CHAPTER 1

ORIENTATION AND BACKGROUND

1.1 Introduction

What happens when teachers are required to implement a mandatory mathematics curriculum whose purposes are distinctly different from that of mathematics curricula of the past? More specifically: How do teachers beliefs and understandings of the curriculum affect the implementation pathway of a mathematics reform intended "for all"?

In 2006 all South African children were for the first time required to do mathematical literacy or mathematics in the senior high school grades. This was as a result of the new national curriculum[1], which represents a policy statement for learning and teaching in schools, located in the Further Education and Training (FET)[2] band. The new curriculum is significant in that Mathematical Literacy as a subject is mandatory for all Grade 10 to 12 learners not choosing the subject of Mathematics.

The introduction of this compulsory subject has brought renewed national attention to mathematics reform in South Africa, challenging the mathematics education community to look deeply into the purposes, principles and scope of this reform in order to ensure its successful implementation. The apartheid dispensation, which was responsible for inequitable funding, resources and access to mathematics, left as its legacy a nation with unacceptably low levels of mathematical literacy[3] and mathematics achievement. This curriculum has been developed by the democratic government in an attempt to redress these longstanding inequities, and in so doing has joined a renewed international chorus of voices calling for the accessibility of quality mathematics curricula for all (Leading

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[1] *The National Curriculum Statement Grades (NCS) 10-12 (General)* (DoE, 2003a,b)
[2] This band includes Grade 10 through to Grade 12.
[3] See Howie 2002, PISA 2003, SACMEQ II 2000, TIMSS & TIMMS-R 2004.

Maths Success, 2004; NCTM, 2000), and the recognition that every adult and therefore every child can and should do some form of mathematics.

The stated goal of the mathematical literacy curriculum is to enable all learners to become numerate. That is, to give learners the ability to make sense of the world of numbers that surrounds them. It includes enabling them to think numerically with confidence in "order to interpret and critically analyze everyday situations and to solve problems" (DoE, 2003b: 9). This goal is a product of the fundamental principles that underpin this curriculum which are drawn from the new Constitution with an emphasis on human rights, equity and democratic participation. Considering the crisis in mathematics education in South Africa, such a stated goal seeks to fundamentally recast access to mathematics education. Not only will the new curriculum be a challenge to implement due to the lack of resources, both human and material, in the majority of classrooms in the country, it will challenge the beliefs and understandings of teachers who for a long time have considered the teaching of mathematics to be the competence of a few.

The unstated goal behind this policy is more political in nature. In order to serve democratic interests, the new mathematics curriculum has been positioned as "a people's subject, a subject that relates to the context in which people find themselves, a subject that enables people to see and question the unjust" (Bopape & Volmink, 1998:78) and in so doing realizing the needs and wants of "the large numbers of people who voted democracy in the 1994 election" (*ibid*.). Mathematical Literacy as the compulsory alternative to Mathematics would then be the subject offered and taken by the children of those 'large numbers' that voted in democracy.

The challenge for research is to examine how this curriculum will be implemented in the classroom. How will teachers' beliefs and understandings and their enaction thereof affect the implementation of this new curriculum? Early indications of teacher understandings suggest that Mathematical Literacy is been viewed as 'watered down' mathematics or as equivalent to the former Standard Grade Mathematics curriculum[4](Webb & Webb, 2004) Furthermore even those who claim a deeper understanding of the nature of mathematical literacy often do not reflect this in their practice (*ibid*.). Also, a range of problems has already been identified in the implementation process of the umbrella curriculum-Curriculum 2005[5] (C2005) in the earlier grades (Pabale & Dekkers, 2003). The ways in which teacher understandings direct and modify the implementation of the Mathematical Literacy curriculum will have ramifications for the reform of mathematics in South Africa.

The initial research questions that then arise include:

1. What do teachers understand to be the purpose of this reform?

2. How do teachers make-sense of a curriculum that is meant for all?

3. Why would teachers implement this curriculum in the first place?

Add to this core of questions the expected migration of learners from traditional Mathematics to Mathematical Literacy, and the shortage of appropriately qualified teachers in the schooling system, and it is evident that a monumental change in the landscape of secondary school mathematics in South Africa is envisaged. This opportunity for all learners to become mathematically literate requires understanding of how teachers understand and enact this curriculum within the unequal and demanding contexts of schools after apartheid.

1.2 Rationale

> "... If we add to this scenario the fact that Mathematical Literacy is a new subject that has neither been taught before nor completely understood, you will get a sense of how carefully we need to tread" (Minister of Education, 2005).

[4] Subjects in South Africa before the NCS were differentiated into Higher, Standard and Lower grades, based on decreasing levels of difficulty.
[5] C2005 is separated into two bands, Grades R-9 or the General Education and Training Band (GET) and the Further Education and Training Band (FET) for Grades 10-12.

It is often argued that there is a dearth of research on curriculum policy and its implementation in developing countries (Fuller & Snyder, 1991; Verspoor, 1989). However, over the past decade there has been a steady trickle of research related to the link between curriculum policy, practice and achievement outcomes in developing countries, both in general and in the field of mathematics (Amit & Fried, 2002; Bishop & Volmink, 2002; Kyriacou *et al.*, 2002; Mwakapenda, 2002; O' Sullivan, 2002; Rogan, 2003a; SAARMSTE, 2004). What the literature shows is that the implementation problem is often explained in relation to resources, lack of teachers and teacher qualifications, teacher beliefs, emotions and understandings, and teacher knowledge (Coleman *et al.*, 1966; Fuller & Snyder, 1991; Hargreaves, 1998a; Hill *et al.*, *2004*; Lockhead & Verspoor, 1991).

The research however reveals contested views on which variables in fact contribute to better learning outcomes (see Darling-Hammond *et al*, 2001;Hanushek, 1996;Howie, 2005). What does emerge nonetheless is that despite the complexity of the whole (curriculum implementation) it is still the sum of its parts (resources, beliefs, understanding, qualifications, pedagogy etc.). Talbert & Mc Laughlin (1993:188) describes a view of teaching as "permeated by multiple layers of context, each of which has the capacity to significantly shape educational practice". In turn, Spillane (1999) concurs with the view of complexity-ensconcing teacher’s reform practices and proposes a 'six P's' model to account for these-personal, public, private, policy, professional and pupil. If on the surface it appears that these parts do not add up, it may be that the importance of one such part has been underscored or is missing altogether.

It is one such gap, that of teachers understanding of mathematical literacy curricula and curriculum policy implementation in developing countries, that constitutes the primary motivation for conducting this study. True, research on teachers understanding of curricula and their effects on implementation exist (see Rogan, 2003b; Sanders & Kasalu, 2004); however, this is not the case for mathematical literacy in developing countries[6].

[6] For the gap between developed and developing countries with respect to learning and achievement see Bloom (1976) and Schiefelbein & Schiefelbein (2004).

As Adler (2004:177) explains," a critical element that has emerged (here) is growing acknowledgements that there is specificity in the mathematical work that teachers do". Sherin *et al* (2004) is of the same mind when they write about the unique characteristics of mathematics as a discipline that stands in stark contrast to social studies. Shulman & Sherin (2004:136) also state, "if reform policy must be 'learning policy' (Cohen & Hill, 2001), then it must also be domain specific". Given, therefore, the paucity of empirical literature on teacher understandings, the introduction of mathematical literacy in 2006 presented an opportunity to explore how such understandings influence the implementation of a compulsory curriculum.

From the perspective of the policymaker, as the capacity to implement a curriculum necessitates a common level of understanding of the reform, not only must every endeavor be made to recognize and explore such understanding of curriculum, but to institutionalize these understandings in the context of the classroom. The exploration of such understanding can then contribute towards the knowledge base on the implementation of mathematical literacy in developing countries, which to date is mostly underpinned by international research from first-world countries (Hargreaves *et al*, 1998b; Matthews, 2005; Mc Laughlin, 1998). Thus, in essence, this research will explore how teachers understand the Mathematical Literacy curriculum, and with what consequences for curriculum implementation. The significance of looking at the teacher as unit of analysis is because, as Hill and Cohen (2000:329) state, "teachers figure as a key connection between policy and practice... and what the policy implies for instruction are both a crucial factor on their practice and at least an indirect influence on student achievement".

Teachers do what they do for complex reasons. Research on teacher thinking and understanding indicates that teachers' personal theories and knowledge are a key basis for classroom practice (Peterson, 1998; Peterson & Clark, 1978; Shavelson, 1976, Shavelson & Berliner, 1988; Yinger, 1979); but the nature of this relationship related to compulsory mathematical literacy curriculum understanding and implementation is poorly understood (Ross et al, 1992). With rare exception (Askew, 1997; Keiser & Lambkin, 1996; Pennell et al, 1996; Pennell & Firestone, 1996), little research on teachers' understanding and interaction with innovative and compulsory mathematical literacy curricula exist. This lack of empirical research further motivated this study.

I will juxtapose curriculum intentions with curriculum enaction. This unfolding of the 'curriculum-in-practice' at the inception of the reform will render a broader understanding of the relations between mathematical literacy curricula and practice in developing countries. In doing this, I provide empirical accounts of how these understandings of purpose; possibilities and problems affect reforms intended for all. The guiding assumption of this research is that to implement a new curriculum of mathematical literacy "for all" requires that teachers have a deep and nuanced understanding not only of content but also of purposes.

A further motivation for this study is more personal. As an educator in senior secondary mathematics for sixteen years and as a Senior Certificate Examination marking moderator, I have repeatedly encountered low levels of proficiency in mathematics amongst teachers and learners alike. I am drawn, therefore to understand why the levels of mathematical literacy are low in South Africa. Contributing factors may include differing levels of teacher understanding of well founded curricula which impact on their instructional practice. Understanding these constraints in reforms targeting teachers is of significance, for as Rousseau & Powell (2005:30) point out, "these efforts inform the design of a system that can better support ALL teachers as they seek to understand change". By providing rich qualitative data this research will then seek to 'inform the design of the system' which is bound to be reviewed in coming years.

When one considers that "virtually every major public issue-from health care to social security, from international economics to welfare reform-depends on data, projections, inferences, and the kind of systemic thinking that is at the heart of quantitative literacy" (Steen, 2005:35) it becomes incontrovertible that mathematical literacy is critical. Given the reality of South Africa joining the global economy and in so doing seeking to empower and numerate its people it becomes a matter of urgency to take a critical look at how this country embraces the mathematical literacy curriculum and to finds ways to develop and promote it. This is the duty of all mathematical stakeholders, including myself.

With this rationale as background, three more defined research questions evolve:

1) What do teachers understand to be the purposes, problems and possibilities contained in a mathematical literacy curriculum?

2) How do teachers proceed to implement a mathematical literacy curriculum in their classrooms?

3) Why do teachers implement this curriculum in the ways they do? In other words, what explains the implementation pathways followed by a mathematical literacy curriculum in real classroom contexts?

The pursuit of the first research question begins with the accumulation of qualitative data with respect to teachers' understanding of curriculum principles, purposes and scope with respect to mathematical literacy.

The second question will probe the discrepancy that may or may not be found between the intentions of the curriculum and the actual enactions in practice. That is, even assuming that the reform was clearly understood among teachers, will their practice reflect such understanding?

The purpose of the last question is to explore why teachers implement the reform. That is, is it because it is official policy to offer it as a compulsory subject, or is it as a result of an understanding and belief of the opportunities it can provide?

My intent is to provide a rich qualitative description of how the Mathematical Literacy curriculum, in varying contexts of re-interpretation, plays out in the classrooms of South Africa. As Hargreaves (1994: x) states:

> Teachers don't merely deliver the curriculum. They develop, define it and reinterpret it too. It is what teachers think, what teachers believe, and what teachers do at the level of the classroom that ultimately shapes the kind of learning that young people get.

1.3 The meanings of mathematical literacy

The concept of mathematical literacy is the subject of widely contested definitions. As this will be a term used throughout this research study, I will briefly present some of this debate in order to clarify the meaning as used in my study.

To begin with, mathematical literacy is often used synonymously with numeracy and quantitative literacy and/or reasoning. The term numeracy itself was first used in the Crowther report in the United Kingdom in 1959, were it was mirrored to literacy (Department of Education, Training and Youth Affairs, 2000). In this report the implication for numeracy was twofold, "on the one hand (it implied) an understanding of the scientific approach to the study of phenomena and on the other hand...the need in the modern world to think quantitatively, to realize how far our problems are problems of degree even when they appear to be problems of kind" (Ministry of Education, 1959:270). In 1998 the United Kingdoms' National Numeracy Task Force (Department for Education and Employment, 1998:11) re-fashioned the definition as follows:

> ...an understanding of the number system, a repertoire of computational skills and an inclination and ability to solve number problems in a variety of contexts. Numeracy also demands practical understanding of the ways in which information is gathered by counting and measuring, and is presented in graphs, diagrams, charts and tables.

Over twenty years later the British Government, in their report on mathematics education, further associated numeracy with an 'at homeness' with numbers in the practical challenges of daily life, and also an 'individual awareness and comprehension of information numbers and data' (Cockroft, 1982).

This need to reframe the meaning of a concept is not unique, for as Dewey (1931:1932) noted, "often change outruns continuity"; accordingly, meanings and definitions must continue apace for, "this is the need of a society that are themselves in a process of constant change" (*ibid*.).

In Australia, the definition is more expansive:

> To be numerate is to use mathematics effectively to meet the general demands of life at home, in paid work, and for participation in community and civic life.
>
> In school education, numeracy is a fundamental component of learning, performance, discourse and critique across all areas of the curriculum. It involves the disposition to use, in context, a combination of:
>
> - underpinning mathematical concepts and skills from across the discipline (numerical, spatial, graphical, statistical and algebraic);
> - mathematical thinking and strategies;
> - general thinking skills; and grounded appreciation of context. (Australian Association of mathematics Teachers Inc., 1997:15)

A comparable interpretation is also articulated by the Organization for Economic Co-operation and Development (OECD) Program for International Student Assessment (PISA); however, PISA uses the term 'mathematical literacy':

> Mathematical literacy is an individual's capacity to identify and understand the role that mathematics plays in the world, to make well-founded judgments and to engage in mathematics, in ways that meet the needs of that individual's current and future life as a constructive, concerned and reflective citizen (OECD, Paris, 1999:41).

Closer to home, the Southern and Eastern Africa Consortium for Monitoring Educational Quality (SACMEQ) in the SACMEQ II Project defined mathematical literacy as "the capacity to understand and apply mathematical procedures and make related judgments as an individual and a member of a wider society" (SACMEQ II, 2000). In Botswana, numeracy is included in what it means to be literate: "literacy is the ability to read and write with understanding, in Setswana, English or both; and the ability to carry out simple computations in everyday life" (Republic of Botswana-Ministry of Education, 2005).

Finally, in South Africa Mathematical Literacy in the National Curriculum Statement (DoE, 2003:9) is defined as follows:

> Mathematical Literacy provides learners with an awareness and understanding of the role that mathematics plays in the modern world. Mathematical Literacy is a subject driven by life-related applications of mathematics. It enables learners to develop the ability and confidence to think numerically and spatially in order to interpret and critically analyze everyday situations and to solve problems.

From these descriptions and definitions above, critical variations in meaning become evident. However, a common thread is that the concept embraces the capacity of an individual to competently manage the quantitative situations of everyday life.

In this study I will use the term mathematical literacy to capture the actual subject of Mathematical Literacy as described in the definition of NCS (DoE, 2003). The implications that the term will carry are that as provided by the South African definition, or more simply put: the ability to critically and competently engage with 'numbers' around oneself.

1.4 The case for mathematical literacy

> “An innumerate citizen today is as vulnerable as the illiterate peasant of Gutenberg's time" (Steen, 1997).

The growing cross-national preoccupation with mathematical literacy skills is driven by studies and reports that show that the lack of numerical competencies negatively impresses upon employment and human development (NFER, 1998; OECD, 1995;

Parsons & Brynner, 1997). Globalization, technology and the information age have made it a necessity for all citizens of the 21st century to be numerate as this provides them with access to full citizenship (D' Ambrosia, 2003).

Goal 6 of the Dakar Framework for Action for the attainment of Education for All by 2015, further recognizes the need for the world's commitment in "improving all aspects of the quality of education and excellence for all so that recognized and measurable learning outcomes are achieved by all, especially in literacy, numeracy and life skills" (Unesco, 2000, emphasis added). This goal is been fervently pursued in most first-world countries and emerging economies (United Kingdom, United States, Singapore, Malaysia, Cyprus, Canada The Netherlands etc.) with progressive thinking mathematical literacy strategies and curricula that are adapted and reviewed constantly. In developing countries these ambitions are also beginning to emerge, as in Botswana and South Africa. But as Chimombo *et al.* (1994) advises such ambitions requires long-term strategies and not short-term solutions if capacity building is to be achieved and maintained. It is imperative therefore that the agenda for such reforms should include comprehensive instructional implementation strategies to optimize the use of limited resources.

As indicated earlier, in South Africa the agenda for mathematics reform includes the introduction of Mathematical Literacy as a mandatory alternative subject to Mathematics for Grade 10-12 as from January 2006.An account of the why and the what, has been mandated, follows.

1.4.1 The mathematical literacy crisis-a legacy of apartheid

> “South Africa was again rated last in the Third International Mathematics and Science Study". (HSRC, 1998)

Reports such as the above have come to typify the findings of the 'steady drumbeat' of studies evaluating mathematical competency in South African schools (see PISA, 2003; TIMSS & TIMSS-R, 2004; SACMEQ II, 2000). Common findings in all these studies are that the country's students do not measure up globally in mathematics and mathematical literacy competencies. For example secondary analyses of the South African data generated by the TIMSS study reflect not only a poor picture of performance in reasoning and social utility in mathematics, but also that no obvious improvement has been observed in mathematical proficiency after four years of additional mathematics instruction (Howie, 2002). Also of national concern is that the average age of Grade 12 learners is higher than that of students from other countries and that these students attain poorer results despite the finding that on average they spend more time on mathematics homework than students in other countries (HSRC, 1998). The implications of such results are that school leavers enter the workplace and/or attempt to enter tertiary education without the knowledge and skills required by both.

Recently, national reports of improvement in these results, particularly in the Grade 12 Senior Certificate, are starting to surface. However Kahn (2005) cautions against taking such reports at face value, as often they are politically motivated. The reality is that end-of -school results are still unsatisfactory and reflect deep race inequities.

This is the legacy of nearly five decades of apartheid education, which prohibited black students in South Africa from obtaining quality education in especially the key disciplines of mathematics, science and technology. Even those that were privileged in receiving 'quality' education, found themselves on the receiving end of curricula that encouraged rote learning and racism. And so, post-apartheid South Africa inherited a legacy of a nation schooled to be innumerate.

It is these legacies that *The National Curriculum Statement-Mathematical Literacy* seeks to redress.

1.5 The goals of mathematics education and Mathematical Literacy (ML) in South Africa

Mathematical Literacy was entrenched into law as a mandatory subject on the 2nd of November 1998 (Government Gazette, 1998). Also of importance is that whilst new policies and curricula were being put into place, strategies and programs addressing the need for numeracy were also been developed as a commitment by government in improving the status quo. Included in these strategies was The National Strategy for Mathematics, Science and Technology Education, which housed the flagship Dinaledi project (DoE, 2001) and more recently the Thuthuka project (SAICA, 2003). Recent findings have shown both these programs to be making valuable contributions to uplifting numeracy competencies (SAICA, 2007).

All these developments played and continue to play a key role in the establishment of the teaching and learning of mathematics. The NCS Grades 10-12 (General) Mathematical Literacy was introduced in 2003 (DoE, 2003) and is the curriculum response for bringing the government agenda in mathematical literacy and its subsequent policy into the classroom.

1.5.1 A snapshot of the Mathematical Literacy Curriculum

The Mathematical Literacy curriculum supports the application of the nine NCS principles, as follows (DoE, 2003:8, 9):

1) Social Transformation
The prevalence of low levels of numeracy skills among the adult population due to limited and poor education in the past requires intervention to ensure that the trend is broken. Mathematical Literacy seeks to transform this situation.

2) Outcomes-Based Education
The focus of Mathematical Literacy is on the development of skills, knowledge, attitudes and values related to the use of mathematics in authentic everyday life situations.

3) High levels of knowledge and skills for all
The subject aims to produce mathematically literate citizens who will apply their skills to improve their lives and participate effectively in a democratic society and contribute to developing the economy of the country.

4) Integration and applied competence
Integrated understanding of mathematical concepts is provided for in the holistic view of the learning outcomes.

5) Progression
Assessment standards for each learning outcome imply an increasingly more complex, deeper and broader understanding of knowledge, skills, attitudes and values to be achieved in each grade in the FET band. These go hand in hand with increasingly complex situations in which mathematical thinking must be applied.

6) Articulation and portability
The Learning Outcomes and Assessment Standards for Mathematical Literacy are so designed that they ensure portability between the formal school sector and the colleges or the workplace related learning programs registered on the NQF.

7) Human rights, inclusivity, environmental and socio-economic justice
The subject is designed with the aim of providing access to mathematics for all, through contexts that interest learners and relate to their aspirations.

8) Valuing indigenous knowledge systems
FET learners from the many cultures that make up the school going population of South Africa must be made aware of the mathematics that is embedded in these cultures.

9) Credibility, quality, efficiency and relevance
The teaching of Mathematical Literacy and the choice and the design of support materials will determine the relevance. Parents, learners and institutions for Higher Education will judge the credibility of the subject based on evidence from learners exiting FET.

The role of Mathematical Literacy in these key principles that underpin the NCS, reflect the deep and important role that this subject has to play in the new educational dispensation. This role is further secured and enhanced in the purpose statement of this FET curriculum in that Mathematical Literacy not only contributes to the attainment of critical and developmental outcomes but also forwards capacity building by ensuring that citizens of the future are:

- highly numerate consumers of mathematics;
- self-managing persons;

- contributing workers; and
- participating citizens in a developing democracy (DoE, 2003:10).

These wide-ranging purposes focus on empowering learners with mathematical literacy skills that will enable them to effectively deal with 'number situations' that arise in their developing democracy and the world around them. This is at variance with past mathematics curricula whose main intentions were to differentiate learners in levels of mathematical ability through the teaching of mostly abstract concepts with little or no relevance to context. The pursuit of abstract knowledge and rote regurgitation, although important in several academic tertiary fields did little to develop the knowledge and skills required by all critically numerate consumers.

Furthermore the scope of the curriculum articulates the broadness of what Mathematical Literacy encompasses (DoE, 2003:11):

- use numbers with understanding to solve real-life problems in different contexts including the social, personal and financial;
- use mathematically-acquired skills to perform with understanding financially-related calculations involving personal, provincial and national budgets;
- model relevant situations using suitable functions and graphical representation to solve related problems;
- describe, represent and analyze shape and space in two dimensions and three dimensions using geometrical skills;
- engage critically with the handling of data (statistics and chance) especially in the manner in which these are encountered in the media and presenting arguments;
- use computational tools competently (a scientific calculator is taken as the minimum).

These are all essential conditions for mathematical proficiency. To be achieved, the curriculum recommends, for one, that teachers become 'interpreters of curriculum'. This is essential for as Fullan (2005:9) cautions, "it would be a fundamental misunderstanding of systems theory to assume that the system should change first. Each of us is the system; there is no chicken and egg".

1.6 The significance of this study

The literature on educational change in discipline specific domains is mostly limited to reform efforts in mathematics. For mathematical literacy, scholarly writings include the broadening of the teaching of mathematics and other subjects to contain the competencies required for becoming mathematically literate. However, such accounts do not take into consideration mathematical literacy as a subject domain in itself, particularly in new and emerging democracies.

This study contends that mathematics reform efforts need to be opened up to include the subject of mathematical literacy in order to understand the challenges that teachers implementing this subject are faced with. Furthermore it provides for a theoretical analysis that is different and new for reform efforts in teaching for mathematical literacy.

In advancing a new theoretical perspective on mathematical literacy reforms, I endeavor to augment scholarly understanding and knowledge on the 'curriculum-practice' impasse in educational change settings. I also raise questions related to teachers' sense of their identities as mathematical literacy educators with implications for theory, practice and mandatory curriculum research.

1.7 The limitations of this study

This explorative research entailed two in-depth case studies and an informal snapshot survey of over fifty educators. As the in-depth case studies only involved two respondents, the findings and results may not be generalisable in the usual statistical sense of the word. However, insights gleaned into how the Mathematical Literacy curriculum was unfolding in its first year of implementation in two South African classrooms may offer useful insights and hold valuable lessons for similar classroom contexts.

In addition, the snapshot survey was conducted informally and as such can only be used to provide a preliminary and tentative picture as to how mathematical literacy educators were experiencing the new curriculum.

Another limitation pertains to the conceptual framework. It is too soon to expect a deep change in educators in the first years of implementing a curriculum as the acquirement of understanding and knowledge is a dynamic and unfolding process. However, the deep change illuminates what needs to be done to engender a long term and sustainable sense of education reforms.

The research design was an explorative one and used propositions to define and focus its purpose. As such findings relating to domains outside these propositions may not have come to light.

1.8 Organisation of the dissertation

The complexity of 'connecting the dots' between curriculum intentions and curriculum practice, in mathematics and mathematical literacy reform, will be the subject of the next section.

A synopsis on how the rest of the chapters of this thesis are organized is given in the overview below:

In **Chapter 1** the problem statement, aims and objectives of the study and the rationale have been included. In addition, the background of the Mathematical Literacy curriculum has been discussed as well as an overview on the varying definition of Mathematical Literacy and the general crisis in mathematics education in South Africa.

Chapter 2 gives a report on the literature pertaining to the implementation of mathematics reform curricula, which includes theories and evidence as to why implementation of such reform curricula is a thorny and complex undertaking. The critical synthesis of the literature also identifies the gap that this study wishes to address, namely that of providing empirical evidence for Mathematical Literacy implementation strategies in developing countries, which is found to be crudely lacking. This required specificity is accounted for in the literature synopsis.

In **Chapter 3** I provide a conceptual framework, which takes in the propositions that this study seeks to test. The framework forwarded is that of Deep Change, which describes and explains the need of such change in teachers understanding when pursuing curricula that are distinctly different to those of the past.

Chapter 4 contains the research design and methodology of this study. It also explains the road I took into finding willing respondents for the case study. Furthermore, reasons are given as to why and how this design changed from the time of the research proposal to the time that the actual research was carried out.

In **Chapter 5** I included a snapshot survey of 54 educators that were informally interviewed during the course of this study. Data has also been captured in this chapter of responses from an Internet forum, which was set up to discuss issues pertaining to the new FET Mathematics curriculum. Several subscribers also posed and answered several questions and concerns with regards to Mathematical Literacy on this Internet forum that spoke to the research questions, and as such were included as embedded units of analysis in this explorative study.

Chapter 6 and 7 provides the two detailed case studies (two teachers) presented in narrative form. Included in these reports are biographical background accounts, contextual information, and the themes that emerged in response to the research questions and the propositions of the study.

In **Chapter 8** I conclude with an in-depth analysis of the data by embedding the empirical evidence that was elicited from the study in the Deep Change conceptual framework and extant literature on mathematics reform and implementation. This chapter also further provides recommendations for future research, the significance of this study and also the limitations of this study.

The next chapter provides a critical review on the literature on the implementation of mathematics reforms in the classroom.

CHAPTER 2

The implementation of mathematics reforms in the classroom: A review of the literature

> "There is one thing that distinguishes teaching from all other professions, except perhaps the Church-no change in the curriculum has any meaning unless the teacher understands and accepts it".
> Beeby (1969:154)

2.1 Introduction

The purpose of this chapter is to critically describe the role of the teacher in addressing the implementation predicament of mathematics reforms. In the context of educational change, I review the extensive literature on mathematics and the limited literature on mathematical literacy and present theories and evidence as to why instructional practice is so hard to change. I conclude by arguing that notwithstanding its explicatory significance, there has been no key focus in emerging democracies on how teachers' identities as mathematics educators are impacted upon by new curricula. What is more, there is a critical gap in the literature on teachers' understanding of mathematical literacy reforms.

Momentous designs for mathematics reform are a familiar feature in the literature, but so are reports of failed reforms (Burgher, 2000; Cockroft Report, 1982; Cohen, 1990; Humenberger, 2000; Plowden Report, 1967). This failure is not unique to mathematics education but encompasses a broad range of disciplines. As Fullan (1982:ix) explains," how to get new educational programs to work in practice has increasingly frustrated and mystified those involved in education over the past two decades".

A review of the literature shows a chorus of voices been raised highlighting this unresolved tension between curriculum policy, implementation, and practice, some dating back close to fifty years ago (Havelock & Huberman, 1977;Mc Laughlin, 1998;McCulloch, 1998). This chorus and others include the 'problem' of implementation in both developed and developing countries (Angula & Grant-Lewis, 1997; Frykholm, 1996; Fullan, 1991; Jansen & Christie, 1999; Verspoor, 1989). In mathematics reform, some themes are heard again and again; "And even though reform energy is mostly devoted to mathematics curricula and not numeracy" (Steen, 2001:107) there has been a drive over the past two decades to change such curricula to include numeracy, and/or mathematical literacy, and/or quantitative literacy.

This new wave which emphasizes changing traditional mathematics curricula also echoes several of these tensions as found in countries such as, England, Australia, Canada, the United States, and most recently, South Africa. In these countries, governments have been explicitly pressing an agenda that urges mathematics at school level to be made more socially useful.

The National Council of Teachers of Mathematics in *Principles and standards for school mathematic*s (NCTM, 2000) in the U.S.A. calls for mathematical literacy as a central tenet to mathematics education. In Ontario, Canada (Ontario Education, 2004), publications addressing mathematical issues for 'children at risk' are also looking into the competencies and strategies required for the teaching of mathematical literacy. To better understand quantitative literacy and the educational challenge it presents in the United States, the National Council on Education and the Disciplines (NCED) initiated a national examination of concerns contiguous to Quantitative Literacy education, principally in the framework of school and college studies.

To begin with, NCED published *Mathematics and Democracy: the Case for Quantitative Literacy*, which presented a case statement on the meaning of numeracy as a starting point to the debate (Steen, 2001). The twelve respondents to this debate presented discourse on the central relationships amongst "mathematics, numeracy, and democracy in the changing world of the twenty-first century"(Orrill in Steen, 2001: xviii). A point of coherence in these dialogues was that attempts to deepen and strengthen mathematics curricula "do not necessarily lead to increased competency with quantitative data and numbers" *(ibid.)*.

To further develop this conversation NCED funded a national forum, *Quantitative Literacy: Why Numeracy Matters for Schools and Colleges*, held at the National Academy in Washington, D.C. on December 1-2, 2001.This forum's key results concentrated on the need for quantitative literacy both as a personal and societal concern (Madison & Steen, 2003). It looked at matters of curriculum design in terms of inclusion and grades; it questioned policy challenges such as: articulation, assessment, relation to mathematics, core curriculum, and it also called for stronger mathematical education of teachers, policy perspectives and also for stronger curricula, and institutional policies in secondary and tertiary education (*ibid*.).

In South Africa this tenet is even more explicit, in that Mathematical Literacy is a compulsory alternative to Mathematics. Furthermore, it is a new subject offering and not a 're-curriculation' of the cognately close and already established school subject of Mathematics.

In addition, recent literature on the need of this progressive reform includes amongst others writings from Mogens Niss of Denmark, Michel Merle of France, Geoffrey Howson of Britain and Ubiratan D'Ambrosio of Brazil. This focus on mathematical literacy as a reform has been spurned by the numerous international studies[7] that are placing an emphasis on mathematical literacy as an area of concern distinct from the traditional mathematics curricula. The distinction or relationship between mathematical literacy and mathematics knowledge and skills depends on how mathematics is defined. A broad partly sociological and partly epistemological perspective by Niss (1994) perceives mathematics as a field possessing a five folds nature: as a pure, fundamental science; as an applied science; as a system of tools for societal and technological practice; and as a field of aesthetics. In this non-restrictive definition mathematical literacy "is more or less the same as the mastery of mathematics" (Niss in Steen, 2001:216). There is also literature and definitions that pronounce that quantitative literacy and mathematics are really "two quite different things" (Cohen in Steen, 2001:23). However, as the

[7]See: International Adult Literacy Survey (IALS) (OECD 1995);OECD through its Program for International Student Assessment (PISA) whose major focus in 2003 was mathematical literacy (NCES 2002); Adult Literacy and Life skills Survey that took place in 2002 and 2003 &TIMSS-R (1999).

curriculum is normally one, a literature review can not but includes the broader discipline of mathematics in a review of mathematical literacy.

There is also a widespread agreement in providing explanations for reform implementation to look in the direction of the teacher, for teachers are the 'final brokers' when it comes to implementing policy and enacting curricula (Fullan & Hargreaves, 1992; Mc Laughlin, 1987, 1990; Sarason, 1995; Wideen, 1992).

2.2 Implementing Agents

Fullan (1991) concurs with the importance of the teacher, for he explains that successful reform necessitates teachers that are ready to change, and teachers that have the required resources to implement and sustain change. Additionally he describes reform to be local and restricted by the 'ownership' that teachers ascribe to it in the classroom. Such accounts are important for they elucidate the non-linear relationship between curriculum and classroom practice that is often ignored by policy planners. Hopkins *et al*. (1994:17) note:

> It is almost always the case that centrally imposed (or top-down) change implicitly assumes that the implementation is an event rather than a process; that a change proceeds on autopilot once the policy has been enunciated or passed. This perspective ignores the critical distinction between the object of change...and the process of changing-that is how schools and agencies put the reforms into practice.

Analyses of the tension in the implementation themes that emerge in mathematics reform include problems arising in connecting, the knowledge of mathematics, the knowledge of the didactics of mathematics and pedagogical knowledge and, the mathematics education of teachers to the reform (Ball, 1988, 1990; Hill et al, 2004; Manouchehri, 1998; Sherin, 2002; Shulman & Grossman, 1988; Thompson et al, 1994). These findings substantiate the impact of the role of teachers' content and pedagogical content knowledge in creating and sustaining instruction promoting student discourse and in teaching for conceptual understanding, which are important elements for the successful implementation of new waves of quality mathematics curricula.

2.2.1 Professional Development and Knowledge

In mathematical literacy similar tensions resonate. Romberg (2001:8) states that the function of "professional development in helping teachers to develop their own classrooms to promote understanding and how the school supports (or impedes) the work of teachers in developing and sustaining these classrooms; and how non-school agents (such as parents), agencies (district), and their actions support (or impede) the development of these classrooms" is imperative in understanding the implementation of mathematical literacy reforms. Schoenfeld (2002:17) in an analysis of the Pittsburg Data on the NCTM *Standards* based reform is of a similar opinion when he asserts, "reform appears to work when it is implemented as part of a coherent system effort in which curriculum, assessment, and professional development are aligned". Consequently "not only do many more students do well, but the racial performance gap diminishes substantially" (*ibid*.). Such suitable professional development is not only required in secondary schools but also in primary schools that seek to implement numeracy strategies successfully (NNS, 1999). Such training necessitates more than developing and educating teachers on the needs of a reform; it also requires similar execution in the development of leadership, the absence of which has shown to significantly negatively impact on implementing reforms as intended by policy and curricula (*ibid*).

On the issue of content and pedagogical knowledge Steens' (2001:89) words "that a teacher's knowledge of content seldom guarantees that he or she can structure and communicate that knowledge in ways that enable a diversity of learners (particularly those that are compelled to attend classes) to understand and apply the knowledge that has been learned" become imperative in structuring the above mentioned staff development programs. Such comments even though contested in mathematics (see Adler, Slonimsky & Reed, 2002; Brodie, 2004;Monk, 1994; Rowan, Chiang & Miller, 1997) remain scarcely addressed in mathematical literacy. Mainly because, teacher subject knowledge of ML is largely taken as an extension of subject knowledge in mathematics.

The teaching of mathematical literacy is however a deviant progression from traditional mathematics curricula which brings into focuses the levels of subject knowledge both content and pedagogical that are required for its teaching. This intensifies the quandary on who is best suited to edify mathematical literacy and, as Steen (2001:46) observes, what "mathematics background might or might not be best suited for the teaching of quantitative literacy ". It is important however to note that here the implication is not that a weak subject knowledge is favored, not only as an intuitive appraisal but also as evidenced in the empirical findings of the Ofsted Publications (NNS, 1999), but that traditional, strong subject knowledge of teachers does not necessary translate to better student achievement or aligned curriculum implementation.

Further implementation tensions arise through the non-use of curricula and policies as intended. In an assessment of the *Standards* reform in the U.S.A., Briars and Resnik found that "weak implementers were either not using the curriculum at all, or using it so little that overall instruction in the classroom was hardly distinguishable from traditional mathematics instruction" (Briars & Resnik, 2000:6). This limited and surface use of curricula documents is further exaggerated during instructional assessment, as teachers do not align assessment practice with curriculum intentions. What is required is an employment of, "rich, varied, and effective assessment strategies for students at risk in mathematics" (Ontario Education, 2004:89). The absence of which is either due to a lack of curriculum understanding or an absence of supportive staff development strategies in the face of strong and variant theories of change (NNS, 1999; Schoenfeld, 2002).

Beyond these matters of content and pedagogy for teachers' enactment of curriculum in the classroom are questions concerning the 'black box' of teaching established within the classroom context (Mc Laughlin, 1998).

2.2.2 'Black Box'

It is a common goal of this new genre of addressing implementation issues, to promote the building of an awareness of the teachers beliefs, attitudes, values and understanding of the nature of the reform, and in doing so enable the engagement of the often difficult and complex work of how teachers make-sense of a new curriculum. There is also an additional area within this genre that remains narrowly researched in educational change, namely that of self-awareness or identity (Allen, 2005).

To begin with, beliefs and attitudes are a broad encompassing domain and deal with self and society.

2.2.2.1 Attitudes and Beliefs

Teacher attitudes and beliefs[8] to mathematics reforms have been studied and researched and found to contribute to the affectivity of mathematics education. This focus of interest has grown in the larger mathematics community in the last three decades since the founding of *Psychology of Mathematics Education* (PME) (Gutierrez, Boero, 2006).

A major research study in England, namely the *Effective Teachers of Numeracy Study* graded teacher efficacy according to student gains in tests (Askew, Brown, Rhodes, Johnson, & William, 1997). Teachers' underlying beliefs about teaching and mathematics were found to be compelling discriminating factors between highly effective teachers and those not charged likewise. Such findings are further substantiated in the *Standards* reform were a similar 'implementation pitfall' was identified, with the report on the critical issues surrounding this reform maintaining that (www.ncrel.org, 1995):

[8] "Defining beliefs is at best a game of player's choice. They travel in disguise and often under alias-attitudes, values, judgements, axioms, opinions ,ideology, perceptions, conceptions, conceptual systems, preconceptions, dispositions, implicit theories, explicit theories, personal theories, internal mental processes, action strategies, rules of practice, practical principles,perspectives,repertoires of understanding, and social strategy, to name but a few that can be found in the literature"Pajares (1992:2).Drawing on the work of Dilts (1999) ,I will define beliefs (in this dissertation) as judgments and evaluations that teachers make about themselves and their teaching.

> The area where reformers are most likely to run aground in bringing about change is the task of building consensus on the beliefs and values that should guide the teaching and learning of mathematics. An additional implementation pitfall is related to the pervasive practice of teaching the procedures of mathematics detached from the meaning and applications of these procedures.

Furthermore, Romberg (2001:8) claims that, "the complexity of instructional issues involving creating classrooms that promote mathematical literacy include amongst others the normative beliefs within a classroom about how one does mathematics". What complicates research on beliefs however is not only that they are wide-ranging based on personal and societal constructs but also that like attitudes they are difficult to measure and ascertain. Nonetheless, this difficulty does not preclude the importance of aiming to develop in students' positive attitudes towards mathematics that are derived from teacher's attitudes (Cockcroft, 1982). This line of inquiry into beliefs and attitudes in teachers teaching for mathematical literacy is underdeveloped, particularly in democratically developing countries, like South Africa, where mathematical literacy is being introduced as a unique discipline and not as an integral component of the core mathematics curriculum. Likewise, so is teacher understanding of mathematical literacy curricula.

2.2.2.2 Understanding

The importance of understanding as a condition that can contribute to educational innovation was recognized in the seventies by Gross *et al* (1971) .The lack thereof, or what he termed,' lack of clarity about the innovation' he found to be a factor to implementation failure. McLaughlin & Marsh (1978) established that the acquisition of such conceptual clarity couldn't be given to staff at the beginning of the reform, as it is something that evolves during the implementation phase. What it evolves to is dependent on frames such as 'career stage', 'career stories' and 'structural contexts' in which teachers are situated (Ball, 1997; Drake *et al,* 2001; Schifter, 1996). These frames have in recent studies been shown to contribute to reform success in both developed (Macnab, 2003) and developing countries (Pabale & Dekkers, 2003; Sanders & Kasalu, 2004).

The predispositions and understandings that teachers hold are both consciously and unconsciously replicated in their own classrooms during their teaching.Teachers identify with teaching in the way that they were taught (Borasi, 1990). Gellert (1999:22) reported, "In mathematics education research, it seems to be undisputed that the teacher's philosophy of mathematics has a significant influence on [their] mathematics classes". Studying pre service elementary teachers in Germany, he found that teachers' "learning experiences exert a tremendous influence on their design of mathematics classes" Gellert (1999:27). As teachers seek to embrace a new reform they "reach out with their old professional selves, including all the ideas and practices comprised therein" (Cohen, 1990:339). Instead of changing conventional practices the common response for reform has been the 'nominal ' adoption of the reform ideas (Romberg, 2001:8)

Spillane (1999:159) has coined the term 'zone of enactment' to refer to "the space in which [teachers] make sense of, and operationalize for their own practice, the ideas advanced by reformers...differences in teachers' enactment zones are key in understanding their efforts to change the core of mathematics instruction". He further states that, "the new ideas about practice that teachers encounter through the policy and professional sectors can only work in and through teachers existing knowledge and beliefs" (169). These findings are consistent with those of Romberg (1997), and Cohen & Ball (1990).

In mathematical literacy education, a widespread misconstruction amongst teachers is that pupils have to master mathematical algorithms and skills before using them for applications and problem solving. Teachers, who understand the curriculum and required pedagogy as such, focus first on these mathematical skills, assuming that problem solving and the understanding of 'mathematics in context' will follow. The result is the falling back on teaching the traditional curriculum due to the use of traditional methods (Schoenfeld, 2002). This understanding is difficult to change, as it is different to that common to mathematics practice. Hughes-Hallett (in Steen, 2001:94-96) explains this as follows:

> Mathematics is about general principles that can be applied in a range of contexts, quantitative literacy is about seeing every context through a quantitative lens...The reason that quantitative literacy is hard to learn and hard to teach is that it involves insight as well as algorithms. Some algorithms are of course necessary-it is difficult to do much analysis without knowing arithmetic, for example. But algorithms are not enough; insight is necessary as well. Insight connotes an understanding of quantitative relationships and the ability to identify those relationships in an unfamiliar context (*emphasis added*).

Romberg (2001:8) further concurs with the difficulty of this when he claims "non-routine patterns of instruction that allow students to become mathematically literate are not easy to create". A foremost raison d'être for this is that "teachers must be agents of change that they did not experience as students" (Anderson & Piazza, 1996) - teaching and learning with the use of context, to successfully problem solve.

Carraher, Carraher, & Schliemann (1985) observed Brazilian children solving numerical problems as they sold produce on the street. These same children failed to solve the same problems when they were presented out of context in traditional mathematical form. This observation, amongst others, supports the work developed over the last two decades on situated cognition (see Brown, 1989;Collins, Brown & Newman,1990 & Lave, 1988),which focuses on how situations and contexts co-construct knowledge . Closely linked to this work is the work by Etienne Wenger (1998) on *Communities of Practice*, which sees learning as an active co-participation process for students. These views of learning knowledge and skills in contexts that mirror the ways they will be used in real life require an understanding by teachers which may not be within their current pedagogical paradigms.

Cohen's (1990:327) case study of a single mathematics teacher's classroom led him to the following paradox:

> How much can practice improve if the chief agents of change are also the problem to be corrected? This paradox would be trivial if fundamental changes in learning and teaching were easy to make. If...it is implausible to expect students to understand math simply by being

> told, why is it any less implausible to expect teachers to learn a new math simply by being told?

This paradox is deep-seated for it underscores the inconsistency that often exists in reforms. Quality instructional curricula are designed and their implementation is considered to be linearly linked to the written word. However this is often not the case. In a study in four Colorado school districts implementing Standards-based mathematics reforms, Haug (1999) found a 'great variability' in the understandings teachers held about the reform. Similar findings of variance are also characteristic of mathematics reform research in the work conducted by Hill (2001) and Spillane & Zeuli (1999). Understanding, as Drake (2002:314) describes, is a complex issue, one which is "framed by who [teachers] are as learners and teachers of mathematics". It is essential then, in implementing the blueprint of a curriculum, to have a clear understanding of the intentions of the written word in order to change entrenched classroom habits. Allowing time for reflection and discussion become important during the implementation process, for it is here, in the classroom that the curriculum begins to develop. What it develops to is dependent on what is in each teacher and how the external forces available shape his or her extant knowledge.

Response to reforms is thus further situated in the cognitive domain, additionally compounding the complexity of implementation. Spillane *et al* (2002:393) explain this as follows:

> What a policy means for implementing agents is constituted in the interaction of their existing cognitive structures (including knowledge, beliefs, and attitudes), their situation, and the policy signals. How the implementation agents understand the policy's message(s) about local behavior is defined in the interaction of these three dimensions.

What surfaces, in such research is that a multitude of curriculum interpretations exist depending on prior held beliefs and understandings. This may result in comprehending such research as only significant from the individual lens, with no real validity in informing curriculum design. Such an interpretation would be to miss the broader picture. For even though such work may seem to propose an infinite number of interpretations what is of importance are the patterns that manifest themselves as the more dominant. The variables that create these patterns can then be identified and clustered and used to inform the design process. In this way 'demystifying' these more nuance variables.

Understanding has recently also included what has come to be known as the 'spirit of a reform'. The spirit resonates with grappling with the purpose and process of the reform, which is paramount in 'changing what counts'. This has been found to be habitually not understood or neglected in its entirety (Chisholm, 2000; Spillane, 2000). In the link between mathematics and statistical literacy Burrill (2003:52) found that in teacher training workshops "teachers understand the process but not the spirit involved in the materials and techniques". In the *Standards* reform the 'key question to be addressed' amongst the requisite actions to be taken to ensure a more congruent and successful implementation is the integration of the 'spirit of the *Standards* into classroom practice' (Cook, 1995). This facet is insightful and relevant, for new mathematics reforms. For in exploring teachers' understanding of the purpose and process of mathematical literacy the lens for implementation issues may be widened and as such, strengthened.

This may also be realized by exploring the impact that new mathematics reforms have on teachers' sense of their identities as mathematics educators.

2.2.2.3 Teacher Identity

The construction of teacher identities is a complex issue as it entails not only narratives teachers read in official documents such as policies and curricula about the roles that they should be fulfilling, but also narratives that they hear in the public domain (Soreide, 2007). In addition, "The structure and culture of schools have been some of the most powerful factors which have shaped teachers' identity" (Dinez-Pereira, 2003:3).

These narratives in mathematical literacy are seldom heard with regards to teacher identity and educational change, for mathematically literacy reforms are normally an integral part of the mathematics curriculum or are integrated in other disciplines. In South

Africa recent findings showed that "teachers' retrospective subject-centered professional identities were incongruent with prospective official identities constructed by MLMMS" (Mathematical literacy, Mathematics and Mathematical Sciences) "(Naidoo & Parker, 2005:67), a new mathematics curriculum introduced in the General Education and Training Band of Curriculum 2005.It was found that one major contributing factor was that staff development programs were not doing enough to "resocialise teachers into a new subject loyalty" (Bernstein,1971:56). Such evidence on the role that mathematical literacy curricula play in shaping teacher professional and status identities, or in re-shaping mathematics teachers' identities is scarcely researched. This may be more pronounced and therefore profound in developing countries were scarce qualified mathematics teachers enjoy considerable status within the school and the professional community.

Goodenough (1963:217) described seven conditions needed for identity change:

- one desires an identity change,
- one commits to that change,
- one understands what needs to be changed,
- one knows the roles and symbols of the new identity,
- one has the ability to perform new roles,
- one has the new identities recognized and accepted by others, and
- one conceives of oneself as having changed identity.

Allen (2005) cites that these conditions apply well to career changers. It may be found that in South Africa, the introduction of the mathematical literacy curriculum in secondary schools as a distinct and separate discipline to mathematics may require a similar understanding and learning of the impact this curriculum will have on mathematics teachers', professional identities. In conclusion, for teachers to be able to implement change I concur with Harley and Parker (1999) that posit that "teachers may well need first to shift their own identities, their understanding of who they are and how they relate to others"(p.197).

Collectively such analyses point to the complexity of the process between publication of proposals for curriculum change and their successful and long-term implementation. In a study of curriculum reform in mathematics, science and technology among 13 OECD countries Black & Atkin (1996:189) concluded that; "the perspectives on educational change which have emerged are complex and multiple". This complexity is further evident in a variety of frameworks that have been proposed in an effort to make available explanations for the implementation problems teachers' face in reform attempts.

Spillane's (1999) "six P's" model argues that the public, private, policy, professional and pupil subdivisions all operate to form the teachers' personal response to and implementation of reform in mathematics. Similarly Talbert & Mc Laughlin (1993:183) has expressed a "view of teaching as permeated by layers of context, each of which has the capacity to significantly shape educational practice". Tate (2004), on the other hand, argues that student 'opportunity -to-learn' is related to issues of 'time',' quality' and 'design'. Such explanations are not all encompassing and at times in contradiction with findings of other researchers. What is of importance though is that they provide an analytical lens through which implementation questions and inconsistencies can be addressed, particularly in developing countries (Mwakapenda, 2002; O'Sullivan, 2002;Rogan, 2003) were such implementation issues; particularly in mathematics equity reforms are addressed tangentially, if at all.

2.3 Teaching Context

What is often further ignored is also the context in which teachers work. Shulman & Sherin (2004:136) explain this as follows:

> ..., it is one thing to focus generally on how disciplinary understandings and teacher development interact. There are few examinations of how these factors interact in the context of a specific classroom-and pedagogy-centered school reform.

Numerous other authors have expressed a similar view for the significance of context in the implementation process. Their findings consistently show that successful implementation ultimately depends on the extent to which planners take 'classroots realities' into account (Fullan, 1991; Havelock & Huberman, 1977; Henevold & Craig, 1996; Lockheed & Verspoor, 1991). Mc Laughlin (1998) goes as far as saying that to ignore context is to ignore the very elements that make policy implementation a 'problem'. Such observations are vital for they provide empirical evidence for why quality instructional curricula often fail. What is more is that the examination of the context must be domain-specific. That is, mathematics reform for example, must be viewed in a mathematics context and classroom (Cohen & Hill, 2001; Lampert, 1990). This is because even though disciplines may have a lot of commonalities they also have a lot of variance. In the literature there is paucity in looking into mathematical literacy classrooms mainly because the discipline of mathematical literacy, as previously mentioned is rare as an entity of its own.

O'Sullivan (2002:222) has usefully divided the 'classroots realities' identified in the extensive general literature into 'objective' and 'subjective' implementation factors. Objective reality factors include; resources, professional capacity, support services, personal obligations, location of school, principal capacity, communication networks, learner capacity and political influence. The subjective reality list includes: relevance, desirability, motivation, attitudes/perspectives, feasibility, realism, complexity and, culture.

2.3.1 'Objective Realities'

The objective realities are particularly pronounced in developing countries, such as South Africa, and in minority groups where resources and capacity are often lacking. Properly qualified teachers in mathematics instruction in high-poverty classes are a common denominator the world over, which negatively impacts reform initiatives (Arnott *et al*, 1997; Darling- Hammond, 1997; Weiss, 1994). This is because poorly qualified teachers often provide low-level access to high-level content and reform-based mathematics pedagogy (Lubienski, 2002; Oakes, 1990). Time factors, quality factors and design as put forward by Tate (2004) are further additions to the objective realities list of mathematics instruction. And even though not all of these factors are agreed upon by other researchers[9] as either influencing student outcomes or contributing significantly to implementation failure, the examination of these with respect to 'opportunity-to-learn' is useful, for as Tate (2004) suggests it informs the design of a more effective and equitable system.

To ignore resource shortages and to seek only more rich qualitative descriptions of reform initiatives is not an option for the reality is that capacity is severely underdeveloped in many countries seeking to make ambitious changes. These conditions capture a significant proportion of the inequities that prevail in access to quality mathematics for all (Berry, 2005; NCTM 2000). What is however clear that is the objective reality taken alone does not exhaustively account for implementation failure.

2.3.2 'Subjective Realities'

The 'subjective realities' are on a more of a social level. That is the contexts within which teacher's work significantly impinge on their readiness and capability to assimilate pioneering methods and materials in their classrooms. Teachers' personal constructs and beliefs related to teaching, learning and students' needs are central to how they bring into play mandated mathematical reforms, but again the social foundations within which they work influence these personal theories. Battista (1994:462) pointed out that," teachers are key to the success of the current reform movement" and that "many teachers have beliefs about mathematics that are incompatible with those underlying the reform effort". Beliefs and attitudes are of particular importance in reforms that are intended for all, for as Nieto (1998:413) explains, "Until societies believe and act accordingly to the belief that all children are worthy and capable of learning, most students of non-dominant groups will be doomed to academic failure".

In some instances, as in South Africa, the groups doomed to academic failure were the dominant groups due to the belief held by educational stakeholders that indigenous South

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[9] E.g. For the effects of class size see Howie (2005), and for teacher qualifications see Fuller & Snyder (1990).

Africans were incapable of making decisions and shaping their own educational destiny. An example of such an extreme belief can be seen in a speech given in 1953 by the then minister of Native Affairs Dr. H.F.Verwoed:

> When I have control over native education I will reform it so that the natives will be taught from childhood to realize that equality with Europeans is not for them...people who believe in equality are not desirable teachers for natives...What is the use of teaching the Bantu mathematics when he cannot use it in practice? The idea is quite absurd (3585).

This viewpoint, premised upon the conception that blacks were incapable of mathematics and science education, ensured that few black students had access to quality mathematics and science instruction (Clegg, 1989). The inclusion of Mathematical Literacy as a compulsory alternative to mathematics in the new curriculum in the South African secondary school context as from 2006, will thus front an enormous test for teachers implementing the subject with regard to their extant beliefs of who can and should, and cannot and should not do mathematics, the urgency of which is similar to that called for by Robert Moses (2001:5):

> Today...the most urgent social issue affecting poor people and people of color is economic access. In today's world, economic access and full citizenship depend crucially on math and science literacy. I believe that the absence of math literacy in urban and rural communities throughout this country is an issue as urgent as the lack of Black voters in Mississippi was in 1961.

Notions of who should and should not do mathematics, are not unique to the South African context, and have been expressed in many reform documents[10] throughout the world. They have become 'encapsulated' in the 'hallmark slogan' advocated by the National Council of Teachers of mathematics, *mathematics for all* (Matthews, 2005). The emergence of this equity perspective in mathematics is however hindered by both objective and subjective realities.

[10] See-an Agenda for School mathematics (1980), Curriculum and Evaluation Standards for School Mathematics (NCTM, 1989), Standards for school mathematics (NCTM, 2000).

Meyer (1991) found that the limited success of such reform efforts was often linked to the design of such documents as they contained little detail to guide teachers in implementing them as intended. Moreover, negative expectations often resulted in negative mathematics outcomes (Cousins-Cooper, 2000; Kitchen, 2003; Strutchens, 2000; Weiss, 1994). The expectations that teachers possess for their pupils show a discrepancy along socio-economic standing and racial and cultural lines (Stiff, 2002). Qualities of the instructional milieu indicate social division and sanction and authenticate the deeds of specific groupings. As students navigate their path through this milieu, they grow to be highly conscious of their social limitations. In due course these students appear to believe and accept less of them and, in the end aspire too less (Bourdieu & Passeron, 1977). Accordingly, Mc Laughlin's (1990) maxim that 'belief can follow action' takes on an even richer significance, and as a consequence so does the assertion by Sutton & Krueger (2000) that "all students can learn mathematics, and they deserve the opportunity to do so" (1).

Supplementary cases in point showing the positive correlation between attitude, beliefs and successful implementation of curricula in mathematics and mathematical literacy are evident in the studies of, NCTM (2000), Askew (1997) and, Dosey *et al* (1998). They show that beliefs can and do effect actual student learning. That is pupils achieve better if their teacher believes that they can do better.

The question that arises then is succinctly framed by Matthews (2005:56), in discussing the constraints he has identified in the implementation of mathematics reforms, when he asks, "What is the resistance to equity ideology?" The answer to this may be linked to the high status of mathematics because of its socioeconomic utility, thus having the ability to serve political interests. Skovsmose and Valero (2001:44) write:

> We consider that mathematics education has the potential to contribute to the development of democratic forces in society. However, such potential is not linked intrinsically to the nature of mathematics and mathematics education. It emerges from a combination of factors such as whose engaged in mathematics practices, whose purposes they serve, which aims they pursue, when and where they occur, and why they are

> executed. As much as mathematics serves democratic interests, it has served antidemocratic ones.

In South Africa, in order to serve democratic interests, the new Mathematical Literacy curriculum, has been positioned as a subject intended for all. That is, a subject that the majority of pupils will have access to thereby entrenching their democratic right to mathematical literacy which is an essential component of any education system in the 21st century. However allowing for mathematical literacy on paper is not sufficient for its practical attainment. How the curriculum will be turned into reality in the classroom taking into consideration the multitude of contexts is only briefly addressed.

The implementation process of mathematics reform, that is the enactment in real time and context, is far more important for successful reform than are the politically laden curriculum dicta. Mathematics reform and educational change has thus consequences for social justice, equity, and democracy (Ball, 1994). For the reason that knowledge is closely associated to power, the two can be unified in the attainment of suppression (Foucault, 1983). What is a disturbing consequence of this overly political nature of the mathematics change process is that policy principles do not meet up to classroom realities (Kitchen, 2003; Rousseau & Powell, 2005) .It is one thing to argue and mandate that all pupils can and should do mathematics, but another to provide the necessary capacity equitably, in order to implement this successfully.

2.4 Linking the literature review to the conceptual framework: surface change

Surface changes are a common feature in classrooms where there is a lack of reform clarity. According to the Glenn Commission (2000), the actual learning experience in the United States is grounded in a basic teaching style that has remained essentially the same for two generations. The Commission described a typical mathematics class as one that begins with a review of previous material and homework, and then moves to a low-level problem illustration by the teacher. This is followed by supervised student work that imitates the teacher's procedures, and ends with a checking of solutions and the assignment of homework.

Research done by Taylor & Vinjevold (1999), amongst others confirms the findings of the Glenn Commission of the typical mathematics classroom. Together these matters of unchanged classrooms point to curriculum enactments that do not meet the intentions that the top-down prescriptions intend for implementing agents. What is required, is teaching practices that support, in all mathematics instruction, the ability and proclivity to make sense of the purpose of reform curricula and tackle implementation problems by serious exploration of teachers' own understanding and that of others. McLaughlin's (1990:13) states," you cannot mandate what matters".

Contemporary reform in mathematics urges deep changes in teaching and learning." Such learning would require substantial intellectual resources-ideas, images, materials, time-to provide opportunities to learn about mathematics, students and pedagogy" (Price & Ball, 1997:638). Cox (1975:9) recommends the art of entertaining ideas. He advise us "to invite [ideas] in and make them feel at home as you do company-while you get to know them". Getting to know ideas in this way is at the heart of learning. Yet issuing these invitations, staying in touch with the ideas, and exploring new aspects of them is easier said than done. Teachers differ with respect to their willingness to engage with new ideas. Indeed as individuals, teachers may find some ideas easy to invite in and others hard. To the extent that they keep an idea at the threshold, however, they limit their understanding of it, its complexity, and its potential.

For most South Africans, mathematical ideas are rarely invited in for a lengthy visit. Everyday experiences show little of the power and complexity of mathematical thinking in the teacher. It is common, given their school experience with mathematics, for teachers in this culture to experience mathematics as something to be remembered or told-procedures, rules, and facts that are given to teachers as ready-made. It is much less common for them to experience mathematics as something to be understood and created by their own work. It is an appreciation of such subtleties and the challenges they bring out that show how difficult it will be for South African teachers to learn and understand a new practice of mathematics instruction, that of Mathematical Literacy. In the end, "the disparities factor in curriculum reform is what teachers know, believe, and or willing to do" (Darling-Hammond, 1998: 650).

A foremost limitation to the scholarly work on mathematics reform implementation is that it has largely focused on the discipline of mathematics, which indicates that there is a scarcity of research on implementing agents of mathematical literacy. The literature on teacher understanding of ML curricula, and the impact of teaching ML on mathematics teachers identities is mostly limited in the former to first world countries and, in the later, is scarce and restricted to all encompassing mathematics curricula.

As this is a new curriculum and discipline in South Africa, there is no empirical evidence on how and why teachers implement ML .It is this 'gap' in the research literature, namely, how teachers understand and implement a mathematics curriculum distinctly different from the traditional curriculum, that my study is focused on.

In the context of ML implementation, this research may expose some key features that encumber or advance instructional changes in emerging democracies. Such empirical evidence could significantly provide for emerging explanations for ML reform change.

2.5 Summary of Chapter Two

Chapter two explored the literature on curriculum implementation in both mathematics and mathematical literacy. What is evidenced is that instructional practice in classrooms and especially mathematics classrooms remains unchanged despite the willingness of teachers to embrace reform change. Numerous theories some based in empirical evidence and others not, were offered as explanations with the argument converging that in the face of progressive mathematics reforms, a broader perspective of understanding implementation in ML is required.

The next chapter provides for a conceptual framework that allows an analytic lens for the paradox of 'theory and enaction'.