, Elias M. Molefe and my sisters, Onica M. Mbewe and Louisa M. Molefe, I thank you for always being there for my family. A special note of gratitude goes to my sons Molefi and Lebang, who continue to grow in all respects even in my absence. Your continued support and love is unequaled. Finally to my wife, Patricia, I depended and relied on you beyond reason; I express and offer my sincere gratitude and appreciation for your unwavering and ever growing support and love. Thank you all.
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CHAPTER 1

INTRODUCTION

“Consistent with most mainstream research in mathematics education, I thought that a strict focus on mathematical content, curriculum, and problem-solving behaviors would be the best way to understand mathematics achievement and persistence issues among African-American students. [T]here were issues with their beliefs about what counted as mathematics and their beliefs about the importance of mathematics in relation to other aspects of their daily lives.” (Martin, 2000, p.3)

Rationale

As a player in the global economy and advanced technological arenas, South Africa urgently needs to train more and more mathematics and science school graduates. Therefore one of the daunting challenges facing the new South African education system is to improve the teaching and learning of mathematics. This challenge is particularly acute in the historically disadvantaged communities. Despite various reform attempts in the teaching and learning of mathematics, studies are still not encouraging in their findings. In its executive summary report of the Third International Mathematics and Science Study-Repeat (TIMSS-R), the Human Sciences Research Council of South
Africa [HSRC], (2002) reports that South African students performed poorly. The report cites factors like socioeconomic background, culture, language of instruction, teaching, and learning as negatively contributing to poor results.

The current investigation is an attempt to find the effect and role that culturally relevant problem solving in the language of the student’s choice may have on learning mathematics. This form of pedagogy has been researched in the United States of America (Ladson-Billings, 1995a; Tate, 1995). It is therefore my intention in this study to replicate this study in the South African context.

Overview

The purpose of this study is to explore students’ thinking in a multicultural mathematics classroom where most students learn mathematics in a second language. It is further the intention of this investigation to determine whether struggling students can understand mathematics through culturally relevant problem solving.

In this chapter, I begin by discussing the daunting challenges that the South African education system is currently facing, that is, low achievement in mathematics and small number of students taking mathematics as one of their matriculation (Grade 12) subjects. This is the problem, that is low participation and coupled with low achievement. Then I will discuss the theoretical base on which this investigation is grounded. This base includes constructivism, critical theory, and the situated cognition theory which will support what Mercer (1993) calls neo-Vygotskian theory. The discussion of these theories will be followed by the research questions I wish to focus on and document. The chapter will close with the discussion of the limitations and delimitations of the investigation.
Chapter two will focus on the review of literature. Firstly, I discuss what the literature says about theories underpinning the current study. This will be followed by an analytical literature review of problem solving. Then literature discussion on culturally relevant instruction in mathematics will follow. Then at the penultimate end I will give a synthesis of the literature review and close the chapter with the focus question.

Chapter three will introduce the research methodology followed by the rationale for the choice of the methodology. This chapter deals with the how part, that is, how do we answer the questions in chapter 2. I will then discuss the procedures I followed in the current study. Then the discussion of the methods of data collection and the chapter closes with the issues of validity and reliability.

Problem Statement

Traditionally, mathematics instruction has been one rigid approach of moving from definitions, axioms, and theorems through structured problem solving. The teacher in this instance was the authority and giver of information while the learner was represented as an empty vessel, metaphorically speaking (Freire, 1970). Freire further describes this type of teaching as “banking” where knowledge is banked in the student’s head to be retrieved later during examination time. Tate (1995) agrees by characterizing the traditional mathematics instruction as:

- a problem solving routine of well-defined problems,
- communications as answering questions that require only yes or no or one answer,
- reasoning that relies on the teacher and/or the book,
- connecting by learning the skills out of context, and
computation of numbers by memorizing rules and algorithms and rounding numbers out of contexts.

The consequences of such an instructional approach are numerous as stated by various reports. Some of the learners who survive become isolated meek followers of authority. They have difficulty in applying what they have learned in practical everyday situations (Boaler, 2001). Of course, the majority fall by the way side and give reasons such as mathematics is difficult, because they cannot make sense out of it (HSRC, 2002).

According to HSRC’s (2002) analysis of TIMSS-R study, about a quarter (26%) of the South African participants had the language of the test as their first language and these, the report notes, scored better in mathematics and science. Further analysis reveals that South African participants have poor self efficacy in mathematics as compared to their international counterparts.

Of the 26 countries in TIMSS-R, South Africa achieved the last overall position. The study further finds that low achievement was related to: (a) low socioeconomic status, (b) fairly low parental educational level, and (c) lack of fluency in the language of testing. This last factor implies difficulty in communication.

The problems of low achievement and poor self efficacy in mathematics call for rethinking in the teaching of mathematics. Thus the purpose of this investigation is to explore students’ thinking during culturally relevant mathematics problem solving. It is further the intention in this study to determine whether struggling students can understand mathematics through culturally relevant problem solving using their own thinking.
Theories of Learning

Following is a brief discussion of theories on which I wish to ground this investigation. These are constructivism, critical theory and situated cognition theory to inform neo-Vygotskian theories. These theories should not be seen as competing against each other but rather as complementing each other. Much of the theories will be discussed in chapter two.

Constructivism

The protagonists of constructivism view learning as constructive and receptive, where there is an interaction among what the learner knows already, new information, and learner’s action as s/he learns. It is seen as an invention in the learner’s world, an invention whose raw materials are learner’s ideas, strategies as well as knowledge they encounter along the way (Brooks & Brooks, 1993; Bruning, Schraw, and Ronning, 1999; Wadsworth, 1996). Bruning, Schraw, and Ronning in particular characterize constructivism as construction, structuring, self-awareness, and self-regulation of knowledge where social interaction and the contextual nature of knowledge play an important role. For example, if a learner is grappling with a problem like:

*I have five sweets, how many more do I need to have eight?*

Here the learner needs to engage in and guide her/himself in cognitive operations. S/he will either picture the problem or use physical objects to construct meaning and organize these thoughts into actions. The problem requires her/him to draw from knowledge in memory. It is important to note that it is the mental process (internal representation) of the learner that reorganizes and structures information when solving a problem.
(Bruning et al., 1999). Bruning et al. maintain further that “once the problem has been represented, its solution requires knowledge of action schemata” (p. 331). Since the schemata contain much different information, the learner needs an appropriate strategy to select that, which matches the problem that requires “regulation of cognitive knowledge, a form of metacognitive knowledge” (p. 332).

One of the characteristics of the current study is solving problems from a culturally relevant context. The constructivism perspective will inform the learning part of my investigation where effective active learning is emphasized. New knowledge will be captured from the existing knowledge which may be formal mathematics or intuitive mathematics or even ethnomathematics; and an active, yet effective learning will expect students to explain, justify, and describe their thinking. It will also require them to reflect on the new cognitive worlds thus constructed.

Complementing constructivism as it impacts on problem solving will be the critical theory as it gives learner voice and emancipation from authority. A discussion of critical theory follows.

Critical Theory

One of the theoretical underpinnings of the current investigation is the critical theory as described by Glesne, (1998) and Kincheloe and McLaren (2000). It is based on how knowledge is used an instrument of power and politics (Glesne). Kincheloe and McLaren define critical theory as that which “is concerned in particular with particular issues of power and justice and the way that economy, matters of race, class, and gender, ideologies, discourses, education, religion and other social institutions, and cultural
dynamics interact to construct a social system” (p. 281). For the purpose of the current investigation, theorists in this perspective may be characterized as those:

- who want to transform power relations,
- who question and investigate how ways of lived experiences may be misrepresented,
- who give voice to the voiceless,
- who believe that knowledge “is shaped by social, political, cultural, economic, ethnic, and gender values.” (Lincoln and Guba, 2000, p. 168)

Traditionally, the authority and control resided in the teacher and/or the book (Tate, 1995). The critical theory perspective will inform the current study about redressing imbalances of power such that their voices could be heard and that their lived experiences should not be distorted. Tate argues that critical theory provides “a framework to explore the relationship between political and economic inequality and the school mathematics curriculum” (p. 169). Therefore the learners’ thoughts as generated by social, cultural context and the language of choice will be informed by this theory. While pedagogy will be informed by constructivism, and the redressing of power asymmetries will be drawn from critical theory, the context and language part will be underpinned by neo-Vygotskian perspective.

The Neo-Vygotskian Theory

The neo-Vygotskian theory as described by Mercer (1993) is a sub-theory of Vygotsky’s social constructivist and situated cognition theories. Central to this theory is
the role played by culture and context. Mercer argues that cultural network generates and transmits knowledge. He maintains that

... culture is something which is not just received but which is also revised and recreated by children. It remains a source of meaningful representations of objects and actions, representations which are socio historical because they emerge from the historical experience of a social group. Children’s interpretations of experience—the meanings they attach to their learning—. . . [and] any educationally oriented study of learning must recognize that schools have their own body of cultural knowledge, and their own ways of communicating and legitimizing knowledge.” (p. 31).

On the other hand Mercer (1993) believes context plays an important part in educational discourse. Context is whatever the learner finds relevant and that which makes sense to her/him.

One key concept of the neo-Vygotskian theory is “appropriation”. Mercer (1993) compares appropriation to Piaget’s concept of “assimilation”. It is argued in this theory that learners appropriate understanding if they acquire knowledge through a contextualized cultural contact and “child’s unaided explorations” (p. 36).

Mercer (1993) further believes that the educational process of appropriation encompasses three “socio-dynamics of development of understanding.” These are:

(1) Appropriation may be reciprocal - In a classroom talk, a teacher may take a learner’s “remark and offers it back, modified, into the discourse” (p. 36), (2) Paraphrase – A
teacher may paraphrase a learner’s talk to fit in with present discussions, and (3)
Reconstructive recap - A reconstruction of events or previous experiences in a way that
will fit with educational requirements. Thus, the neo-Vygotskian theory is a relevant base
for mathematics teachers in multilingual classrooms because “[by] strategically
appropriating children’s words and actions, teachers may help children relate children’s
thoughts and actions in particular situations to the parameters of educational knowledge”
(Mercer, p. 37).

Summary

The conceptual framework for this study as shown in Figure 1, shows clearly that
the three perspectives underpin the framework. While complementing each other, each
one informs particular components of the study. Constructivism will be used to inform
the problem solving component; while the critical theory undergirds the issues of
authority and emancipation. Finally neo-Vygotskian gives the culture and language
component shape. The three components are brought together to form culturally relevant
problem solving, which enters into the three knowledge circles at the point of
concurrence. The inner circle contains ethnomathematical and intuitive knowledge. These
form the base knowledge and as the knowledge grows it overflows into bigger circles
where formal mathematics definitions may be formed as well as axiomatic and deductive
knowledge may develop.

Research Questions

The question of how students think and the nature of their thinking during
construction of knowledge is central to learning. Perhaps the teacher’s knowledge of
students’ thought processes during problem solving may help her/him to structure an instructional approach to facilitate better learning. In any case “students must necessarily construct their mathematical ways of knowing in any instructional setting whatsoever, including that of direct instruction. The essential question here is not whether they are thinking, but what is the quality and nature of their thinking” (Cobb, Yackel, & Wood; 1992; p. 28).

My intention in this study is to explore the following questions:

• What are the students’ concepts of mathematics when posed with culturally relevant problems?

• Using any language of their choice, can students’ articulation of their thinking help us understand their learning process?

• What can we learn about student mathematical understanding when students are provided an opportunity to solve culturally relevant problems using their own thinking?
Figure 1 Conceptual Framework
CHAPTER 2

REVIEW OF LITERATURE

Introduction

This chapter includes reviews of literature about learning theories. It will describe constructivism and draws from it how problem solving impacts on the teaching and learning of mathematics. Teaching and learning mathematics in a second language will be elicited from situated cognition and neo-Vygotskian theories (Mercer, 1993). The discussion on theories will be concluded by describing the critical theory as a basis for culturally relevant instruction. Following the review of the theoretical underpinnings will be the general review of research on problem solving and teaching and learning mathematics in a second language. The chapter will conclude by reviewing two framework models of teaching mathematics in second language followed by the research questions of this study.

Constructivism

Definitions

In contrast to a behaviorist, who emphasizes that the best way to learn mathematics is drill and practice (Boaler, 2000), the constructivist believes that learning is the product of the interplay between the internal cognitive processes and the environmental
conditions (Brooks & Brooks, 1993). That is, learners actively construct their own meaning and knowledge by interacting with their environment (Confrey, 1990; Kamii, 1990; Orton, 1987; Silver, 1985; Simon & Schifter, 1991). Theorists like Simon (1986) describe constructivism as that process which engages the learner in construction of new knowledge from perceptions and experiences, unlike the traditional view of instruction where information flows from experts like teachers (Tate, 1995).

Background for Constructivism

Simon and Schifter (1991) posit that the theory of constructivism is drawn from the empirical and theoretical work of Piaget. They maintain further that Cobb, Confrey, Steffe, von Glaserfeld and others extended this theory into mathematics education.

Piaget’s theory on the development of thinking is grounded on the notion that people construct their own knowledge. The construction of knowledge comprises two processes namely assimilation and accommodation. To understand our environment and the world, people organize new experiences and adapt new ideas into schemas (cognitive structures). Assimilation occurs when these new experiences and ideas are incorporated into our existing knowledge. On the other hand, accommodation occurs when a person adjusts her/his knowledge to a new idea. That is, when we encounter an unfamiliar experience or idea, the schema tries to fit it into on the existing knowledge. If no similar structure exists, a new schema is created to accommodate the unfamiliar experiences (Piaget, 1983; Wadsworth, 1996). Thus according to Orton, (1987); Simon and Schifter, (1991), and Wadsworth, (1996), the construction of new knowledge occurs when new ideas disturb
the current organization of knowledge. This disturbance is known as disequilibrium which leads to mental activity and adaptation of new ideas.

Roles of students and teachers in a constructivist classroom

The learner in a constructivist classroom is autonomous and constantly interacts with manipulatives and physical materials. It is the learner’s thinking during problem solving that drives the lesson, shifts instructional strategies, and alters content (Brooks and Brooks, 1993). Therefore, students are encouraged to explore and discover mathematical concepts instead of passively learning mathematics.

The core of the constructivist view is construction of knowledge using old knowledge and materials at hand. They create representations and explanations of new information which will meaningfully connect with prior knowledge. The theorists in this perspective argue that cognition is enhanced when construction of knowledge is encouraged within the classroom discourse (Ball 1991; Erickson, 1999). That is, construction does not occur in vacuum. The learner interacts with the environment, objects or persons (Wadsworth, 1996). The nature of the object (representation) causes a reaction in the schema, which according to Piaget’s theory, causes either an equilibrium or disequilibrium state. If it matches, then there is assimilation or if not, the schema is rearranged for new information to be accommodated (Brooks & Brooks, 1993).

The constructivist believes discourse during interactions. The teacher encourages the learners to engage in a dialogue, both with the teacher and with one another. Learners communicate about their interpretation of the representation. They elaborate and justify their interpretations. This enables learners to reorganize their existing knowledge and
accommodate new constructed information (Ball, 1991; Brooks & Brooks, 1993; Mikusa & Lewellen, 1999).

Situated Cognition Theory

Situated cognition is discussed here to support Mercer’s neo-Vygotskian theory. The Vygotskian theories of socio-cultural influence on cognition contributed heavily to the thinking related to the situated cognition theory. The situated cognition theorist characterizes learning as (a) knowledge is conceived as lived practices, and (b) as participation in communities of practice (Driscoll, 2000).

Unlike other theories like cognition theory that focuses on thinking of an individual, situated cognition directs its analysis toward activities embedded in socio-cultural settings (Boaler, 2000; Kirshner & Whitson, 2000). This implies that knowledge is accumulated through the interaction with the community members. In fact, Kirshner & Whitson describe the theory as “an aspect of inter-psychological relations in which tools, linguistics or material, in the social environment are used by the novice adaptively in experimental invitation of the larger culture’s usage” (p. 5). The interactions are meaningful in relation to their lived culture.

Learning is seen as a function of activities and interaction among people, materials settings, and goals. Lave and Wegner, (1991) contend that learning in a situative perspective is that participation which “focuses attention on ways in which it is an evolving, continuously renewed set of relations . . .” (p. 50). The participant while interacting among persons, their activities and the world, develops an identity. The development of identity with mathematics was demonstrated by Boaler (2000) in her
study of the relationships between knowledge, practice, and identity. She argues from a constructivist perspective that knowledge is related differently to those in a behaviorist perspective. Knowledge is developed and used differently. Both use previous knowledge to generate new knowledge through practice. Learners in the traditional class use known procedures from textbooks and those given by teachers to acquire knowledge. They prepare well for end of term exams. However, it becomes difficult to relate their knowledge to the outside world where they discover that their classroom knowledge does not relate to the real world. They then lose interest in the subject which does not prepare them for the outside world. Thus, in this perspective, there is no connection between practice and identity. Also little or no relationship exists between their knowledge and identity.

Driscoll, (2000) identifies four implications of situated cognition to learning. These are:

1. Cognitive apprenticeship

For aspirant teachers to learn about teaching, they are expected to go through a period of apprenticeship. That is where they participate gradually in the art of teaching.

2. Anchored instruction where the newcomer is presented with an everyday problem situation to solve.

3. Learning communities. Here the culture of the traditional classroom must change. Traditionally the teacher is the dispenser of knowledge and books are the authority in knowledge. In learning communities, both the teacher and the student
learn collaboratively. This allows the student to bring to the community his
previous knowledge. Discourse glues the community together.

4. Assessment in-situ where both the continuous and paper-and-pencil assessment
play an important part. Students are assessed on what they have learned at a
moment.

Neo-Vygotskian Theory

The neo-Vygotskian theory as described by Mercer (1993) is a sub-theory of
Vygotsky’s social constructivist and situated cognition theories. Central to this theory is
the role played by culture and context. Mercer argues that cultural network generates and
transmits knowledge. He maintains that

... culture is something which is not just received but which is also
revised and recreated by children. It remains a source of meaningful
representations of objects and actions, representations which are socio
historical because they emerge from the historical experience of a social
group. Children’s interpretations of experience- the meanings they attach
to their learning- . . . [and] any educationally oriented study of learning
must recognize that schools have their own body of cultural knowledge,
and their own ways of communicating and legitimizing knowledge.”
(p. 31)

On the other hand, Mercer (1993) believes context plays an important part in
educational discourse. Context is whatever the learner finds relevant and that which
makes sense to him. Here Mercer confirms what Moschkowich (1996) said that research
on problem solving in bilingual classrooms focuses on students solving problems from an English context. This, they argue, results in not performing to their best ability because of an unfamiliar context. Mercer (1993) echoes Vygotsky’s principle of semiotic and psychological tools where languages are seen as playing special roles in the development of thought. He argues that any successful teaching and learning activity are functions of contextualized discourse. The participants who are engaged in a useful conversation, use past shared contextual information to have access to new emerging knowledge. An effective teaching and learning depends on how students are allowed/not allowed to use contextualized information relevant to cultural norms. Teaching mathematics in a second language may not result in effective learning if problems are posed from unfamiliar contexts.

One key concept to the neo-Vygotskian theory is “appropriation”. Mercer (1993) compares appropriation to Piaget’s concept of “assimilation.” It is argued in this theory that learners appropriate understanding if they acquire knowledge through a contextualized cultural contact and “child’s unaided explorations” (p. 36).

Mercer (1993) further believes that the educational process of appropriation encompasses three “socio-dynamics of development of understanding.” These are:

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2. Paraphrase – A teacher may paraphrase a learner’s talk to fit in with present discussions
Reconstructive recap - A reconstruction of events or previous experiences in a way that will fit with educational requirements.

The neo-Vygotskian theory is a relevant base for mathematics teachers in a multilingual classrooms because “by strategically appropriating children’s words and actions, teachers may help children relate children’s thoughts and actions in particular situations to the parameters of educational knowledge” (Mercer, p. 37).

Problem Solving

Teaching and learning mathematics from a constructivism perspective seems to be tied to problem solving. Studies on mathematics problem solving tend to focus on four areas: (a) research done between early 1970s and 1980s that concentrated on identifying problem features; (b) those studies done from late 1970s to mid 1980 that laid emphasis on expert and novice problem solvers; (c) instruction on problem skills and heuristics was the characteristics of the early 1980s until early 1990s; and (d) how metacognition impacted on mathematical problem solving (Smith, 1998). Schoenfeld (1992) observed that studies on early problem solving investigated mainly on task variables. These fell short of taking into consideration the nature and characteristics of the problem solver.

The ensuing research began to investigate some traits in problem solvers. Characteristics of expert and novice problem solvers were described. Lester (1994) identified three traits of good problem solvers: (a) they can identify and focus on the structure of the problem; (b) can differentiate between their strong and weak problem solving skills; and (c) are reflexive. On the other hand, Smith (1998) argues poor problem solvers cannot be taught these traits because they may produce unintended results.
Recently, research on problem solving from a constructive perspective has generated interest. Arguing against early form of problem solving (where learners solve problems out of context, Tate, 1995), van de Walle (2001) highlights two problems associated with “teach-then-solve paradigm”, and those are (a) most learners develop a belief system that mathematics is mysterious and hard to understand, (b) most learners are used to getting answers from the teacher, which means learning is separated from the problem solving process. Carpenter, Fennema, Peterson, Chiat, & Loef’s (1989) report states that there are significant differences between problem solving and the liberty given to construct own strategies. Hiebert, et al. (1996), citing Carpenter, et al. (1989) and Hiebert and Wearne (1992, 1993), argue that there are two strategies students can use in solving problems. These are that they should be allowed to problematize procedures and adjust these for future. They claim once these two strategies have been combined, “they shall have integrated conceptual knowledge with their procedural skill” (p.17). Teaching through problem solving increases other skills. Differences were also noted in how the teacher knew their students thinking and the students’ growth in problem solving.

Van de Walle (2000) gives values of teaching with problems. He argues that problem solving:

- places the focus of the students’ attention on ideas and sense making,
- develops ‘mathematical power’,
- develops belief that they are capable of doing mathematics and mathematics makes sense, and
• provides ongoing assessment data that can be used to make and change instructional decisions, helps students succeed, and inform parents (p. 41).

Carpenter, et al. (1989) reported that when emphasis is placed on problem solving then (1) students’ attention on ideas and sense making increases (2) there is liberty to construct own strategies, (3) other skills are enhanced, and (4) there is difference in how the teacher knew their students’ thinking and the students growth in problem solving. In a research which investigated classroom factors which supported students’ thinking, Henninsen & Stein (1997) confirmed that high level of mathematical thinking and reasoning.

To understand how students think in mathematics, we must learn how children develop conceptual and procedural knowledge of mathematics and how they develop the connection between them.

Carpenter, Coburn, Reys, and Wilson (1976) describes conceptual knowledge as that which involves relationships between mathematical concepts or ideas, which could be connected or integrated with each other. These abstract notions are referred to by Piaget (1983) as logico-mathematical concepts, which are part of logico-mathematical knowledge. Studies reveal that many elementary school students commit errors, which indicate the underlying weak or nonexisting understanding of basic concepts of fractions (Carpenter, et al. 1976; Carpenter, Hiebert and Moser, 1981; Steffe and Oliver, 1991).

Piaget (1983) also identified two other types of knowledge; physical knowledge and social knowledge. Students could figure out average without being taught the conventional algorithms They used their class points (physical knowledge) to invent own
methods of computing averages. They also used known words to describe and conventional symbols (social knowledge) to represent their ideas. Therefore, for children to learn mathematics, they need to use all three types of knowledge.

Does having procedural knowledge imply understanding of mathematical concepts? Procedural knowledge comprises the mathematical symbolic representational system related to social knowledge and step-by-step procedures used in solving mathematical problems (Carpenter, et al., 1976; Hiebert and Lefevre, 1986). Kamii et al. (1996) contends that the conventional approach of using algorithms can be learned. They argue, however, that children as well as university students are unable to reason logically after learning the use of algorithms. This belief is shared by Nitabach and Lehrer (1996) who argue that procedural competence fails to develop spatial sense in children. They used the experience of conflict between conception and visual perception. They report further that the learners challenged their visual perception with their emerging understanding. Based on their observation of children figuring out average scores and making good estimation using own invented methods, Kamii et al. (1996) report that children use what they know to construct, or invent new knowledge. The belief is shared by Empson (1995) in her study of first graders using their intuitive knowledge to invent their own strategies to solve story problems. Also along the line, Erickson (1999) agrees that problem solving tasks presents situations where no readily known or accessible procedures or algorithm determines the method of solution. She argues further that students make sense of mathematical situations where no well-defined routines or procedures exists. The research cited here highlights the interplay between conceptual and procedural
knowledge. The procedures used need to have a conceptual base, and the symbols used must represent the concept.

Is there interplay between mathematical knowledge and the cognitive analysis of learners’ construction of mathematical knowledge? Bartolini Bussi, et al. (1999) claim to have illustrated that the cognitive counterpart of activity with everyday referents leads to some early theoretical thinking. Therefore by manipulating objects, children are more likely to think about how and why they are doing a specific activity. To help children reflect on their actions and create relationships, a problem solving environment should be used and children be encouraged to use self-validation of ideas (Kamii, 1990; Yackel, Cobb, Wood, Wheatly and Merkel, 1990). Misconceptions can be caught early on by listening to children’s thinking processes or observing what they are doing or challenging their ideas. Davis (1986) and van de Walle, (1990) agree that to connect procedural knowledge with the conceptual knowledge, conceptual knowledge should be developed before the procedural knowledge. While thinking about new concepts, children should discuss their thoughts in writing or even orally. Then the language and ideas in the discussion can be later used to create algorithms, rules or symbols used to represent a concept (van de Walle, 1990). All the above cited research indicate how problem solving facilitate the acquisition of logico-mathematical, physical, and social knowledge.

Researchers report that learners in a problem based class develop mathematical power. Carpenter, et al. (1989) compared learners in a cognitively guided instruction class to learners in a traditional class. Their findings indicate that the experiment group actively defined and synthesized the given problem. This group further showed a feeling
of ownership of the solution of the problem. However in a study that investigated a learner who moved from inquiry-based class to the traditional one, McNeal (1995) reports that the learner abandoned his “self-generated computational algorithms in favor of less understood conventional procedures” (p. 205).

Problem solving develops the belief in students that they are capable of doing mathematics and mathematics makes sense. The development of self-efficacy in students was confirmed by Malloy and Jones ( ) in which African-American students were involved in problem solving while talking aloud.

Fraivillig, Murphy and Fuson (1999) provided evidence that teachers who continually extend their learners encourage mathematical reflection. This ongoing assessment will help solve the ever-changing problem.

Tate (1995) disagrees when the physical and social knowledge is strange, the logico-mathematical knowledge will be hard to acquire. Arguing against out-of-context problems for bilingual mathematics class, Moschkovich (1995) refers to such a situation as second language speakers solving English problems whose context they do not know. This leads us into the discussion of research on culturally relevant problem solving.

 Culturally Relevant Mathematics Problem Solving

As stated before, that according to HSRC’s, (2002) analysis of TIMSS-R study, about a quarter (26%) of the South African participants had the language of the test as their first language and these scored better in mathematics and science. Further analysis reveals that South African participants have poor self efficacy in mathematics as compared to their international counterparts.
The study finds that low achievement was related to:

- low socioeconomic status,
- fairly low parental educational level, and
- lack of fluency in the language of testing which implied difficulty to communicate.

These findings are the same as those found by Treisman (1985) who did an ethnographic study on underperforming African-American in calculus. The professors he was interviewing, indicated the same findings as those found by HSRC (2002). Since there are few studies done on South African students, except those done by HSRC (2000), Adler (1999), and Setati and Adler (2000), much of my review will come from the literature in United States.

This section will discuss literature on issues pertaining to language, and context as they affect the learning of mathematics in a multicultural setting.

Language issues

Studies about issues on learning mathematics in a second language have been going on since 1928 (Setati and Adler, 2000). The following discussion will focus on research that could be classified as those belonging to:

- the deficiency perspective,
- the situative perspective, and
- the culturally relevant perspective.

The Deficiency Perspective

In this perspective linguistic factor is used as negatively affecting mathematics learning in bi/multilingual classroom. Eleanor Orr, a mathematics teacher posited that
Black English Vernacular can affect certain quantitative relationships (Delpit, 1995). Orr bases her arguments on the invisible power of English. Delpit cites three flaws with Orr’s assumptions:

- Black English speakers “do not have access to certain concepts needed in mathematical problem solving” (p. 64)
- confusion in mathematics is as a result of the Black English,
- “mathematics is linked to the syntactical construction of standard English” (p. 64).

Delpit argues further that conceptually Orr’s solution is not the answer to her assumptions. Orr’s solution was that teachers and students created a shared system that helped students acquire “a knowledge of the content of the language of mathematics and not the form” (p. 65). Tate (1995) agrees with Delpit when he notes that “standard English is as a dialect is more archaic than nonstandard English, but it is not more logical, and the history of English has not been developed by precepts of mathematics” (p. 168). I am reading into this that mathematics can be learned with or without the command of English language.

Arguing from the same premise that South African Black Languages’ mathematics register has not developed to the same level as English, Setati and Adler (2000) argues for code switching. The linguistics experts such as Yumoto (1996), Ncoko, Osman, and Cockcroft (2000) describe code switching as interchange and mixing of languages during one discourse or even within a sentence. Setati and Adler contend that even though at general political and pedagogical level it makes sense for teachers to use code-switching as a teaching and learning resource, this is however not a straight forward matter. They
however believe that this will only be a resource in so far as it helps teachers to bring learners to “mathematical English” (p. 265). This does not hold well with Delpit (1995) (quoted in the previous paragraph) who maintains that this is an indication of the power of the English language, which shadows learners from mathematics content. Delpit is agreement with HSRC’s (2002) findings that South African students cannot articulate their mathematics knowledge clearly using the language of the test.

The Discontinuity Perspective

This model describes learning as a discontinuous mapping across a language and mathematics register (Cummins, 1981). It can take three forms:

• First language mapped onto the mathematics register. This usually when a solves a problem using first language the medium of instruction. Though not absent, difficulties of same word/concept,

• meaning different things in everyday talk and mathematics register are minimal.

• A mapping between second language and mathematics register,

• A combination of 1 and 2 a case which is prevalent classrooms using a second language to teach mathematics (Brenner, 1994; Khisty, McLeod and Bertilson, 1990).

Much of research particularly those studying Spanish speakers learning mathematics in English have also alluded to the reason of discontinuity, claiming students in bilingual classrooms are faced with several discontinuities (Moschkovich, 1995; Adler, 1999; Setati and Adler, 2000). However, argues Moschovich, (1995), these studies “focused
largely on students solving English word problems, rather than participating in mathematical conversation and constructing mathematical meaning” (p. 35).

The advantages of the discontinuity model are that it can be used as an analytical tool to explain learning in bilingual classes. On the other hand its shortcoming are that it may be interpreted that learning of mathematics is reduced to learning vocabulary and it can also be termed a ‘deficiency model’ Moschovich (1995). To pass by this dilemma, Moschovich proposes a situated model as described below.

Situated Model in a bilingual/multilingual classroom

The situated model uses language, social and cultural materials to communicate about situations. The language is used contextually to solve everyday problems. That is, language use and its relation to mathematics learning is a function of a situation.

Context

Tate (1995) argues that the problems facing research in the United States are focused on:

• African American students need to experience what White students experience in order to succeed in mathematics,

• equity debates are based on quantifiable issues when there are those subtle ones which cannot be counted.

Tate’s argument is not unique to the United States. South Africa has the same challenges. Culturally relevant instruction suggests instead of absorbing students into the current social and economic order, education should link with culture and society (Ladson-Billings, 1995b; Nelson Barber and Harrison, 1996; Tate1995). Several studies have been
done to explain the connection of learning and cultural background. These were given names such as “culturally appropriate” (Au & Jordan; 1981 in Ladson-Billings, 1995a), “culturally responsive” (Erickson & Mohatt; 1982 in Ladson-Billings, 1995a), “culturally compatible” (Vogt, Jordan, & Tharp; 1987 in Ladson-Billings, 1995a). However, Villegas (1988) argued that these studies did not go far enough to investigate the macro social context.

Ladson-Billings (1994; 1995) did a reflective and empirical study of effective teachers of African-American students and generated Culturally Relevant Pedagogy theory. The results of this study are contained in her definition of the theory. She defines it as a pedagogy that “rests on three criteria or propositions: (a) Students must experience academic success; (b) students must develop and/or maintain cultural competence; and (c) students must develop a critical consciousness through which they challenge the status quo of the current social order.” (Ladson-Billings, 1995a) (p. 160).

In a mathematics specific study, Tate (1995) agrees with Ladson-Billings (1994; 1995a). He argues that African-American students do not perform well in mathematics because they are exposed to a “foreign mathematics pedagogy” (p.166). Ladson-Billings (1995b) agrees that the problem given to students in a multicultural class should be in tune with the student’s culture. Tate reports about a teacher Sandra Mason using culturally relevant mathematics instruction in a class of African-American students. Tate further reports: “her students were prepared to engage in economic and social debates on issues relevant to African-American students” (p. 169). From the study discussed above,
Tate (1995) (p.171) made the comparison between culturally relevant problem solving and traditional problem solving (see Figure 2 below):

<table>
<thead>
<tr>
<th>Sandra Mason’s Pedagogy Instruction</th>
<th>More Traditional Mathematics Instruction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem Solving</td>
<td>Problem Solving</td>
</tr>
<tr>
<td>Investigating open-ended problems</td>
<td>Solving routine, well-defined problems</td>
</tr>
<tr>
<td>Formulating questions from problem situations</td>
<td></td>
</tr>
<tr>
<td>Representing real situations verbally, numerically, or graphically</td>
<td></td>
</tr>
<tr>
<td><strong>Communication</strong></td>
<td><strong>Communication</strong></td>
</tr>
<tr>
<td>Persuading others with mathematics</td>
<td>Answering questions that require only yes, no, or one answer</td>
</tr>
<tr>
<td>Providing multiple responses to a problem situation</td>
<td></td>
</tr>
<tr>
<td><strong>Reasoning</strong></td>
<td><strong>Reasoning</strong></td>
</tr>
<tr>
<td>Reasoning with ratios and proportions</td>
<td>Relying on teacher or book</td>
</tr>
<tr>
<td>Reasoning with graphs, charts, and tables</td>
<td></td>
</tr>
<tr>
<td><strong>Connecting</strong></td>
<td><strong>Connecting</strong></td>
</tr>
<tr>
<td>Connecting mathematics to other disciplines and to the world outside of school</td>
<td>Learning skills out of context</td>
</tr>
<tr>
<td><strong>Number/Operations/Computation</strong></td>
<td><strong>Number/Operations/Computation</strong></td>
</tr>
<tr>
<td>Developing numerical literacy</td>
<td>Memorizing rules and algorithms</td>
</tr>
<tr>
<td>Creating mathematical algorithms</td>
<td>Rounding numbers out of context</td>
</tr>
<tr>
<td><strong>Statistics</strong></td>
<td><strong>Statistics</strong></td>
</tr>
<tr>
<td>Using statistical methods to make decisions</td>
<td>Memorizing rules</td>
</tr>
</tbody>
</table>
To bring together the theories and the literature review discussed above, I draw on Boaler’s (2000) study of the relationships between knowledge, practice and identity (see Figure 3). She argues from a constructivist perspective that knowledge is related differently to that in a behaviorist perspective. Knowledge is developed and used differently. Both use previous knowledge to generate new knowledge through practice. Learners in the traditional class use known procedures from textbooks and those given by teachers to acquire knowledge. They prepare well for end-of-term exams. However it
becomes difficult to relate their knowledge to the outside world where they discover that their classroom knowledge does not relate to the real world. They then lose interest in the subject which does not prepare them for the outside world. Thus in this perspective, there is no connection between practice and identity also little or no relationships exist between their knowledge and identity. On the other hand I argue that a full Boaler triangle is realized if not only constructivist form of teaching and learning (which corresponds to the practice vertex of the triangle) is used but also situative and the neo-Vygotskian perspectives.

To connect knowledge and practice, learners construct knowledge based on the contextualized previous experience and previous agreed norms of the community, class and culture. By solving unstructured problems from everyday situations they learn how the community relates to the knowledge. They learn through the use of language by asking question, observing, justifying and defending their discoveries, explaining, and negotiating meaning. Anyone let alone the learner feels comfortable to debate and negotiate in a language in which she/he is proficient and comfortable. It is therefore important, particularly where mathematics is taught in a second language, to make this connection. Otherwise learners only solve problems procedurally without conceptual understanding.

From the discussion above and the foregoing theories, we see that students gained knowledge learned out of context does not develop identity with the discipline. Such a learner becomes disenchanted and isolated.
Language and context are the connecting devices between the vertices. In attempting to understand why bilingual mathematics classrooms are in the majority poor problem solver, Moschkovich (1996) compared two models of understanding learning of mathematics from a language perspective. She argues that rather seeing learning as a discontinuity, which is mapping between a language and mathematics register, it should be seen as “a situated model [which] describes students’ construction of knowledge as sociable and materially situated.

My intention in this study is therefore to explore the following questions:

- What are the students’ concepts of mathematics when posed with culturally relevant problems?
- Using any language of their choice, can students’ articulation of their thinking help us understand their learning process?
- What can we learn about student mathematical understanding when they are provided an opportunity to solve culturally relevant problems using their own thinking?
CHAPTER 3

RESEARCH METHODOLOGY

Introduction

The current investigation is an attempt to find the effect and role culturally relevant problem solving may have on learning mathematics. My target audience are my colleagues, teachers who are grappling to implement reformed way of teaching mathematics and student teachers from whom the wind of change must come.

This part of the current study comprises four components. I will start by discussing issues of the choice of methodology. The discussion of the selection of the participants will follow. I will then categorize the data collection and discuss how and how often each type was collected. I will then discuss instrumentation and the reliability of the instrument. The limitations and delimitations will also be discussed and the chapter will close with a discussion of how I will analyze the data.

Rationale for Method Selection

This investigation is based on a participatory action research design from a critical perspective. Participatory action research allows a researcher to be an observer and a participant at the same time. According to Glesne, (1998) “the participant observer’s role entails a way of being present in everyday settings that enhances your awareness and
curiosity about the interactions taking place around you. You become immersed in the setting, its people, and the research questions. One way to test if you are being there appropriately is whether or not you are seeing things you never noticed before” (p. 60). I may say this is one reason chose to do this study in South Africa because I feel one important obstacle, the cultural difference will be eliminated.

However, doing research in an environment where I grew up, where I was a student and a teacher I feel somewhat like Smith (2001) says is internal “individual struggle to engage with the disconnections” where “there are a number of ethical, cultural, political and personal issues that can present special difficulties for indigenous researchers who, in their own communities, work partially as insiders . . . and partially as outsiders” (p. 5). I feel like an insider because we share the same cultural background and have been a teacher in the community. The feeling of an outsider may be brought by working from a different paradigm and thus may be marginalized.

Glesne (1998) suggests working away from home where one is not emotionally attached to the participants. Glesne posits that “as an established insider succumbing to temptation to be a covert observer may lead to guilt and or anxiety over that role”(p. 27). I regard myself as a classroom teacher where I will be doing autobiography and biography to help guide my colleagues and myself improve the teaching of mathematics.

I used the critical perspective as a guide to give the previously voiceless participants a voice and emancipate them from the asymmetrical authority.
The Selection of the Participants

As stated earlier on about the effects of the previous system in the South African education system, my choice of participants was directly biased towards those who were previously disadvantaged. Secondly, the present grade ten students were the first to be taught through the new curriculum, Curriculum 2005. Thirdly, the new curriculum has been suspended from the high school classes.

Since this is research about context and language in mathematical problem solving, participants in the current investigation were chosen “through a process called community nomination” (Ladson-Billings, 1994; p. 147). In this process, researchers rely on members of the community to nominate participants. The importance of such a selection procedure is emphasized by Tuckman (1999) that “… interview might seek input from people who neither participants or direct observers, but are aware of a set of experiences through secondhand information. In school research, such secondary sources could be parents, for an example” (p. 407). The procedure for the nomination was as follows:

1. The Area Project Manager (Superintendent) suggested names of two schools from historically disadvantaged communities. One school each in a rural (village), and urban (township). All schools use English as medium of instruction in mathematics. He further granted permission (see appendix ..) for me to proceed with the current study at these institutions

2. I then approached these schools and requested teachers to suggest three students from the tenth grade class, two of whom they believe to be struggling in their
school work and one above average. To cross check their nominations, I requested the Departmental Head of Mathematics and Deputy Principal to check and verify by using their progress (students) reports.

3. For the sake of openness I then arranged a meeting with them to explain the purpose of my study and their rights. They agreed after asking some questions for clarity. Each one of the participants was given a consent form (see appendix C) to their parents/guardian who each gave permission to participate in the study.

The Participants

The subjects were seven tenth graders whose average age was fifteen and a half years. There were initially three boys and three girls. The third girl withdrew from the group during the third week. Then two girls joined the group voluntarily without being asked and parental permission was initially sought by phone then the girls took the consent forms home after the their first session.

Ethics & Confidentiality

I conducted this investigation under the Guidelines of the Ohio State University. The confidentiality of the participants was respected through the entire process by assigning pseudonyms to each participant.

Types of Data

Since this is a qualitative participatory research, I used multiple data collection methods to explore each individual’s thinking. These methods included audio taped interviews, observations, journals, student work and video recording.
Interviews.

Several forms of interviews were done during the course of data collection ranging from the exploratory interview (to gain rapport with the participants) to informal conversational form of an interview. Guidance on the latter form was sought from Tuckman (1999). Tuckman further warns that:

Qualitative researchers often must implement some special procedures for conducting successful interviews with children. Questions must accommodate the limited verbal repertoires of children from preschool through adolescence. It must anticipate paradox that children seldom give responses as socially controlled as the statements of adults, but on occasion they do strictly censor their responses according to rigid rules (p.408).

Since my initial objective was to establish rapport with each participant, I remained cognizant of Fontana and Frey’s (2000) standpoint when they maintain that:

[b]ecause the goal of unstructured interviewing is understanding, it is paramount that the researcher establish rapport with respondents; that is, the researcher must be able to take the role of the respondents and attempt to see the situation from their viewpoint, rather than superimpose his or her world of academia and preconceptions upon them (p. 655).

Thus the following initial exploratory interview was done with all the six participants at their respective schools.

1.1 Tell me something about your home life and your school life.

1.2 Can you tell me which school subject you like the most and the one
you like the least? Tell me why you feel that way in each case?

1.3 What can be done to make you feel good about that subject?

1.4 How important in your life is mathematics? What about its importance in your village/township/farm? Is there a place around where you see the use of the mathematics you are learning? Name five of these places and tell me the type of mathematics in those places or instances you named. Can you tell me why you think mathematics is important there?

Four more task-based interviews were held for each individual. These were held when the participants were solving problems from the worksheets. Reaction and responses were recorded transcribed and analyzed.

There are notable strengths and weakness to this type of interview. The advantages are that the aptness of the questions increases and also they are also a product of observations. They can also be suited to individuals and contexts. While on the other hand it is less systematic and not comprehensive particularly when different individuals are interviewed (Tuckman, 1999).

During the protocol interview, I used types of questions and prompts like:

Can you tell me what you are thinking about? How does/did that help you? Is there another way of doing? Is this the best way of doing this? Tell me more about your strategy? Can this strategy work every time? What did you learn and what went through your mind when.....? How do you feel when you answer in your own language?
2 Observation

Additional data were also collected by me in the form observational notes. I sat in the participants’ class during their regular mathematics time. Sometimes I shadowed them during group work or while working individually at their seats. I kept field notes which I later transcribed and analyzed.

Field note taking was guided by Wolcott’s (1994) four strategies of ethnographic observers. He identifies these as:

- Observe and record everything
- Observe and look for nothing— that is nothing in particular
- Look for paradoxes
- Identify the key problem confronting the group.

Even though Walcott (1994) maintains that the last two strategies require a skilled observer, I chose to use them. I chose them in order to lift up answers to my focus questions.

Instrumentation for interview protocol

My purpose is to understand and document participants’ mathematical thoughts gleaned as they solve culturally relevant problems. I selected problems based on what they were doing during their normal mathematics lessons. Fortunately the two schools were doing the same unit of linear equations and inequations. However they had not taught problems leading to equations. Problems were picked out of their textbook, *Modern Graded Mathematics for Grade 10*. These problems were adapted accordingly to suit their environment and experiences while mathematics content in the textbook was
not changed to suit the cultural and social content of the participant (see appendix A). Problem sheet number four was adapted from those developed in the United States of America. For an example aluminum becomes aluminium in South African English and “groovi” for local dialect. Some of them were translated into local language. I consulted with a Mathematics professor who checked on these adapted problems. I consulted with colleague to ensure that there is mathematics content in these problems and such mathematics is not swamped by unnecessary translations. I also informally consulted with a Setswana education official. I consulted her on issues of terminology.

Issues of Validity

I have been a mathematics teacher for about 26 years and have a passion for always searching for better ways of teaching mathematics. This may lead to subjectivity of my data to answering my own questions. During the years of teaching, I agreed with some colleagues and disagreed with others. My subjectivity may have led me to take what I agree with and discredit the rest. However, I kept track of my bias by taking field notes of my feelings before and after each interview and observation. This I hope, took care of balancing pre- and post-conceived ideas.

The selection of the participants may also have lead to a bias. Teachers might have nominated participants making use of subjective judgments. The participants may have given the answers they thought I wanted to hear. All these threatened the validity of the data. However, I think I tried to follow persistent observations and prolonged engagement.

Triangulation was one way I checked against bias. Fetterman (1998) maintains that a qualitative researcher uses triangulation to compare “information sources to test the
quality of the information (and the person sharing it), to understand more completely the part an actor plays in the social drama and ultimately to put the whole situation into perspective” (p. 93). I shared my transcripts and thoughts with the participants to ensure if they represented their thoughts. I used multiple data collection method to check the information I might have lost in one data collection technique.
Chapter 4

DATA ANALYSIS

Unless we begin to uncover and understand the meanings that mathematics knowledge assumes for students, parents and their communities and how these meanings are internalized to produce productive or unproductive agency, attempts to alter achievement and persistence results by manipulating variables only inside the school will have little effect in reversing negative trends. (Martin, 2000, p.186)

Introduction

The main objective of this chapter is to listen and give voice to seven students at two schools in the Rustenburg Area, South Africa. The chapter will start with a background account on the education system in South Africa leading to a description of the setting, that is the two schools I will call Matla High School and Lerokga High School.

The schools will then lead us into the classrooms to let the participants, through my observation, their journal entries, protocol and interview transcriptions, reveal how they
make meanings of and internalize mathematics knowledge. Their stories are organized around four factors namely mathematics knowledge construction, environment (culturally-relevant), mathematics identity, and how language directs their thoughts to make meaning of and internalize mathematical knowledge.

**Background**

I selected the two schools because I believe they represent schools of the Bantu Education era. Blacks in this era (between 1953 and 1990) were subjected to an inferior and under-resourced form of education. The architect of the *apartheid* Dr. Verwoerd (then Minister of Native Affairs and later Prime Minister of South Africa) introduced the Bantu Education Act of 1953 that led to the deterioration of standards in schools. There was a mass production of poorly trained and under-qualified teachers. When addressing parliament in 1952 he promised that “I will reform it [black education] so that Natives will be taught from childhood to realize that equality with Europeans is not for them”

([http://www.socsci.kun.nl/ped/whp/histeduc/apartheid.html](http://www.socsci.kun.nl/ped/whp/histeduc/apartheid.html)).

The teaching of mathematics did not escape his wrath when he argued that “What is the use of teaching a Bantu child mathematics when he cannot use it in practice?” and further said that “Education must train and teach people in accordance with their opportunities in life.”

([http://www.socsci.kun.nl/ped/whp/histeduc/apartheid.html](http://www.socsci.kun.nl/ped/whp/histeduc/apartheid.html)).

It is against this backdrop that I selected Matla and Lerokga schools. Matla is situated in what was called Bantu Township called Tlhabane. This is a ghetto like
urban area where people live in matchbox like houses. This is a school where Lerato, K gobane, and Tumi (Kedi and Monki volunteered during the third week) attend. While Bakang, Mogomotsi, and Mpho go to school in Lerokga, which is in a village run by a chief.

I selected grade tens because this is a group that went through three education systems during their earlier school life. They were taught Bantu Education during their elementary school years up to grade six. From grade seven to nine they were introduced to the new curriculum, Curriculum 2005.

Outcomes Based Education is a big part of C2005, and it is about activating the minds of young people so that they are better able to take part in economic and social life. Outcomes-based education, as expressed in C2005 ensures that: a) the process and content of education are emphasized by 'mapping' the learning process backwards from the outcomes at the end of Grade 9 and b) all learners are able to achieve to their maximum ability and are equipped for lifelong learning in a democratic society


The document further characterizes Outcomes Based Education as “understanding and flexibility are as important as content. Outcomes do not
depend on the content. Outcomes are the results of learning, and can be measured and assessed.”

Outcomes-Based Education:

- is a learner-centered process;
- is developmental: it encompasses both what learners learn and are able to do at the end of the learning process;
- is an activity-based approach to education designed to promote problem-solving and critical thinking;
- through its outcomes at the end of the learning process shapes the learning process itself - the process of learning is considered as important as what is learnt;
- emphasizes high expectations of what all learners can achieve.

According to the initial plans of the South African government, Curriculum2005 should be implemented in all grades K-12 by the year 2005. However the curriculum was not ready to be implemented in Grade 10. They have changed back to the old curriculum.

Observation Context

I began classroom observation during the second week after the reopening of schools from winter break. I spent two days a week in a mathematics class. I had to
attend to two classes at Matla High School because Lerato and Kgobane were in different classrooms as Tumi, Kedi, and Monki. These classes were also taught by different teachers. Lerato and Kgobane’s class was taught by a white male teacher (Mr. Landman) whose first language is Afrikaans. I am highlighting this to indicate that there were sometimes communication breakdowns between him and some students.

Mr. Lekwapa, a black male teacher, teaches the other mathematics class. He speaks the same language (Setswana) as the majority of the students. The atmosphere is somewhat relaxed in this class. Even though he uses English to teach, most students answer, question, and explain in Setswana.

The sizes of the classes ranged from 40 to 48 students. Mr. Landman’s class would for most part be engaged in the same routine. He starts by checking if the homework has been done, corrects the home work on the board, introduces the lesson for the day using same teaching style and method and gives homework towards the end of the period.

Generally most students in this class do not do their homework. Some bring incomplete work. Lerato and Kgobane were in most cases in this group. Throughout the first four weeks my field notes from Mr. Landman’s class showed almost the same until suddenly during the fifth week when I record the following:
Mr. Landman checked on the homework. He asks those who have not done it to step outside. There are about 28 of them and Kgobane is amongst them. Mr. Landman then asks those remaining to review the homework on the board. He then led the culprits to the deputy principal’s office who also is the departmental head for mathematics. I followed. I wanted to hear how the homework problem will be solved. The deputy principal does not speak the local language. When questions were asked, the only answer that came almost in chorus was: “we don’t understand.” The deputy principal then gave them a warning and promised to call their parents if they continue not doing their homework. We all returned to the class after 15 minutes. Today Mr. Landman handed out a worksheet. I walked around to monitor the students, they appeared to be working or they were acting out. Many students appear unmotivated which looks like it is interfering with their ability to get their work done. When questions were asked, only two to four students would answer and these are normally those who do their homework. Many hide behind others to avoid being asked to respond to a question.

Mr. Lekwapa’s mathematics class presented a slightly different scenario. Even though he also starts the lesson by checking and reviewing the homework, he lets the
students do the review on the board while asking them to explain their solutions. Students usually communicate their thoughts in Setswana, their first language. The difference between Mr. Landman’s and Mr. Lekwapa’s class is that there is some form of communication between teacher and students in the latter’s class even though teacher and students use different language of communication. One field note summary reveals that the teacher in a question and answer lesson asked about 25 questions. All the answers were given in a mixture of Setswana and mathematics terminology.

The situation at Lerokga is somewhat the same and also different. The school building here is old and was erected during the Bantustan era. It appears that it used to be beautiful but lack of proper maintenance resources has led it to its present status. When you enter the classrooms, there are broken tables and chairs. The class in which the participants attend mathematics has no teacher’s table. In fact this is their permanent class. Teachers move around to classrooms and students stay in one classroom for the rest of their school day.

Mrs. Masana, whose class I observed is one such teacher at Lerokga High School. Tables in her classroom are arranged to allow for group work. The three participants, Mpho, Mogomotsi, and Bakang are in different groups.

Mathematics lessons in this class start like those at Matla High School. The teacher starts by checking homework. Then she asks the students to write their
solutions on the board. The class is then asked to comment on the solutions.

Comments and questions from students are asked in Setswana. I was almost daily making observation entries like the following excerpt from my field notes:

School: Lerokga                                      Date: 7/24/03

Class: Grade 10b

The teacher, Mrs. Masana enters the class and greets the class. The students were talking and immediately get their mathematics homework books out. She calls out names of four students from different groups to write solutions of homework problems on the board while she is moving around the class from group to group to check homework. She grumbles when she gets to certain individuals. She finishes and watches the board as students write their solutions on the board. Students are exchanging comments and questions. The communication is mostly in Setswana.

Data from my transcribed field notes from the three classrooms reveals that problem solving is that of solving of routine, well defined problems. These are content based which uses content terms like factorize, solve for \( x \), etc. Students answer questions that require yes, no or one answer. The Setswana phrases like:

a) “ansara ke mang?” [what is the answer?], b) “a e fella foo?” [does it end there?], and c) “khalkhuleitha yare, \( \frac{1}{0} \) ke era” [for \( \frac{1}{0} \), calculator displays error] are part of
communication in Mr. Lekwapa’s and Mrs. Masana’s classes. In Mr. Landman’s class these can be heard in student-student discourse. In fact, Mpho, the participant from Lerokga confirms in her journal entry the notion that mathematics is about answers. When prompted to describe her experiences with mathematics, she writes (unedited):

Mathematics is fun; you make use of many things like solving products, drawing graphs etc. It is fun but full of challenges, you have to know and understand maths and that is quiet difficult if let it be difficult. When solving a mathematical problem, you must put all your efforts into it and have intension of finding the answer. When doing mathematics you must like everything about because when you hate it or it teacher your won’t go any far, every time you will fail this subject ‘cause you hate everything about it. I like everything about mathematics.

These statements also reveal that reasoning by students relies on some source, be it the teacher, or the textbook or even the calculator.

On the other hand, the observation transcripts reveal that even though the official medium of instruction is English, the preferred language of communication and expression is a mixture of Setswana and mathematical terms used in Setswana form. Mr. Lekwapa asked one of his top students to explain her procedure on the board while solving for $x$ in:
\[ 2(2x - 3) - 4 \geq 4 - 3(3x -2) \]

Student: *Ke remuva dibrackete pele* [I remove the brackets first]. She talks using a mixture of English and Setswana and writes until she reached the following step:

\[ 4x - 6 - 4 \geq 4 - 9x + 6 \]

She then says: … *eeeh… yaa mos jaanong re kholekta dilaek thems…mh….re be re transpousa di-x ko left and tse dingwe ko right.*

[…eeeh…yes but we now collect the like terms and then transpose the \(x\)’s to the left and others to the right ]

The reader will realize that there is use of the mixture of languages without the loss of the mathematical content. I agree with Setati and Adler (2000) when they argue that the African languages in South Africa have not yet developed mathematical language. However students in this class as well as those in Mrs. Masana’s language use a language that helps them to explain their mathematical meaning and understanding. This is reminiscent of Delpit’s (1995) position against Orr’s deficiency argument.

What mathematics are they thinking: Participants’ interview protocols

Introduction
Teaching and learning school mathematics is complex and there are many factors leading to low motivation and underachievement in mathematics. This section gives voice to a group of students to articulate their thoughts. Their narratives will be used to explain and describe emerging themes. These themes, which form the lower level triangle on which rests the body of mathematical knowledge (as in my theoretical framework), are:

- beliefs about importance of mathematics knowledge and about ability to learn mathematics
- experiential (cultural) and intuitive mathematics knowledge
- mathematics knowledge construction.

Initial interview

I interviewed seven grade ten students during the latter half of the second week of my observation. Four of the students were selected because of their low achievement in mathematics, while the other two were from average achievers’ group. For participation, each school, Lerokga and Matla, provided three students for the study in the ratio two underachievers to one average achiever. I was however not aware of which student is an underachiever and which one an average achiever. This knowledge rested with the deputy-principal and the mathematics teachers only. One female participant (Tumi) from Matla High School opted out during the third week after problem solving session. It was however, during the said problem solving
session that two female students volunteered to participate in the study. These two, who assumed names Kedi and Monki came from the same class as Tumi; Mr. Lekwapa’s mathematics class.

Initial Interview

Before looking at participants, I wish to describe what I gleaned from the initial exploratory interviews. These were held at each school during the second week of my observations. They were held at different days of the week and different times of the day. These were held during the flexi time period (same as homeroom time in the U.S). During this period, students remain in the classrooms to do whatever they wish to do; they may be completing their class work or attending to assignments, etc. This period comes once a week in a class. I used this period during my eight week stay at these schools. At Matla, I was allocated the library while at Lerokga I was using the Physics Laboratory. Participants would come to these rooms during these times for the interviews. Interviews were held at two different times on Tuesdays at Matla, while at Lerokga were held once on Wednesdays during the course of this study.

The major purpose of the initial exploratory interview was to gain further rapport with the participants. I had already established this during a week of observation in their various classrooms. The teachers had allowed me to help out with tutoring during working of problems at their seats.
The initial interview reveals that even though these participants were from almost the same socio-historical background, their personal backgrounds did not fit one particular background. Some were from single-parent families; others were from two-parent families while others were living with relatives. Their socio-economic background also had some differences. Some parents and or guardians were unemployed or have been recently retrenched. Other’s families were professionals like teachers while others were mineworkers.

The initially selected students were three girls and three boys. Two girls and a boy came from Matla High School while two boys and a girl came from Lerokga High School. One limitation about the interviews is that I did not discuss issues of gender.

Before listening to the participants, I would like to make the reader aware that the vignettes do not in anyway capture all aspects of what it means to be a mathematics underachiever or average achiever in a historically disadvantaged school in South Africa in general. This number of students cannot describe, in general how grade tens internalize mathematics knowledge or even what is the form or amount of mathematical knowledge they have. However, we can glean from these stories what their thoughts are when problem solving culturally-relevant problems. We can also glean what effect, positive or negative, language has on their thoughts and beliefs about mathematics.
Mpho possessed a very positive attitude towards mathematics. She believes that she has to work hard but at the same time enjoying her efforts. When prompted by the researcher about the school subjects they like the most and the one they like the least, varying responses came from the participants. Mpho’s (at Lerokga) favorite subject is mathematics.

Researcher: *Can you tell me why you feel that way?*

Mpho (answering in English): “*Mathematics is … eeh fun… is… eeh … I like challenges… jaa*”

Kedi the volunteer was not at the initial interview. She expresses her mathematical ability without any doubt. When asked about her favorite subject, she said in Setswana: “Ke Metshe, [paused and looked at her friend Monki] . . . *ke bona tlhaloganyo yame e kgona, gone Metshe o batla motho yo elang tlhoko thata . . .*” [It’s maths, . . . I think I have the ability, because you have to be observant in mathematics. . . ]

Mathematics is not Kgobane’s (in Mr. Landman’s class) most liked subject. He feels: “. . . there are many formulas and methods to cram . . .” and rationalizes further “. . . many people hate mathematics…… that’s why they take it in Standard Grade.” Standard Grade is the lower of Grade 12, which in most cases does not give a student entry into University Mathematics. Kgobane is not alone in this category. Tumi feels that mathematics is difficult as she says: “I see maths as the hardest subject, and I don’t think I can go far with it….”
The above excerpts reveal variety of beliefs of what mathematics is to the group. Some like Mpho believe it to be where you solve problems using a variety of representations like graphs, numbers and so on. In addition to that I can glean that they believe that problems have one answer. The goal is to get the correct answer. This is a point where they agree with people like Kgobane. He argues that to get to the correct answer one must commit to memory a number of procedures and algorithms.

When the participants were prompted further to give some thoughts on what could be done to make them feel good about the subject, again a variety of suggestions were given. These centered mostly around the teaching of mathematics and the perception of their teachers. Lerato is a quiet student in Mr. Landman’s class. She is a bit small in stature and sits, to her advantage I think, behind a girl with a larger frame than hers. I observed her on several times, when Mr. Landman ask questions, she reduces her frame further into her chair. I noted several times in my field work notes that her homework is not completely done or not done at all. Mathematics is also one of her least favorite subjects. Here she responds in Setswana to the researcher’s question.

R: Lerato, if you were a maths teacher, what would you do to make your students feel good about and like maths?
L: I think, I need to be an easy going teacher.

R: Mmm…. An easy going teacher neh! Tell me more about an easy going teacher.

L: Oh it’s a teacher who teaches in easy and understandable language.

Lerato clearly sees herself as doing and understanding mathematics as along as it is taught in a language she will be free to use. Her journal entry number two was as follows:

Today’s problem was written in two languages English and Setswana. I chose the one written in Setswana because it is much understandable and it is my mother tongue.

About the instrumental use of mathematics and its importance, I had the following conversation with Mogomotsi.

Researcher: How important is mathematics in your life?

Mogomotsi: There is nothing to succeed to succeed without mathematics.

R: Are you saying that for one to be successful in life, one has to learn mathematics? Can you tell me more?
M: Yaa, when you pass mathematics well in final examination, you get a free bursary… And the mining companies can send you to America to get more educated. And it is easier to find job…. But you must work hard.

Tumi who came to the initial interview, and left the group, made the following journal entry:

- I experience that what we eating as our food is mathematics.
- The earth that we live in, everything that moves, like cars, trains ect. Its all mathematics.
- Electricity that gives us power is mathematics

All the participants except two (Tumi and Mpho), would like mathematics to be taught in the mother tongue. Monki’s journal entry, answering the journal prompt [which language is easier to use in answering mathematics questions]

I think it is Setswana because it our own language. We are can understand faster using our own language not a different language.

On the other hand Mpho and Tumi prefer English as a medium of instruction. Tumi writes (unedited): “Okey-Setswana is one official language but it does not take you anywhere And it will be difficult for other nations. I think if it was used as Setswana It will not be an important subject.” While Mpho argues that:

First of all English is my favorite language but it not my mother tongue. I
understand English and I prefer talking English. I find questions much
easier than Setswana questions. When I read English questions I can know
the answer very quickly, but Setswana go round and round, I take very
difficult. I love English because I want to know more about it.

Kgobane thinks differently and this is his translated version:

I think it would be better if the language of instruction is Setswana
because questions would be better understood. We can even solve/workout
problems on our own without help from anybody. And also that we should
be given problems to solve without tying us to a method/procedure to
pursue. We should be left to use our own method that which we
understand.

All students in this study contextualized the importance of and the role
played the language of instruction. We can also glean from the snippets that the
participants further contextualize the importance of mathematics in socio-
economic term (like to get a good job) or as a requirement to for a better future
(like to get bursary; the mining company will send you to America to get more
educated). The students’ narratives also beliefs about what is mathematics. They
renounce algorithms as dictated by authorities like teachers.

Do they have mathematics?

After observing the participants in their respective classrooms and schools
for two weeks and the initial interviews were held, I gave them the first work
sheet during the third week. As a working station, I was allocated the library at
the Matla High School and a Physics laboratory at Lerokga High School.

The interview protocols were held on Tuesdays at Matla and Wednesdays
at Lerokga. The classes were not far apart with regard to the syllabus. They
were almost around the topics: The Solution of linear equations and inequations.

I selected a problem that required the use solutions of linear equations.
Today they have 45 minutes while working on worksheet 1 (see appendix A). I
did not want to interview them but listen as they talk among themselves and
make some reflections. In the following vignettes a construction of what the
participants were doing. These were recorded by using audio cassette. In
brackets next to my name are my reflections and observation and those next the
participant’s are my English translations. First problem is written in English.
Seated around the table with papers pencils are Kgobane, Tumi and Lerato.

Researcher [Greeting them first and engaged them in small talk]:

I would like you to look and read the problem sheet in front
of you. I would like you work it out in whatever way you
wish. You can work alone or together. Use whatever way or
method. You may use numbers or words or pictures or tables
or even a calculator. Remember there is no correct way of
doing this. Every method is okay. Try to do it in as many
methods as you can. Remember talk to each and loud as you
can. Ask each other questions. Write down everything you
are thinking. Do you have questions?

The problem reads like:

\[
I \text{ have twice as many 20 cent coins as 10 cent coins and half the number of 5 cent coins as 10 cent coins. I have R4,20 altogether, find out how many of each coin denominations I have.}
\]

Kgobane: \textit{Goo fa mos, ba batla go itse number yadi-10sent, gore ke bokae, a kere} [But here they would like to know the number of the 10cent pieces.]

Lerato (nodding her head in agreement): \textit{mmm} [Yes]

Researcher: [What!! Did they read the properly, well Tumi is still reading or she. She has not said word. Kgobane is getting to the table to get a calculator]

Lerato: \textit{Ee, le di-10sent le di 20sent. Mara rea itse gore 20c ke twice ya 10c le 5c ke half ya10c} [Yes as well as the 10c and 20c pieces. But we know that 20c is twice 10c and 5c is half the 10c.]

The first three lines in method 1 are translated to:

There are 21 of the 20 cents coins in R4.20; there are 42 of the 10 cents coins in R4.20, and there are 84 in R4.20.

From their written responses and Lerato’s agreement, it appears that they are interpreting the question to be requiring the number of each of the denominations.
Researcher: [Kgobane is on the calculator and Lerato has written something on paper (as in the Figure 4). After having started some twenty minutes ago, do we really have to come to this?

Figure 4: Kgobane and Lerato’s work
Lerato even further adds that the “twice as many” emphasizes what she knows already. It is obvious of course that 20 cents is twice as 10 cents and 5 cents is half the value of 10 cents. Actual the past comment appears in their method number three where statements number one and two literally translated say:

Number of the 10 cent (coins) in 20 cents (coins) is twice

Number of the 5 cents (coins) in 10 cents (coins) is twice.

Statement number three is not part of the given problem but deduced it based on their previous experience. It reads (All words in brackets are mine and not part of their statements):

Number of the 5 cents (coins) in those of the 20 cents (coins) goes four times.

Researcher: [Ah!! Don’t say that. Tumi has been working alone up to this point. She has already written as in Figure 5. It appears she wants to use the ‘let x’ procedure, but what is she thinking? How is she using the information? Does she interpret as two times the 20 cents or what?]

Mr. Lekwapa had just introduced the topic about problems leading to linear equations. The problems are those from their traditional mathematics textbook. He gave the class few examples. On asking her what was she thinking when she wrote “unknown=coins, Let x=coin, x=10=42”. She answered: “Ke batla go itse palo ya di coin… gape le gore di-10 cents di kae mo 42” [I’d like to know the number of coins, also how many 10 cents are there in 42]. I think here is classical example of solving a problem out of context. The fourth
statement indicated to me that she is using “twice as many” differently from Kgobane and Lerato. Clearly she understands that to mean multiply by 2 but interpret it to mean multiply 20 by 2. This statement “20 cent X 2 = 40” is a mathematical statement which is literally terms equivalent to “. . . twice as many 20 cent coins . . .” The same can be said about Tumi’s fifth statement: “5 divided by 2” is equivalent to “. . . half the number of 5 cent coins . . .”

Figure 5: Tumi’s work
Researcher: [Kgobane is on the calculator and Lerato has written something on paper (as in Figure 4). After having started some twenty minutes ago, do we really come to this? I think maybe this problem is incorrectly stated. Is this problem from their everyday experience? Don’t they use rands and cents here anymore? I am getting frustrated. How can I change this problem? Perhaps I should ask them to add their answers. Will it make them read the problem again? This is a flop. Do I really understand what their thinking is or does the problem make them think what I want them to think? I’ve reached a point where Moskovich (1995) posits that students are given English problems to solve. I collected the paper and thanked them then they left. I concluded by thinking that I should rethink the problem again but should first find out what the Lerokga students would do.]

I wanted to share this frustration with the readers. Participants at Lerokga were no different as they also gave answers 21, 42 and 84 and let x strategy. However Mogomotsi, whose working appears in Figure 6 below, started by writing $75 + 75 = 150$. When prompted to explain he said “well I want to know how many 75’s are there in 4.20” He abandoned this and started subtracting 150 from 420 twice and got 120. He tried another strategies like $140 + 140 + 140 = 420$ and $175 + 175 + 70 = 420$ until he came to point where the ‘twice as much’ comes into play. Just like Tumi above, he multiplies 28 by 2.
Figure 6: Mogomotsi’s work
Remarks

The above snippet does not reveal much of students’ mathematics concepts. Since knowledge is conceived as lived practices, it appears their knowledge is only passive (Driscoll, 2000). They know that the amount of a 20 cents piece is twice that of a 10 cents piece. This knowledge is taken out of context. This matter itself disqualifies the problem as culturally relevant. It does not reveal any activity and interaction among people, materials, settings, and goals (Boaler, 2000; Kirshner, 2000). The language in the problem was used out of context as seen in the above Figure 6, where ‘twice’ meant multiply by 2, but which number bigger or smaller. Also, the meaning of the context appears to be lost during the translation. The students appear to read the problem in parts and not as a whole. The reason for appears to be that they are concentrating on translating the English words correctly, whether in context or out of context, it does not matter. Thus on this reflection I reformulated the problem to include the above remarks. This problem was set in two languages, namely English and Setswana.

Before starting with the next analysis, I would like to explain the next problems and how I attempted to make them culturally relevant problems.

The first one involves transport culture in South Africa, particularly where Blacks live. Few Blacks own cars and most people use taxi minibuses where fares like R4.20 are typical. According to annual reports of the department of transportation in South Africa, a bigger slice of all road accidents are caused by taxi-buses. Some of
the reasons given are that drivers give change while the vehicle is in motion. Thus, responsible drivers are most of the time required to have enough change with them.

Reformulating the problem to that of a taxi driver is closer to a problem taken from their everyday interactions. This applies to the second and third problems.

The following weeks were marked by some changes. During the fourth week, I brought in a plastic container in which there were some R6.00 worth of 20 cents, R6.00 worth of 10 cents, and R6.00 worth of 5 cents pieces of coins to each session at both schools. Also from now onwards, each worksheet was written in languages, English and Setswana. There were those who chose one version and those who chose the other version. Some exchanged version during the session. However mostly started using the Setswana version. I also realized some students started using materials I brought along.

Data emerging from the task-based interview and students’ answer papers revealed that some mathematics concepts and varying strategies began to appear. For an example, I challenged Mogomotsi to continue with his ‘75 cents strategy’ using coins with the problem reformulated as.

You are taxi driver between Luka and Rustenburg. The rule from the taxi owner is that every morning you must leave with a float/change of R4.20. The change must be in the form of 20 cents, 10 cents, 5 cents coins. These coins must be such that the number of 20 cents coins are twice as many as the number of 10 cents coins and the number the 5 cents coins are half as many as the number of
10 cents coins. How many coins of each denomination should you have in your change back?

Even though it took him some trips to the table, he eventually came up with the version below in Figure 7, which revealed the knowledge of distributive property and the balancing of equation.

Figure 7: Mogomotsi’s solution

Mogomotsi initially brought an amount of 75 cents made out of three twenty cents coins and three 5 cents coins. The next trip, while still at the table, he counted six 20 cents coins and six 5 cents coins and before leaving, counted
three more 20 cents coins and three more 5 cents coins. That accounted for his second statement:

\[
\begin{align*}
1,50 &\quad 6 \times 20c &\quad 3 \times 5c
\end{align*}
\]

He later counted all his 20 cents and 5 cents at his table and wrote

\[
12 \times 20 \quad \text{and} \quad 12 \times 5
\]

before putting all money together and wrote 3,00. He then went back to the table and brought twelve of the 10 cents coins. He then wrote

\[
4,20 \quad 12 \times 20c \quad 12 \times 10c \quad 12 \times 5c.
\]

When prompted and without using the coins, he explained that 6 of the 5 cents coins and 1 of the 10 cents is the same as 2 of the 20 cents coins. He further said, that the number of the 20 cents coins is not two times those of the 10 cents coins and the number of the 5 cents coins is not half that of the 10.

The use of manipulatives like the actual coins helped trigger some thinking. I later discovered that Mogomotsi’s uncle own some taxi-buses and Mogomotsi usually helps with counting of takings. I now realized why he arranged his coins systematically.

The data further reveal the use of table and proportion as they reason out their solution. For the same problem, Monki and Kedi reasoned that if they started off with 5 cents they should have two 10 cents and four 20 cents their total is R1,05 which did not make sense because they should have R4,20. They then adjusted strategy and extrapolated as shown in Figure 8 below.
Lerato and Kgobane used the squeeze property as they solved the third worksheet given hereunder.

*Your mother is a home curtain maker. She buys 12 meters of cloth at Mahomed in Ziniaville at R8.00 per meter. Some of the material is not of a good quality and is sold at R7.00 per meter. She pays R93.50 altogether. How many meters of poor quality material did she buy?*
They started by using a rudimentary strategy. When prompted to explain their strategy as shown below, Kgobane said “we want to be careful, we wrote the numbers in between because we realized that these numbers do not give us the R93.50 she paid.” Pointing to the 80 + 14 = 94 line, Lerato took over and said in Setswana but saying numbers in English “you see, if 2 meters is spoiled, she pays R94.00, and bigger by 50 cents, for 3 meters she pays 50 cents less so it must be 2 1/2 meters” We can glean this was making sense to them when they adjusted their strategy and reflected on those strategies.
Some cultural influence can be gleaned from Bakang’s work. In South Africa, plastic bags carrying merchandise are not given for free, but sold.

Bakang almost followed Kgbane and Lerato’s strategy even though they are at different schools. He arrived at R93.00 and added 50 cents for plastic bag.
The first statement tells us that there are 3 meters of poor quality material. She goes on and explain how she found 3 meters. By using proportion she writes (Figure 10)

(one) meter (is) R8. 00

for nine (meters) is R72. 00 good quality (material)

+ R21. 00 poor quality material

R93. 00

+ 50 (for) plastic (bag)

R93.50

Figure 10: Bakang work

Even though there is one calculation error, that multiplying by 4.5 twice, Mpho’s work shows why she prefers mathematics to be taught in English. Her logic can be gleaned from her report writing. She uses her own strategy to make sense of the following problem.
Your town/village is facing two problems. There has been a short supply of electric energy. To save energy, families have been asked not to operate their television sets. Secondly the town/village cannot cope with aluminium can litter. You and your friends made some research to help alleviate the problems. You discovered that the energy saved from 1 recycled aluminium can operate a television set for 3 hours. How many aluminium cans should be recycled to furnish enough energy to operate 680 television sets for 4.5 hours per day for 1 week? Write down all your thoughts clearly. Be prepared to explain all your thoughts to the councilors/chief.

Mpho’s report was as follows

Firstly we realized that there is a shortage of electricity in our village. Because we’ve asked to switch off our television, we do some researches and we found that one aluminium can can be recycled and operate tv for 3 hours.

Secondly our village is facing another problem of littering aluminium cans. In order for our village to play 680 tv sets for 3 hours, and our village need 4.5 hours to watch tv daily. It means that we will multiply 680 cans times 3 hours and it is 2040 + that halves of 1.5 cans and 1020 + 2040 and it is 3060 for 4.5 hours multiply by 7 days it will be 31.5 hours weekly. We will multiply 3060 times 31.5 hours and is 96390 and we will need 96390 cans per week.

Calculations are in the next page.
Summary

This chapter has presented description and analysis of my observation transcripts. The observation was done in two mathematics classrooms in an urban high school taught by two male teachers, one white and the other black. The other observation was done in one classroom of village high school taught by a black female teacher. The chapter also dealt with initial interview transcripts in which the mathematics identity and beliefs about mathematics of 7th grade 10 students were revealed. The transcripts also give an indication of what language, in general, do these students prefer as a medium of instruction in mathematics. The students’ paper and pencil solution sheets were also presented in this chapter. These solution sheets revealed how students make meaning and internalize mathematics knowledge.
CHAPTER 5

DISCUSSION

Introduction

This study was undertaken to learn and report about the effect and role that culturally relevant problem solving may have on learning school mathematics. The current study explored the following questions:

1. What are the students’ concepts of mathematics when posed with culturally relevant problems?

2. Using any language of their choice, can students’ articulation of their thinking help us understand their learning process?

3. What can we learn about student mathematical understanding when they are provided an opportunity to solve culturally relevant problems using their own thinking?

Based upon the data presented in chapter 4, this chapter attempts to give possible (a) answers to the questions stated above and (b) avenues for future research.

*What are the students’ concepts of mathematics when posed with culturally relevant problems?* Throughout my eight-week classroom observation, students were solving routine well-defined problems. Teachers struggled to explain procedures and
algorithms. I think teachers here are honest and sincere. From the manner in which they were teaching, their belief system is that of mathematics is taught in one way only. That way is by starting with definitions, rules and explanations. These were thoroughly explained and followed by many examples and then worksheets. This teacher-centred approach is, however, producing the desired results. I cannot blame teachers for having this form of belief because it is generally still believed that this is the only and accepted way of teaching mathematics.

The belief system held by teachers about Mathematics is overflowing into students. This was also evident in the first work sheet with the focus group, where the participants were looking for an answer from me or the calculator. The given problem was not taken from everyday life experience but from textbook. Participants wanted to use algorithms and rules like “let $x$ be . . .” They got so frustrated that one even opted out saying “ke batla go dira methse ole wa dinamba le matshwao . . .” [I’d like to that maths of numbers and signs . . .]. I read out of this statement that according to her mathematics involves only basic operations and procedures and algorithms. It does not matter where it is used. I believe this student wanted to be given formulas first.

Conceptual mathematics knowledge began to emerge as soon as we started solving culturally relevant problems. Participants formulated questions from the given problem situations. These questions varied from rudimentary to high-order type of question. One such was when solving the good/poor quality material problem. Part of their solution, which I transcribed at this level was (words or numbers in brackets are mine, otherwise the rest are the students’):
They questioned if there was any typographical error. They questioned further, after seeing the ascending sequence of length and the descending prize sequence. These students, I think have not been taught about sequences, but used Setswana words like “e e oketsega ka 1 mara e e fokotsega ka 1” [this increases by 1 and this decreases by 1]. I think that they arrived at 93.50 they questioned whether to take half the distance in each case.

The most form of reasoning used was proportion coupled with tables (see Figure 8.) Distributive law was also used (Figure 7). The most interesting mathematical concept which, emerged was the squeeze property which is widely used in Calculus (Figure 9.)

So, giving students a chance to solve culturally relevant problems with manipulations, there is a chance of getting some mathematics concepts.

*Using any language of their choice, can students’ articulation of their thinking help us understand their learning process?*

It was evident that five of the seven participants who did journal entry number one, did not understand the journal prompt. Participants gave varying responses to the following prompt:

*Describe your experiences with mathematics to your younger sister/brother/cousin. Think about 5 things.*
1) She needs more explanation in Setswana.

2) Show her example

3) Let her try by herself

4) Give her more attention

5) Help her to find an answer

In my opinion, the above responses answer the question/prompt: How would you help your sister understand mathematics.

English has been the medium of instruction since the first post-primary school was incepted in South Africa. There were times (mostly before Bantu Education was introduced) when it was accepted as the only medium of instruction in all South African schools. It was therefore a given that any teacher of any subject should be eloquent in English. In fact, the HSRC’s (2000) TIMSS-R report recommends that since South African participants could not communicate their mathematical ideas in English, mathematics teacher should in addition to mathematics workshops, be in-serviced in the English language. This is a noble idea for teachers. However, students hear and speak English at school and this is about eight hours in a day. The rest of the time they speak in their first language.

The previous paragraph may seem to give some explanation because some participants could not interpret problems written in English. The use of a phrase like ‘twice as much’ was correctly interpreted as two times but a wrong number was in some cases multiplied. All but one of the participants chose problem written in Setswana. The participants in those classes taught by Black teachers always answered in a mixture of
Setswana and English words. English words were used where no Setswana was readily available, for an example, "ke remuva dibrakete" [I’m removing the brackets] or even “ke transpousela dilaek thems tsotlhe ko raete” [I transpose all like terms to the right]. However, only those with a smattering knowledge of English could answer in class taught by a white teacher unless one word answer was required. This seemed to hamper the learning process. On the other hand, all but one participant communicated with me in the mixture of English and Setswana during course of this study. This was confirmed by journal entries in which most prefer to be instructed in what they call Setswana meaning the mixture.

The South African Education Language Policy Document saw the vital signs by arguing in the preamble number five and six that:

1. A wide spectrum of opinions exists as to the locally viable approaches towards multilingual education, ranging from arguments in favor of the cognitive benefits and cost-effectiveness of teaching through one medium (home language) and learning additional language(s) as subjects, to those drawing on comparative international experience demonstrating that, under appropriate conditions, most learners benefit cognitively and emotionally from the type of structured bilingual education found in dual-medium (also known as two-way immersion) programs. Whichever route is followed, the underlying principle is to maintain home language(s) while providing access to and the effective acquisition of additional language(s). Hence, the Department’s position that an additive approach to
bilingualism is to be seen as the normal orientation of our language-in-education policy. With regard to the delivery system, policy will progressively be guided by the results of comparative research, both locally and internationally.

2. The right to choose the language of learning and teaching is vested in the individual. This right has, however, to be exercised within the overall framework of the obligation on the education system to promote multilingualism.

Siegler (1998) agrees by tying language and thought by suggesting three possible relations:

1. Language shapes thought. This position, also known as the Whorf hypothesis . . . is based on the view that language shapes thought so profoundly . . . that a culture’s language shapes the way members of the culture interpret information about the world . . .

2. Thought shapes language. Piaget . . . saw language development as awaiting the relevant cognitive development (development of representational ability) rather than causing it.

3. Language and thought influences each other . . . The child’s thinking about the world is expressed increasingly precisely in language, and language becomes increasingly effective in directing thought and action Eventually much thought becomes internalized language. (p.169)

The above findings, The South African Education Language Policy Document, and Siegler are reminiscent of HSRC’s (2000) TIMSS findings. They report that low
achievement in mathematics is related to lack of fluency in the language of testing which implied difficulty to communicate their mathematics ideas. The findings seem to make sense to me from experience. It appears some mathematics ideas get lost along the way translation to and from English.

*What can we learn about student mathematical understanding when they are provided an opportunity to solve culturally relevant problems using their own thinking?*

From the fourth week I started to notice that their confidence was coming back as they started to look forward to the next problem. I overheard one of the participants saying “*mara keng re sa ire metshe o so evridei mara man . . .*” [but why don’t we do this type of maths daily?]. This was confirmed by the following journal number four (see appendix A) entries. Lerato, the little girl in Mr. Landman’s class made this entry in English “. . . there are many English word that I don’t understand and it is tough to answer if you don’t understand one word.” Is this the reason that she hides behind a bigger girl to avoid answering in English? Perhaps it is so. While Bakang entered “. . . my mother told me to make the radio speaker cover. I used to take cardboards and measure it by using mathematics . . .”

Perhaps one of the most important outcomes of the current study is the revelation that the participants are able to use their own strategies to some success. They adjusted these when the need arose and they made reflections. These strategies helped them give their own meaning of the problem. The following journal entry (Figure 12) has it all about using their own methods.
It was interesting to note how culture has an influence on problem solving. The South African taxi microbus, curtain sewing and the selling of plastic bag cultures had influences on the outcomes of the problem.

Implications to teaching and learning mathematics

The findings above have some implications for the teaching and learning of mathematics in South Africa. One of the tenets of Curriculum 2005 is that it is an activity-based approach designed to promote problem-solving and critical thinking. If the long-standing issues of participation and achievement are to be understood fully, they must be examined not only in terms of curricular change but to include
other issues like belief system (what is mathematics), culturally relevant problem solving and the role played by language of instruction.

An instruction that fosters memorization of facts and algorithm and procedures promotes beliefs such those gleaned from Kedi who opted out by saying “I want to do that type of mathematics.” This implied we were not doing mathematics because there were no formulas, and examples, to show how such problems are solved. Such unreasonable beliefs affect the learning of mathematics as was seen in her “let x be” algorithm. Arguing against such unreasonable beliefs, Baroody (1987) posits that:

beliefs promoted by an absorption approach discourages thinking and encourages blind procedure following. Such beliefs can interfere with meaningful learning and intelligent problem solving and cause children to go about learning and using school mathematics in mechanical way (p. 69).

The same sentiment is echoed by Zaslavsky (1996) when she says that the “reason that students refuse to learn is that the curriculum is irrelevant and they don’t see that schooling will lead to anything worthwhile in life” (p. 17). I therefore believe that instruction that relates new material to experience familiar to the learner can help reduce unreasonable beliefs.

The discussion and analysis in chapter 4 showed that achievement by the struggling students is possible. Instruction that encourages culturally relevant problem solving, led the students to use their own individual strategies. It also is important for teachers to realize that these strategies lead students to pattern recognition. Students must be nurtured to develop confidence and competency. That is’ analytic and reflexive skills
should be developed as in the curtain problem. When they became frustrated that they could not arrive at R93.50, they retraced and refined their steps. Instruction that encourages problem-solving empowers students in mathematics that is:

- they have acquired the necessary skills to function in our technological society. It implies that they are learning independently and with other people to solve problems requiring mathematical knowledge. It means students are able to direct their own learning to approach new tasks with confidence in their ability to handle them. We know now that people must construct their own knowledge, that mere memorization of rote procedures does not empower students in mathematics.

- Material that is memorized without understanding is soon forgotten or applied incorrectly. (Zaslavsky, 1996) (p. 7)

One other implication, in my view, is that teachers must develop an effective strategy of communication. The seven participants, even though they are from a monolingual community, they prefer code switching where there is no Setswana term. They use terms like *go transpousa; dilaek thems* [to transpose; like terms]. I believe such terms could be used while gradually introducing English terms or until they are confident enough to communicate in their ideas in English as long as this does not interfere with their mathematics concepts. I agree that this is not easy to achieve, particularly where teacher and student have different first languages or even in a multilingual class. Mentor students could be tried where a good English speaker could translate mathematics ideas communicated in his or her first language.

Implications for in-service training/professional development
The legacy of Apartheid has left an indelible mark in the training of mathematics and science teachers. The Sunday Times of South Africa reports that “the majority of mathematics (64.4%) and science (58%) grade 12 teachers have matric as their highest academic qualifications.” (http://www.sundaytimes.co.za/2003/09/07/insight/in01.asp).

The government would like to train teachers using the Labor Law clause which requires employers to set aside 80 hours a year for professional development. This is a Herculean task. I believe for teachers to be successful in implementing the reformed ideas, they must be trained in the same way they are going to teach. That is their workshops should be based on problem-solving techniques.

Summary

The results of this investigation indicate that students believe in the power and use of mathematics knowledge. If given a chance they can connect knowledge and practice by constructing previous experience and previous agreed norm of community, class, and culture. They learn through the use of their own language to communicate and feel comfortable in explaining their discoveries.

Avenue for further research

The data of the current study was collected within a period of eight weeks. Possible areas of research emerged. These avenues, which is not exhaustive include:

- a replication of this investigation over a longer period
- how do the South African students’ and teachers’ perceptions of mathematical content differ
• what are the South African teachers’ perception of the Curriculum 2005 mathematics student?

• Factors that hinder/help teacher professional development

• Factors that hinder/help implementation

• Pre-service, in-service and university program evaluation

The above stated suggested areas of possible research are mathematics teacher- and student-centered. Research that focus on the improvement of school mathematics achievement, should be sensitive to its clientele.
REFERENCES


I have twice as many 20 cent coins as 10 cent coins and half the number of 5 cent coins as 10 cent coins. I have R4,20 altogether, find out how many of each coin denominations I have.
You are taxi driver between Luka and Rustenburg. The rule from the taxi owner is that every morning you must leave with a float/change of R4.20. The must be in the form of 20 cents, 10 cents, 5 cents coins. These coins must such that the number of 20 cents coins are twice as many as the number of 10 cents coins and the number the 5 cents coins are half as many as the number of 10 cents coins. How many coins of each denomination should you have in your change back?
Your mother is a home curtain maker. She buys 12 meters of cloth at Mahomed in
Ziniaville at R8.00 per meter. Some of the cloth are not of good quality are sold at R7.00
per meter. She pays R93.50 altogether. How meters of poor quality cloth did she buy?
Your town/village is facing two problems. There has been a short supply of electric energy. To save energy, families have been asked not to operate their television sets. Secondly the town/village cannot cope with aluminium can litter. You and your friends made some research to help alleviate the problems. You discovered that the energy saved from 1 recycled aluminium can operate a television set for 3 hours. How many aluminium cans should be recycled to furnish enough energy to operate 680 television sets for 4.5 hours per day for 1 week? Write down all your thoughts clearly. Be prepared to explain all your thoughts to the councilors/chief.
APPENDIX B

JOURNAL PROMPTS
Describe your experiences with mathematics to your younger sister/brother/cousin. Think about 5 things.
A problem today was written in two languages, Setswana and English. Which paper, Setswana or English did you use to answer? Can you explain to your friend the reasons why you made such a choice. Give as many as you can.
Journal 3

Name................................................... Date.........................

Mathematics is taught in English. What do you think if it was taught in Setswana. Tell me anything.
Do you find it easier to solve mathematics problems related to your life or school mathematics. Explain to your mother giving about 5 reasons.
Which language is easier to use in answering mathematics questions verbally?
APPENDIX C

CONSENT FORMS
CONSENT FOR PARTICIPATION IN SOCIAL AND BEHAVIORAL RESEARCH

Protocol title: Challenging Students Through Mathematics: Culturally Relevant Problem Solving

Protocol number: 2003B0162

Principal Investigator: Professor P Brosnan

School of Teaching and Learning
Tel: 091 614 292 8060
Email Address: Brosnan.1@osu.edu

I consent to my participation in (or my child’s participation in) research being conducted by Professor P. Brosnan of The Ohio State University and her assistants and associates.

The investigator(s) has explained the purpose of the study, the procedures that will be followed, and the amount of time it will take. I understand the possible benefits, if any, of my participation (and/or my child’s participation).

I know that I can (and/or my child can) choose not to participate without penalty to me (and/or my child). If I agree to participate, I can (and/or my child can) withdraw
from the study at any time, and there will be no penalty. I consent to the use of videotapes.

I understand how the tapes will be used for this study.

I consent to the use of the following information from my academic records:

- Journal entries.
- Transcripts of solutions to problems

I have had a chance to ask questions and to obtain answers to my questions. I can contact the investigators at (614) 292 8060. If I have questions about my rights as a research participant, I can call the Office of Research Risks Protection at (614) 688-4792.

I have read this form or I have had it read to me. I sign it freely and voluntarily. A copy has been given to me.

Print the name of the participant:

______________________________________________________

Date: ___________________________  Signed: ___________________________

______________________________________________________

(Participant)
Signed:

____________________________________

(Principal Investigator or his/her authorized representative)

Signed:

____________________________________

(Person authorized to consent for participant, if required)

Witness:

____________________________________

(When required)
APPENDIX D

STUDENT INTERVIEW PROTOCOL (INITIAL)
Rapport

Explain that I am doctoral student from The Ohio State University in the US. I wish to collect information from three grade 10 students from this school and that I am committed to keeping the information confidential and thus request the pick an alias to use for interview which I will video and audio record, with permission, so as to track of the discussion.

The interview

1. Tell me something about your home life and your school life.

2. Can you tell me which school subject you like the most and the one you like the least? Can you tell me why you feel that way in each case?

3. What can be done to make you feel good about subject?

4. How important in your life is mathematics?
APPENDIX E

LETTER OF REQUEST TO COLLECT DATA FROM SCHOOLS

AND

THE REPLY FROM THE SCHOOLS DISTRICT OFFICE
The Circuit/ District Manager
Dept of Education, NW Province
Rustenburg circuit / District
RUSTENBURG

Sir / Madam

Re: PERMISSION TO USE SCHOOLS FOR RESEARCH PURPOSES

I hereby request permission to use three schools (middle and/or High) from historically disadvantaged communities in your circuit for research purposes. This study intends to investigate the effects of and role-played by culturally relevant problem solving in learning grade 10 school mathematics. This research will be done by Jacob Kgabudi Molefe as part of his program as a doctoral candidate at the Ohio State University, USA.

Two learners from each school will be selected to form a focus group. These will then be requested to write journals, work out mathematics problems, be interviewed and video taped.

One of the purposes of this study is to understand and document participants' mathematical thoughts gleaned as they are culturally relevant problems. Care will be taken to address issues of the ethics and confidentiality by using the guidelines as contained in Human subjects guidelines of the Ohio State University USA.

Should the permission be granted I wish to begin the investigation on the 15th July 2003 until 19th September 2003.

Yours Sincerely

Jacob Kgabudi Molefe
Email: molefe.j@ostn.edu or kgabudi2molefe@yahoo.com
Telephone: 072 152 8538
Memorandum

To: To Whom It May Concern

From: Interim Area Project Manager

Date: 21/07/2003

Re: RESEARCH

PERMISSION TO DO RESEARCH AT YOUR INSTITUTION.

Permission is hereby granted to Jacob Kgabudi Molefe to conduct a RESEARCH with reference to Mathematics Education in your institution.

Parental consent is a prerequisite for this project and it is expected of the Site Manager or his/her delegate to assist in this regard.

Please co-operate with the researcher as we stand to benefit a lot out of this inquiry.

Sincerely,

(Handwritten Signature)

Interim Area Project Manager

21 JUL 2003