The teaching and learning of mathematics: a study of the relationship between academic theories, departmental policy and the socio-political context

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The Teaching and Learning of Mathematics:
A Study of the Relationship Between Academic Theories, Departmental Policy and the Socio-Political Context

A Thesis Submitted in Partial Fulfilment of Requirements for the

MASTERS OF EDUCATION (HONOURS)
from
THE UNIVERSITY OF WOLLONGONG

By Steve Owen

January, 1998
Dedicated to
Tracy
with love
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Abstract

The standards of secondary mathematics teaching across the world have been heavily criticised. There seems to be a large gap between the current thinking regarding the teaching and learning of mathematics and the teaching that occurs in the secondary mathematics classroom.

This inquiry had the purpose of illuminating the relationship between the learning theories of the research literature, NSW Education Policies and the current socio-political context in mathematics education. The most effective paradigm for this inquiry was the naturalistic paradigm as the study aimed to understand the relationship between learning theories and it allowed insights to be developed through descriptive and interpretive methods. Participants were a sample of 6 high school teachers of mathematics from South West Metropolitan and Illawarra high schools in the NSW Public Education System. The interview and participant observation were the primary and most effective methods for achieving a thorough understanding of the beliefs, opinions and knowledge of the participants.

The study developed a grounded theory that helps explain the current state of mathematics teaching in NSW secondary schools: namely, the beliefs and practices teachers currently hold about the teaching of mathematics, 7-12, and the factors that enable or inhibit changes in these beliefs and practices.
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CHAPTER 1.

INTRODUCTION
1 INTRODUCTION

1.1 Purpose

This inquiry will attempt to explore the relationship between and among research literature, NSW Education policies, and the current socio-political context in secondary mathematics education. From this exploration I aim to develop a grounded theory of the teaching and learning of mathematics in NSW secondary schools. The grounded theory will have the potential to inform the development of a model of staff development for teachers of mathematics education 7-12.

Although one of the primary aims of this inquiry is to illuminate and understand the relationship between theory, policy and practice, there are a number of sub-areas of exploration that emerge from this broad statement. In particular I wish to address and illuminate;

• the theories, opinions and beliefs regarding the teaching and learning of mathematics according to:
  - the NSW Education Policies
  - the relevant research literature
  - teacher training programs

• the socio-political context in NSW regarding the teaching and learning of mathematics according to high school mathematics teachers

• the relationship between and among the theories of educational researchers, NSW education policy, teacher training programs and the socio-political context.

• the factors that enable or inhibit any change in the beliefs and practices of the stakeholders in the study.

The following diagram may provide a better understanding of the research focus in this inquiry.
1.2 Rationale

1.2.1 Introduction

"In the course of 20 years, a dramatic rift has opened between the process of teaching and learning in the schools and the ways of obtaining knowledge in society at large, a rift made obvious by the fact that the process of teaching has not changed substantially, even in the past 100 years (David, 1990; Kolderie, 1990). Teachers' colleges and education departments around the country have not seen any wholesale revisions in their curriculum, and graduates of these institutions are much more like their predecessors who graduated decades earlier than they are
like today's children. The result is an estrangement of the schools from society, and from the children who live in it.

This estrangement has had pronounced negative effects. It has caught our children in an awkward bind as they move toward the future, but the institutions responsible for educating them are locked in the past. In the classroom, knowledge is presented to them in a linear, didactic manner that differs dramatically from children's previous experience outside the school. In contrast with the vivid images and self-directed flow of the interactive home and society, school strikes them as rigid, uninteresting, and ultimately alienating. In our view, the resolution of this divergence between our students and our educational practice lies in drastic educational reform, reform that will bring the classroom into line with society.”

(Strommen, 1995, WWW)

As Strommen suggests, drastic educational reform is essential for the good of mathematics education. However, it can be observed that schools often seem to be involved in the implementation of new policies and educational directions (Teese, 1992). Why then, as Strommen suggests, has the process of mathematics teaching not changed significantly over the past 100 years? In this study I make the reasonable assumption that improvements need to occur in the process of educational reform before significant change will occur in the teaching and learning of mathematics. In the following discussion I shall further highlight the importance of reform in mathematics education and how this change may be achieved.

1.2.2 The Need for Improvements

Improvements and changes in the teaching and learning of mathematics are essential for economic, social and personal reasons. On an economic level, with current improvements in communication technologies around the world and the growth of multinational corporations that do not recognise international boundaries, the struggling Australian economy needs to be competitive (Jones, 1988; Carl, 1989). This need for technology led recovery is largely recognised by business and industry. It is a general perception that mathematics is a fundamental area of knowledge which underpins the technological restructuring required for this technology led recovery and the prosperity of our society (Australian Education Council, 1991). Fields such as the physical sciences, engineering and computer science are quite mathematically demanding and fields
such as geography, biology, economics, management and industrial design are growing in their need for mathematical techniques (DEET, 1989).

However, based on a 1989 study by the Australian Science and Technology Council,

"It is predicted that demand in Australia for mathematically skilled people will rise but the supply will fall. This is both due to Australia's population demographics and to shortages in appropriately skilled people across the world, which means that we can no longer expect immigration to fulfil our shortfall."

(Australian Education Council, 1991, p.7)

It can be suggested that recent interest in mathematics has been largely below that necessary for keeping pace with the need for well qualified people, the technological advancement and economical competitiveness of Australian society. Thus, mathematics teaching needs to provide a much more mathematically skilled and knowledgeable population.

On a wider scale, the demands of today's society have meant that all people need to be numerate; to calculate, measure and estimate in a variety of situations (Board of Studies NSW, 1996). The teaching of mathematics needs to prepare some students for the higher level usage of mathematics and to prepare all students to understand the mathematics that will be relevant to their occupational choice and which will assist them in interpreting the world they live in. DEET (1989) suggest,

"The stultifying narrowness of yesterday's mathematics for an elite few needs to give way to more meaningful curriculum and more appropriate instructional strategies suitable for all." (p.30)

Mathematics as a discipline has grown largely in quantity and quality in recent times with more mathematics created in the last fifty years than in the whole previous history of humankind. However, a change in the mathematics syllabi is needed to keep pace with the rapidly growing body of knowledge we know as mathematics (Australian Education Council, 1991). The Australian Education Council further recognise that school mathematics cannot prepare everyone for the mathematics they are going to need through their life. However, they beseech that schools facilitate
the confidence, competence and interest needed to become life-long learners of mathematics.

1.2.3 Reform in Mathematics Education

Over the past few decades, numerous policy changes and new reforms have been tried. In the NSW education system, attempts have been made to implement initiatives with labels such as 'mastery learning', 'problem-solving', 'metacognition', 'radical constructivism' and 'outcome-based education'. Teachers have also been implored to 'teach mathematics through a problem-solving approach', to be 'actively involved in constructing mathematical meaning', and to encourage 'learning through cooperative groups' (Clements, 1995). As the Australian Education Council proclaim,

"Over recent years many changes have occurred in the content and methodologies for teaching mathematics and in community expectations about mathematical outcomes. These changes are likely to continue."

(Australian Education Council, 1991, p.23)

However, according to numerous educational researchers, in Australia and worldwide, these educational reforms have largely been unsuccessful in their implementation and acceptance (eg. Ellerton, 1989; Battista, 1994). DEET (1989) state that although school mathematics curricula continue to change it remains that classroom practice is little different to what it was 20 years ago.

"Our attempts to reform mathematics education in many parts of the world over the past twenty or thirty years might well be susceptible to the claim that we have been doing the equivalent of rearranging the deckchairs on the Titanic, without too much regard to the long-term consequences of such actions." (Higginson, 1989, p.4)

In addition, large criticisms have been levelled at the standard of mathematics teaching. On the international front, such as the United States of America, Great Britain and Canada, the quality of teacher education in mathematics has been a concern (Stephens et al, 1989; Cornelius, 1982, Cockcroft, 1982). Ellerton and Clements (1989) express
their concern for the dismal standards of mathematics education internationally,

"We are convinced that school mathematics in virtually all countries around the world has been tried in the balance and found wanting. Fundamental changes are required." (Ellerton and Clements 1989, p. vii)

1.2.4 Achieving Teacher Change- Beliefs and Practice

The question that becomes obvious is, considering that reform in mathematics education has been generally ineffective, what can be done to improve the teaching and learning of mathematics? Various suggestions and explanations have been offered by educational researchers, especially over the past decade.

Studies have shown that the teacher's beliefs must be addressed to achieve significant and prolonged change in the teacher's practice. Cambourne (1991) explored the relationship between teachers' beliefs and practice in the field of literacy. Some tentative but important research findings emerged. The teachers who went through the process of making their beliefs explicit claimed to feel more confident and empowered as teachers. Cambourne (1991) further observed that the teachers who felt confident and empowered were also the teachers who showed a high level of congruency between their ideology, theoretical understandings and practice. He stated,

"...there is a relationship between the personal sense of confidence and empowerment that teachers with whom I've been co-researching develop and the process of identifying, exploring, reflecting upon and possibly confronting the ideological strata which underpin their theory and practice."

(Cambourne, 1991, p.11)

Owen (1993) in a similar study conducted in the field of mathematics education arrived at similar conclusions. The processes of articulating one's beliefs and reflection upon these beliefs and associated practice led to a more congruent relationship between beliefs and practice. Thus it is not surprising that of all the factors that seem to hinder the reform process,
the failure to address the deeply held beliefs of mathematics teachers seems to be one of the most significant. As Battista (1994, p.462) states,

"However, many teachers have beliefs about mathematics that are incompatible with those underlying the reform effort. Because these beliefs play a critical role not only in what teachers teach but in how they teach it, this incompatibility blocks reform and prolongs the use of a mathematics curriculum that is seriously damaging the mathematical health of our children."

The beliefs held by a teacher of mathematics have been developed and influenced by their own education. Each teacher has experienced over 13,000 hours of schooling before the commencement of any teacher training (Armaline & Hoover, 1989; Sullivan, 1990). This includes the primary, secondary and tertiary training, where often out-dated methods are used and promoted (Battista, 1994).

Battista (1994) reports that recently most university mathematics courses were found to actually reinforce rather than debunk the view of mathematics as a set of procedures to be memorised. It is not that surprising considering that in most institutions, responsibility for providing mathematics studies for secondary pre-service education students rests outside the education faculty (Whitehead et al, 1993).

It has been found that most mathematics teacher training courses do not prepare teachers for teaching mathematics and often engender negative attitudes towards mathematics (Billstein & Lott, 1991; Sachs, 1991). It has been suggested that exposure to these sorts of beliefs through one's own education has the effect of reproducing these traditional beliefs and values (Sullivan, 1990). In evidence, a 1994 NSW study involving a sample of 510 primary and secondary students and primary teachers, it was found that most believed that the memorisation of facts and procedures is the best way to learn mathematics (Southwell & Khamis, 1995).

Boomer (1986) claims that as teachers have not articulated the beliefs that drive their practice, they are in effect paralysed in their capacity to change radically. He claims they are like a "well intentioned, misguided or unguided missile" in the classroom, likely to take on a new idea but unable to generate infinite practice for new contexts.
1.2.5 Teacher Change- The Social Context

Teese (1992) comments that reform in Australian secondary schools has faced considerable opposition.

"In Australia secondary education has undoubtedly been the most important domain of reform. Changes to reform have been most bitterly fought at this level." (p.39)

The reform process and acceptance of new policies and initiatives has been further inhibited by unchanging textbooks, state-testing programs and the expectations of parents and employers. Boomer (1986) claims that textbooks worth millions, university pre-requisites, teacher training, parent and employer expectations which are solidly established, create large costs in time and money if real change is to occur. He argues that "an array of forces collide and conspire to maintain what is, and this, in terms of life and work, is largely dysfunctional (p.7)" Clements (1995) agrees that the teaching of mathematics is controlled by syllabi and textbooks but further states,

"How teachers teach in mathematics classrooms is largely (though not totally) controlled by the expectations of society, by the need to complete syllabuses on time and to get students to pass, and by the behaviours and expectations of students in the classes." (p.8)

The DSE admits that a factor that inhibits teaching mathematics for relational understanding is the constraint of time in completing course requirements (Department of School Education: Curriculum Directorate, 1996A). Teachers may be rushed to complete the syllabus and thus revert to teaching without real understanding (Adelman & Panton Walking-Eagle, 1997). Teachers are also limited in the time they have to prepare new strategies that are congruent with the new policy or initiative (Battista, 1994). The DSE also admit that students may offer resistance to the changing of classroom practices as they are used to a different contract (Department of School Education: Curriculum Directorate, 1996B).
With all these factors inhibiting the reform process, it is understandable that change has been difficult to facilitate in the beliefs and practices of mathematics teachers.

1.2.6 The Shift in Research Methodology

Recently there has been a quite dramatic shift from the use of quantitative research methods in a positivist framework to that of qualitative or interpretive research methods used by a naturalistic framework (Cooney, 1995). This has led to the telling of many stories about the individuals being studied, often in the form of case studies. These case studies have placed a heavy emphasis on teacher’s thinking and on the factors that influence the teacher’s thinking.

Cooney (1995) commenting on the failure during the 60s to recognise that how the teachers learned mathematics would affect the way they taught it, stated;

"It seems rather astonishing that we are only now beginning to recognise the implications for how teachers learn mathematics rather than simply focusing on what they learn. We might attribute this omission to a lack of attention to contextual factors or to the fact that research, then, failed to address the complexity by which mathematics is learned." (p.617)

During the 70’s the teaching profession valued descriptive studies only so long as they contributed to the better development of process-product or experimental studies (Cooney, 1995). Up to the mid 1980s the prevailing paradigm of research methodology was rationalistic and thus required a quantitative research methodology. Research had really only focused on what teachers did rather than what they thought. However during the 1980s the epistomological framework of constructivism began to take hold. Case studies became a common way of describing the teachers thought processes and construction of meaning and therefore methodologies were needed that accounted for creating and interpreting (Cooney, 1995).

Cooney suggests a variety of forces influenced the methodological shift during the 1980s. There was an increasing dissatisfaction with the
positivist paradigm and the perception that the atomisation of teaching behaviours would yield productive results. Further, one of the major assumptions of the positivist paradigm, the notion of achieving objectivity was also being questioned and as mentioned, the constructivist perspective was gaining popularity. Thus this study seemed most suited to the Naturalistic paradigm. It attempts to explore and understand the thought processes of mathematics teachers as they develop in their beliefs and pedagogy.

1.3 Locus of Study

1.3.1 The Sites

The research primarily occurred at two schools, both quite new schools built only in the past 15 years. The first site was a public high school in the South-West Metropolitan Sydney area. The school was a part of the Disadvantaged Schools Program and was populated by approximately 950 students generally from low income families. The students were also of various cultural backgrounds, including a large proportion of students from Pacific Island and Lebanese backgrounds. The school had very limited academic success on comparison with HSC results of other state schools and on average the staff were relatively inexperienced with close to 50% in their first eight years of teaching.

The second site was a public high school in the Illawarra area. It was approximately the same size as the first school, but with more a monocultural population. The students were largely of a white, Anglo-Saxon background from middle to lower class families. The school had an equal mix of high achievements in academic, sporting and dramatic contexts.

1.3.2 The Participants

Six teachers participated in the study, sharing their ideas, beliefs and knowledge on the teaching of mathematics and the factors that influence changes in their teaching. Considering that only six teachers were used, they had a variety of contrasting ideas and backgrounds.
Arnold and Frank were beginning teachers in their mid twenties and still in their first three years of teaching. Arnold, in the South-West Metropolitan Sydney school, had begun as a mathematics teacher, but in his third year had moved more towards the teaching of Computing studies. Frank had taught at a few schools in the Illawarra, doing blocks of teaching as a casual teacher of mathematics and was also in his third year of teaching. Frank and Arnold had also recently become fathers.

Dan was in his late thirties and had experienced the teaching of mathematics in numerous other education systems, including Fiji, Zimbabwe and the Australian States of Western Australia and Tasmania. It was his second year of teaching at the Illawarra high school but he was there on a casual basis, replacing a teacher on compassionate leave.

Jan worked at the South-West Metropolitan Sydney high school and had over twenty years experience teaching mathematics. She had taught at a number of high schools within the state, both country and city. Jan had also experience as relieving head teacher of mathematics and administration.

Both Leo and Violet had over twenty years experience teaching mathematics and currently taught mathematics at the Illawarra high school. Violet had grown up and taught in the same area, with her teaching experience at two high schools, both within a ten kilometre radius. Leo was head teacher over Dan, Frank and Violet. He had taught in both country and city schools within NSW as well as a stint as an exchange teacher in Canada.

Although the above descriptions provide an introduction to the sites and participants in the study, the Results chapter shall further elaborate their background, ideas and experiences.

1.4 Conclusion

In my limited four years experience as a teacher of mathematics, I feel that I have changed considerably my ideas on teaching and learning
mathematics. However, as a teacher of mathematics, I have also been subject to the implementation of new DSE initiatives. My teaching practice has been affected by new reforms promoting mathematics teaching using techniques such as groupwork and greater use of discussion, both written and verbal. The promotion of open-ended technology in the classroom and literacy across the curriculum have also recently effected the teaching of mathematics in NSW public school system.

However, I have witnessed only minimal acceptance of these reforms by teachers of mathematics. It seemed that some teachers trialed certain strategies but soon went back to practices they were more familiar and comfortable with. It seemed that there were inherent problems between the introduction of the reforms and the acceptance of these reforms by teachers or mathematics. However, I believed that by researching more intensely the effectiveness of change in the current mathematics education context, I could better understand and explain why this may occur.

This chapter attempted to make explicit a basis for the research that follows. The next chapter shall provide an understanding of the literature relevant to the study. It provides a basis for interpreting the results of the research and drawing conclusions. Following further will be a discussion of the methodological basis for the research, describing the Naturalistic framework within the study was conducted and the processes of data collection and analysis. The Results chapter shall describe the personal stories of the participants as case studies and will inform development of a grounded theory, discussed in the Conclusions to the study.
CHAPTER 2.

REVIEW OF RELATED LITERATURE
2. REVIEW OF RELATED LITERATURE

2.1 Introduction

The following chapter will draw upon the relevant and available literature to illuminate the important research and theories that precede this study. However the objective is not to accumulate generalisations as a lead to ultimate truth. Rather, the literature review will illuminate the related studies and findings that have occurred in a different context, as well as current theories relating to the teaching and learning of mathematics. The major use of the literature review in this naturalistic inquiry, is thus to provide findings and assertions from the professional literature that can be introduced for consideration in the context of this inquiry.

2.2 Related Studies

A number of studies have attempted to understand the process of change in the field of mathematics education. The following is an illumination of these studies and a discussion of their relevance to this inquiry.

By taking into consideration their knowledge of research on teaching and learning, Fennema, Carpenter and Peterson (1989) designed a model for curriculum development.

![Fig. 2 A Model for Curriculum Development](Fennema, Carpenter & Peterson, 1989, p.180)
The research that followed was to investigate the model and involved a combination of process-product and qualitative methods. In essence it investigated whether teachers' beliefs and knowledge influenced the instructional decisions that they made, and whether those decisions influenced children's learning. They concluded,

"It appears that knowledge and beliefs are interconnected in a way that is strongly linked to teachers' instruction and to students' learning of mathematics." (Fennema, Carpenter & Peterson, 1989, p.185)

The main importance of this model to my research study is that it shows that the knowledge and beliefs that teachers hold share a strong relationship that has a significant influence on their practice. Of further importance is that the model shows how the student behaviour has a significant influence on the decisions that teachers make about their teaching.

The research of Ernest (1989) led to the development of the following model and some important conclusions for this study.

---

Fig. 3 Relationship Between the View of the Nature of Mathematics and Practice (Ernest, 1989, p.252)

This model shows how the teacher's view of mathematics provides a basis for the teacher's enacted model of teaching and learning. However, the
main importance of the model to this study is that the social context of teaching is found to exert a powerful influence between a teachers' views on teaching and learning mathematics and their practice. As part of the social context of teaching, Ernest conveyed that the expectations of others, namely teachers, parents and students, influenced the teachers' practice. He further claimed that the institutionalised curriculum and the adopted text were significant factors that influenced the teachers' practice.

Similarly to Ernest, Grouws and Good (1989) found that a strong relationship existed between the knowledge and practice of mathematics teachers. The study involved interviewing and observing twenty-four teachers over a three year period. They could not define in any detail the nature of the relationship.

Whitehead et al (1993) in a study quite similar to the research conducted in this thesis but at a tertiary level, reported on the extent of implementation of the recommendations of the Discipline Review of Teacher Education in Mathematics and Science. The report also expressed some important findings on the factors that influenced that implementation. The discipline review came at a time when large changes were occurring in the higher education institutions. Whitehead et al comments that in a negative way, the focus on these changes and amalgamations meant that the report was largely ignored. Further reports on education and teacher education since then had also drawn away some of the focus on the implementation of recommendations. Also as institutions have attempted to reduce expenditure, the implementation of the report has been further hindered. Whitehead et al (1993) claimed another problem is the lack of structures that can facilitate cooperation and collaboration between the various parties concerned with teacher education.

Findings suggested that simply releasing a Report is inadequate, irrespective of the quality of the report. It would have far greater impact if the Report was supported by an implementation plan. In a discussion of "Barriers to Implementation" (p.29) staff reported that failure to implement was sometimes due to factors outside their control. Often lack of resources and the reallocation of funding hindered implementation and there were no incentives for those institutions that made the changes
and implemented the recommendations, nor was punitive action to be taken against those who did not. Also, it was suggested that

"...the backgrounds and interests of Deans of Education were rarely in the area of mathematics and science, and that as a consequence they were more aware of, and amenable to, pressures from other areas of study." (Whitehead et al, 1993, p.29)

Another hindrance was the lack of unity amongst faculties. Resistance by the few created difficulties in a united structure of implementation.

The related studies generally concluded that a relationship existed between the teachers' beliefs and practices. This is further supported in the literature by Herrington, Pence and Cockcroft (1982), McQualter (1983), Barnes (1992) and Fennema and Loef Franke (1992). Stephens et al (1989), discussing principles for successful reform, stated,

"Underpinning these classroom practices are beliefs, held by teachers and students, about mathematics, and how it is taught and learned." (p.226)

A further finding of the studies and important to the focus of this study, was that the relationship between beliefs and practice seemed influenced by the social context of teaching. Although these studies have provided us with some clues to an improvement in mathematics education, it is pertinent to investigate the factors that influence change in the current climate of mathematics education in the NSW Education System. This study has added to this knowledge base by focussing on these factors.

2.3 Theories of Learning of Mathematics

In the following discussion, I intend on illuminating the theories of the research literature, the NSW Department of Education and teacher training programs with regard to the teaching and learning of mathematics. The aim of this process is to understand the congruence (or lack there of) that exists between them and to 'paint a picture' of current educational philosophy' in mathematics.
2.3.1 The Relevant Research Literature

In this section I shall draw upon a sample of the relevant and available literature to illuminate the research and theories of educators as it is presented in the literature. This should provide an understanding of what the educational academics and researchers suggest are the most effective ways to teach and learn mathematics.

Various theories have experienced popularity over the past few decades. Ernest (1989) attempted to categorise the theories of learning mathematics into four models. The models were labelled 'Compliant Behaviour and Mastery', 'Reception of Knowledge', 'Active Construction of Understanding' and 'Exploration and Autonomous Pursuits of Own Interests'.

However a more general categorisation was made by Cambourne (1988), suggesting that the various theories may be classified as 'Habit Formation' or 'Holistic Learning' theories. The 'Habit Formation' theories would include the 'Compliant Behaviour and Mastery' and 'Reception of Knowledge' categories as they suggest teaching to be a transmission of knowledge. Other labels for 'Habit Formation' theories are Behaviourist, Mechanistic or Absorption theories. Contrary to the 'Habit Formation' theories, Ernest's (1989) 'Active Construction of Understanding' and 'Exploration and Autonomous Pursuits of Own Interests' categories would easily fit into Cambourne's (1988) 'Holistic Learning' theories. Other labels for 'Holistic Learning' theories include Cognitive, Gestalt, Constructivist or Meaningful theories.

I shall use this distinction to organise a brief overview of the influential learning theories of the last century and to discuss the theories that are presently receiving attention in the field of education. However, rather than be repetitive, I discussed holistic theories as part of the theories that are currently receiving attention. Further, I shall use the terms 'holistic' and 'constructivist' interchangeably for the following discussion.
2.3.1.1 Habit Formation Theories of Learning: An Overview

Until the 1980s, habit formation theories of learning dominated mathematics education (Battista, 1994). Generally, habit formation approaches to learning involve learning through the establishment of desirable habits and the elimination of undesirable habits (Cambourne, 1988). It involves forming a strong association or bond between a stimulus and a response, through continued practice.

Influential educators and researchers such as Thorndike, Skinner and Gagne have supported habit formation approaches to learning over the last century. The conclusions of research often were based on experiments with animals (eg. Paslov, Skinner). These learning theories emphasised the importance of drill and practice and rote learning procedures. A bond was developed or made stronger by the repetition of a stimulus followed by a pleasurable response. Punishment or neglect caused the bond to weaken. Step by step instruction with regular reinforcement was a common teacher pedagogy. Textbooks commonly contained (and still contain) graded examples which suggest that mathematics is best learned in this way (Leder & Forgasz, 1992).

During the 1960s and 1970s, similarly related programmed learning models were popular amongst mathematics educators and researchers. It involved the progression of students through a sequenced set of materials at their own pace, with regular monitoring of their progress (Leder & Forgasz, 1992). A right or wrong mentality existed where student assessment was heavily focused on the final result with little credence given to the process the student goes through to reach that result (Leder & Forgasz, 1992).

However, there have been many criticisms of the 'habit formation' theories of learning. Even during the mid part of this century, when behaviourist learning theories were largely the dominant learning theory, Wertheimer's (1959) findings criticised the effectiveness of drill and practice for learners of mathematics. He believed that the learners were unable to generalise their learning to solving problems of a similar nature (Leder & Forgasz, 1992). Battista (1994) condemned behaviourist teaching methods in stating,
"But by reducing mathematics to the following of set procedures, these teachers were inadvertently robbing their students of opportunities to 'do' mathematics. Because students' intuitive ideas about making sense of mathematics were ignored, and therefore devalued, the development of their mathematical reasoning skills was impeded." (p.647)

Others have supported this notion, arguing that understanding plays no part in habit formation learning theories (Carpenter, 1989; Skemp, 1978).

2.3.1.2 Holistic & Current Theories of Learning

The past few decades have seen a gradual decline in popularity of habit formation theories and the rise in popularity of holistic and constructivist theories of learning mathematics (Stein et al, 1996; Battista, 1994). Thus a discussion of the current theories and holistic theories of learning is in large part, the same discussion. Those advocating a habit formation approach to learning mathematics today are few and far between (Stein et al, 1996).

Constructivism suggests that knowledge is not objective and thus that mathematics should be viewed as a system with models that describe how the world may be, rather than how it is (Hanley, 1994). Knowledge and truth are individual constructions and the real world is determined by individuals based on their own unique set of experiences and beliefs. While objectivists strive for acceptance and closure of a world view, constructivists celebrate difference and debate (Swan & Hughes, 1996).

However, as early as 1830, Colburn advocated that learning should be meaningful for the students (Leder & Forgasz, 1992). He further suggested that new work should be presented in a realistic and practical context, with the work preceding in small steps from easy to more difficult. Colburn proposed that teachers should guide their students to understand mathematical ideas and concepts rather than simply tell them (Leder & Forgasz, 1992). In a statement that has had repercussions for holistic learning theories today, he urged teachers to listen carefully to and accept and encourage the different problem solving strategies that the students expressed.
Piaget's theories of learning were also influential on the holistic theories largely accepted by educators of today. Piaget believed that the human mind was a network of schema or cognitive structures which were modified through interaction with the environment (Leder and Forgasz, 1992). However the label of 'constructivism' has never been entirely clear. There are many variations but essentially it is believed, as Piaget suggested, that knowledge is constructed by each learner onto their already existing understandings (Steen, 1989). This discussion simply outlines some of the main principles of the holistic or constructivist approaches that are currently receiving attention.

The holistic approach suggests that learners have a mental framework or organisation of schema where all their experiences have been organised (Steen, 1989; Long, 1989; Cockcroft, 1982). It is believed that the learners enter the classroom with this wealth of experience and these experiences are the basis upon which all learning occurs (Long, 1989). Learning occurs when a connection is made between the new experience and the mental framework (Choat, 1981). Thus an important implication for the teaching of mathematics, as Vygotsky’s 'zone of proximal development' suggests, is if the gap between these schemata and the new experience is too great, the learners will not be able to construct an understanding.

Thus, the constructivist or holistic learning process is 'student centred'. As Strommen (1995) purports,

"The focus of constructivism, then, is the child as a self-governed creator of knowledge." (WWW)

As knowledge is perceived as the connection of a new experience to those already held, it is important that the students knowledge base be made explicit and built upon.

A further principle of the constructivist learning process is the immersion of the learner in a natural or cultural context where the learner engages in the mathematical experiences (Blumenfeld et al, 1994; Yackel et al, 1990; Tate, 1994). Iran-Nejad, McKeachie and Berliner (1990) propose that;
"...the more situated in context, and the more rooted in cultural background, metacognitive and personal knowledge an event is, the more readily it is understood, learned and remembered." (p.511-cited in Leder & Forgasz, 1992, p.18)

Furthermore, language learning research suggests that learners are better able to understand decontextualised situations if they have been immersed beforehand in a context which is interesting, relevant and meaningful to them (Bickmore-Brand, 1990). Tate (1994) claims that mathematics education has been hindered by a failure to immerse students in an appropriate cultural context that allows the connection of understandings and experiences.

The constructivist or holistic learning theories also suggest that mathematics should be experienced in a variety of ways. Mathematics should be discussed, read, drawn and reflected upon in a language intensive classroom atmosphere (Bickmore-Brand, 1990). This language-intensive atmosphere provides the catalyst for students to draw upon previous knowledge and experiences and make connections with the new experience (Boomer, 1986). Also integral to the holistic learning process is intellectual risk taking, where learners are given opportunities to explore the mathematics and trial ideas in a supportive environment (Stein et al, 1996).

Boomer (1986) suggests that the more of their own language that the learner can use with the new idea, the more ways they can relate the new information to their own experience and the more likely they will reach an understanding. Thus the contributions of the students are integral in the holistic learning process (Webb et al, 1995; Maher & Martino, 1992).

It has been more and more recognised that the process of communicating mathematics assists in the understanding and further construction of mathematics (Greenes, Schulman & Spungin, 1992). Reeves (1990) suggests the importance of language in learning mathematics by stating,

"...mathematics education in schools is fundamentally a language activity. It is through language and not activities or materials that mathematics is learned."

(p.91)
Learners actually construct meaning through the use of language (Stoessiger & Edmunds, 1990). Many researchers suggest that by allowing the students opportunities to express and articulate their thoughts, they are better able to organise, clarify and refine them (Pimm, 1987; Greenes et al, 1992). Mumme and Shepherd (1990) suggest that for these reasons, the mathematics teacher should encourage the expression of ideas, engage the students in discussion and create collaborative group situations where the students may compare and contrast their thoughts.

Prominent educators such as John Dewey (1933) have long advocated classrooms in which learning was a collaborative effort. Cooperative learning opportunities take many forms and have various purposes. The quality of the learning also varies greatly. Good, Mulryan & McCaslin (1992) indicate that the increased use of cooperative learning strategies can improve learning outcomes for students but does not ensure student learning will occur. However, when properly implemented, with careful organisation and appropriate tasks, it can enable students to practise meaningful mathematical topics, to learn prosocial skills, to use various approaches to solving problems and to articulate their mathematical thoughts.

Many researchers suggest that writing is an effective form of discourse for learning mathematics (eg. Miller, 1991; Wilde, 1991). As with verbal discussion, writing provides the learners with opportunities to organise and clarify their understandings. It is further encouraged that the students use their natural language forms to focus, not on presentation but their thinking (Wilde, 1991).

"By presenting what they think is important, students exercise greater power and control over their learning, that is, they become empowered."

(Mumme & Shepherd, 1990, p.19)

Mason (1988) agrees that writing is helpful for clarifying ideas but emphasises the need to firstly contact any mental imagery that is involved or associated with the topic, trying to express verbally to oneself and to colleagues and only then trying to record or express ideas in words or pictures. A learning journal has been suggested as an effective framework for student's writing and learning (Wilde, 1991; Anderson, 1996). It
provides opportunities for students to express and clarify their thoughts as well as enhancing the teacher’s understanding of how the student thinks (Pimm, 1987; Miller, 1991). The writing journal has the added benefit of acting as a reflective tool for teachers to diagnose the effectiveness of their teaching, which may lead to their own professional development.

In congruence with the constructivist perspective, Hiebert et al (1996) propose that rather than the mastering and applying of skills, mathematics learning should be based upon problem-solving. It involves allowing the students to reflect upon phenomena, to inquire, to search for solutions and to resolve incongruities. Curriculum and instruction should begin with problems, dilemmas and questions for students to engage with (Hiebert et al, 1996).

Although the holistic approach to learning suggests that all learners of mathematics essentially construct their knowledge in the way outlined, it is also widely accepted that students will have their own individual learning preferences (Yackel et al, 1990). This point is further supported by the Cockcroft Report (1982) which claimed that there is no singularly appropriate method for teaching mathematics. It needs also to be noted that student’s learning should include a rich variety of experience with multiple forms of representation, such as drawing, graphing, constructing tables and writing (Greeno & Hall, 1997).

Thus, the holistic learning theories that are prominent in the mathematics education field, argue that complete understanding includes the capacity to engage in the processes of mathematical thinking, solving problems, conjecturing, examining, making inferences from data, abstracting, exploring, inventing and justifying (Stein et al, 1996). Students and teachers view mathematics as a dynamic process where knowledge is created through context rich, language intensive and relevant experiences.

2.3.2 Theories of the NSW Department of Education

The Department of School Education (DSE) in NSW holds certain views and theories concerning the teaching and learning of mathematics. By analysing the literature and policy documents that the department has
made available, a reasonable understanding of their views may be achieved. I believe it is necessary to investigate documents from the past decade to gain a broad understanding of the recent beliefs, opinions and learning theories advocated and promoted by the NSW Department of School Education. For the purposes of this research I categorise the DSE as encompassing those government sources that have an explicit influence on the teaching and learning of mathematics in New South Wales schools. This includes the Australian Education Council, NSW Department of School Education, Board of Secondary Education NSW, Board of Studies NSW and the Curriculum Corporation.

Firstly it should be expressed that current DSE thinking advocates relational learning, or learning with understanding of the mathematical reasoning. In contrast 'instrumental' understanding is more a knowledge of procedures, the rules without the reasons (Skemp, 1978). As the Curriculum Directorate suggests, the rewards of instrumental understanding are more immediate and apparent and gives a page of correct answers in a shorter time. However, relational understanding has two main advantages. It is more adaptable to new tasks and is easier to remember. They claim that at the end of year 12, all instrumental learning is simply memorisation and akin to remembering the contents of a phonebook. They believe that a greater emphasis needs to be placed on facilitating relational learning (Department of School Education: Curriculum Directorate, 1996A). In a discussion of the new Year 9/10 Mathematics Syllabus, they comment,

"The emphasis in the new syllabus is on understanding concepts and being able to express that understanding. This provides an opportunity to reflect on the best instructional sequences to facilitate relational understanding and the development of well-connected knowledge structures."(p.3)

Thus teaching for relational understanding seems inherent in the philosophies and teaching strategies of the DSE.

In the publication, 'A National Statement on Mathematics for Australian Schools' by the Australian Education Council (AEC) (1991), effective teaching practice in mathematics and the principles behind them are discussed. These principles and strategies were the result of collaboration
between consultants, tertiary mathematicians and mathematics teacher educators. Further it was claimed that drafts were discussed with cross-section of people including the above people and parents, teachers, professional associations, curriculum developers, community groups, employers and unions (Australian Education Council, 1991).

The AEC (1991) presented a philosophy of learning in close similarity with constructivist principles. They understand that "learners construct their own meanings from, and for, the ideas, objects and events which they experience" (Australian Education Council, 1991, p.16). Students are perceived to construct meaning and new understandings dependent on their existing understandings. It is believed that they can only take from an experience those things that make sense and can be linked to their existing understandings.

The AEC (1991) believe that rather than an internalisation of external things, number concepts are the result of creating or building relationships in the mind of the individual. Learning occurs when the existing conceptions are challenged and the learner feels a need to accommodate the new information. This challenge may come from the physical environment, the social environment or the mathematics itself. Also essential for learning are the processes of action and reflection on the part of the learner. As the AEC (1991) state,

"Reflection on experience is needed in order to link new knowledge to existing knowledge, leading to the expansion and refinement of ideas." (p.5)

This understanding of the learning process is shared by the Department of School Education Curriculum Directorate (1996B). They claim that learning needs to link to, and build upon, student's current knowledge. They also observe that sometimes teachers try to teach intricate methods when the students do not have the required basics first which they claim for students is like trying to build the third floor on a house when the second floor is not in place. They also agree that real life situations become a vehicle for the generation and connection of various representations of the concept (Department of School Education: Curriculum Directorate, 1996B).
Most other DSE documents and publications are shy to make explicit the principles behind suggested teaching approaches. However, a discussion the promoted teaching approaches provides us with further strong clues to suggest they follow similar constructivist principles.

The Board of Secondary Education NSW (1989) suggest that students learn best through investigations and that mathematics should involve the investigation of mathematical patterns, relationships, processes and problems. This belief is further promoted by the Australian Education Council (1991) who believe that the process of investigations will help students develop mathematical concepts and provide them with experiences of some of the processes through which mathematical ideas are generated and tested. Within the process of investigation, the DSE suggests that students explore and create mathematics. The students interact with available resources and build an understanding from concrete to abstract representations (The Board of Secondary Education NSW, 1989).

Further in line with the investigation approach, the DSE promote teaching mathematics through problem solving. Problem solving is believed to encourage important mathematical skills including communication, critical reflection, creativity, analysis, generalisation and validation (Board of Studies NSW, 1996). They suggest specifically that the use of open-ended questions can largely facilitate the student's building of knowledge.

Collaborative learning and the role that language plays in that learning, has received considerable emphasis over the past decade. As the Australian Education Council (1991) express,

"Often regarded as a rather solitary activity, mathematics develops through the interaction of communities of people working mathematically. Furthermore, the posing of problems and their solution almost always involve people in working together." (p.13)

They suggest that we constantly adjust our understanding and interpretation of phenomena through our interactions with other people. They believe that through discussion, students may adjust their
conceptions with the new information. Language, in both verbal and written form, acts a tool for reflecting upon mathematical experiences and allows students to work through and clarify their ideas (Australian Education Council, 1991). The Department of School Education (1989) convey that without reflection the learning will be rote and easily forgotten. It is this process, of talking, writing and representing ideas in our own preferred way that we internalise the new ideas and make them our own (Department of School Education: Curriculum Directorate, 1996). Similar ideas are also expressed by the Board of Secondary Education NSW (1989) and the Board of Studies NSW (1996).

To conclude this discussion, the DSE Quality Assurance Directorate (1995), in their 'School Review Framework', stressed its advocation of constructivist principles with a list of statements that were "descriptions of practice to which schools and teachers may aspire". It included statements for student learning such as,

- Students take responsibility for and are actively involved in their learning. (p.5)
- Students work independently and collaboratively in a range of learning activities. (p.6)
- Students take risks as part of their learning. (p.7)
- Students reflect on their learning and engage in the self-assessment of their progress. (p.8)
- Students are provided with a relevant curriculum. (p.12)
- Teaching programs are designed to respond to student's interests, needs and abilities. (p.13)
- The teacher collaborates with students in the learning process. (p.14)

The purpose of the document was to provide a "best practice" framework to be accessed and encouraged in teachers into the next millenium. Evidently, especially during the 1990s, DSE theories on learning and teaching mathematics have reflected those principles characteristic of a constructivist approach.
2.3.3 Tertiary Training for Mathematics Teachers

A discussion of the educational theories on how students most effectively learn mathematics would not be complete without examining the learning theories that are promoted and taught to trainee mathematics teachers at a tertiary level. The following discussion incorporates the findings and recommendations of a DEET (Department of Education, Employment & Training) inquiry on the education of mathematics and science teachers in NSW (DEET, 1989). These recommendations provide some insights into the directions of teacher education for the 1990s. Therefore the purpose of the following is to provide an idea of the beliefs, opinions and theories that are promoted in trainee teacher education at a tertiary level.

Most pre-service teacher courses involve separate coursework in education and the mathematics discipline. At a tertiary level much of the teaching of the mathematics discipline is through the traditional lecture/tutorial format. DEET (1989) comments that the trainee teachers therefore do not see examples of teaching that are consistent with current teaching and learning theories.

"Students work through examples that bare little or no relationship to real world applications... They are not given opportunities to engage in independent investigation, problem solving and risk taking." (p.32)

Tertiary teachers of mathematics tend to teach in ways they have been taught, thus this creates a much out-dated and impotent model for pre-service teachers (DEET, 1989).

The DEET (1989) panel made a number of recommendations for changes to the current structure of mathematics teacher training. They believed that secondary pre-service teacher education in mathematics needed to provide study in the discipline of mathematics that combined pure, applied, industrial, and statistical mathematics and the history of mathematics.

"Courses should encourage the de-emphasis of memorisation, pencil and paper tests, repetitive computational tasks, textbook reliance, and emphasise the conceptual
development linking concrete to abstract, demonstration of understanding, mathematical modelling and other problem-solving strategies." (DEET, 1989, p.18)

Further, they recommended that teaching should also incorporate technology with the appropriate use of computers, calculators and other learning media.

Another DEET (1989) recommendation was that the teaching style needed to encourage the students to be active learners in a mathematics classroom that becomes a 'laboratory for experimenting'. In this context, communication in a mathematical sense was urged where the learning and experimenting involved real world problems. It was further suggested that the teachers be encouraged to allocate sufficient time to allow students to reflect on their own learning and performance, and recognise their own strengths and weaknesses.

In the specific area of education, DEET recommended that pre-service teachers be encouraged to embrace appropriate learning theories and to accept the learner as a partner in the construction of knowledge. It was seen as important to establish a positive and supportive learning environment which enhanced the learning of mathematics and where teachers built on the experiences of the students. In addition, teachers were urged to keep students up to date with current educational technology, and the relationships between technology, mathematics and social issues.

It was also recommended that pre-service coursework was to help empower pre-service teachers to be able to change and grow while on the job. In consequence, DEET recommended that pre-service teachers were provided with adequate time for reflection on ideas and experiences, for facilitating organisational frameworks and for achieving an understanding of learning styles.

The future directions of pre-service teacher education thus seemed to promote and encourage teachers who teach for understanding. This incorporated the development of a classroom environment where students were active in their learning and built onto previous knowledge through discussion and experimentation. Pre-service teachers were encouraged to become reflective practitioners who were able to change
and develop whilst in the classroom. Although these findings were the basis of the DEET (1989) report, it provides an understanding of the inherent problems associated with current teacher training at a tertiary level.

Even in 1993, in a follow-up to the DEET (1989) 'Discipline Review of Teacher Education in Mathematics and Science', Whitehead et al (1993) found that many of the recommendations had not been implemented and thus tertiary training was continuing to promote out-dated theories on learning mathematics. A discussion of the reasons for the poor acceptance of the recommendations will occur in the discussion of related studies.

2.3.4 The Congruency Between Current Theories

The DSE seemed to hold beliefs that reflected the current thinking of educational researchers. It seemed that a considerable effort had been made to promote the ideas and beliefs that were consistent with the constructivist approaches to learning that had received popularity in the literature. However, this conclusion further suggests that reform efforts have been unsuccessful in the NSW Education System in relation to the teaching of mathematics. Teachers were recently found not to hold beliefs consistent with these constructivist principles (Cooney, 1995).

However, it seems that at a tertiary level, the beliefs on teaching and learning mathematics are not congruent with those beliefs promoted by the DSE and educational researchers alike. As the DEET study recommended, significant change needs to occur if the current theories on teaching and learning mathematics are to be promoted in teacher training programs. As suggested earlier, this inconsistency has led to the reproduction of outdated, traditional beliefs and values on teaching and learning mathematics (Sullivan, 1990).
2.4 Teacher Change

"Teachers' capacity to deal with change, learn from it, and help students learn from it will be critical for the future development of societies." (Fullan, 1993, p.ix)

Although the introduction mentioned the need for reform and change in teachers' practice at a secondary mathematics level, it is necessary to expand on this discussion. This study aims to illuminate the factors that hinder and enable reform, so it is of great importance that I illuminate the ideas, opinions and findings that abound in research literature. In the following discussion I shall highlight these factors and related suggestions for improving reform.

The beliefs held by teachers can create large barriers to reform. The prior beliefs and experiences that teachers bring with them to the experience of learning to teach affects what they learn (Ball, 1996; Grant et al, 1996). When teachers' beliefs do not correspond with the beliefs underlining the reform effort, acceptance of the reform is difficult to achieve. Battista (1994) stresses the role teachers' beliefs play in the process of reform.

"However, many teachers have beliefs about mathematics that are incompatible with those underlying the reform effort. Because these beliefs play a critical role not only in what teachers teach but in how they teach it, this incompatibility blocks reform and prolongs the use of a mathematics curriculum that is seriously damaging the mathematical health of our children." (p.462)

He also discusses the example of teachers accustomed to implementing the traditional behaviourist/instructional curriculum. He claims that they have not required much knowledge of how children learn mathematics as their teaching has required them only to explain set sequences of procedures prescribed by textbooks. Thus these teachers lack the knowledge about mathematics and student learning that is necessary to implement many of the constructivist principles that currently underlie much of the recent reform movements (Battista, 1994).

As Battista (1994) then asks, "why are teacher's beliefs so incongruous with those of the current reform movement" (p.468)? He suggests these beliefs are the result of education systems that perpetuate behaviourist learning
principles. Almost all current teachers were educated at primary, secondary and university levels that promoted mathematics as procedures rather than sense making (Ball, 1996). Battista (1994) also claimed that school environments in which teachers now teach demand this rule based view of mathematics. Further, the textbooks supported this view and state assessment programs adhered to it.

"Teachers who are asked to teach the reformed mathematics curriculum are products of an old curriculum that developed in them beliefs so incompatible with those of the new curricula that they can understand many of the innovations only with great effort. We are caught in a pernicious cycle of mathematics mislearning." (Battista, 1994, p.468)

Burns (1994, p.472) further suggests that teachers will largely ignore reform attempts as they see it as "just another of education's many bandwagons that we must acknowledge superficially until it passes by and the dust settles".

The contexts in which teachers work are believed to have a significant effect on their practice. In particular, students unfamiliar with teaching for understanding resist new reforms, parents protest departures from traditional practice and administrators are intolerant of less orderly classrooms or requests for new resources (Stein et al, 1996). Even the leaders in the school, who advocate the change can hinder the change by being over controlling, too ineffectual or through cashing in on the early success of the implementation by moving on to higher things (Hargreaves, 1997).

The external curricula guidelines also impede change as they often mandate pacing and coverage (Ball, 1996). As Hargreaves (1997) states, the reform is made near impossible when pursued in isolation, where unchanging structures, such as textbooks or standardised tests, create a conflict in direction.

Hargreaves (1997) also believes that the failure of reform is often due to poor implementation. It may be that the reason for change is poorly conceptualised or communicated, the change may be too broad or too limited and specific so that little change occurs. Further, the change may
be too fast for people to cope with or so slow that the participants become bored and lose interest. The change may also be under resourced and not providing the time or resources necessary (Hargreaves, 1997). Adelman and Panton-Walking Eagle (1997) suggest that the time pressures can weigh heavily on the minds of teachers and distract them from their reform goals.

The research literature also suggests various ways to improve the acceptance of reform and new initiatives. Grant et al (1996) believe that teachers should be given the same considerations as learners that they give their students, a fact that has only been discussed during the past five years. However, the process of reflection is seen as central to learning to teach and accepting new initiatives (Ball, 1996; Aitken & Mildon, 1991; Russell & Munby, 1992). As Hart et al (1992) profess,

> If we don’t reflect, we are teaching ‘in the dark’ without knowing if we are effective and if we should modify our teaching.” (p.40)

However, reflective thinking has long been promoted as critical in achieving change and professional growth (eg. Dewey, 1933). Dewey (1933, p.3) simply defines reflective thinking as “the kind of thinking that consists in turning a subject over in the mind and giving it serious and consecutive consideration.” He described reflective thinking as, when a 'perplexity' arises, the person decides to face it and draws together their experiences to relate them to the new experience. The person then forms ideas for courses of action and evaluates them. This process continues until a proposed solution meets all the conditions of the problem. The choice of solution is then verified through practice.

Educational researchers (eg. Blumenfeld et al, 1994; Hunsaker & Johnston, 1992) have documented the central role of collaboration in the reform process and claim it is a process intertwined with reflective practice. Just as many of the new reforms promote collaborative learning as a powerful way of learning mathematics, collaboration allows teachers to develop shared meaning and thus their own socially constructed understanding of their work (Blumenfeld et al, 1994). Fullan (1993) agrees in part but qualifies that the change process needs to involve an equal blending of learning on an individual and collaborative basis. He claims that
collaboration can often involve unthinking acceptance and a suppression of an individual's thoughts but can provide opportunities for the discussion of problems and the seeking of solutions. Alternatively, individualism imposes a ceiling effect on inquiry as solutions are limited to the individual's experiences but allows the teacher to personally reflect, think, inquire and develop their own vision (Fullan, 1993).

Effective reflection, on an individual or collaborative level, would encourage teachers to take risks in trying new innovations and initiatives in their classroom. However, a risk taking mentality is essential in facilitating change. The teacher needs to understand that problems and difficulties need to be confronted for breakthroughs in understanding to occur (Long, 1996; Fullan, 1993). This process of experimentation and ongoing reflection enables teachers to become aware of and examine the beliefs and assumptions they hold (Loewenberg Ball, 1991; Baird, 1992). Further, it enables reforms to be gradually accepted along with their underlying philosophies (Wilson et al, 1996). Wilson et al (1996) further encourage collaboration with people from different parts of the education system as different viewpoints are shared and reflected upon. Others advocate that beginning teachers be given opportunities to talk to more experienced teachers about their practice to improve their knowledge of teaching (eg. Aitken & Mildon, 1991; Feldt, 1993).

Battista (1994) suggests certain changes to the education system need to occur to facilitate reform in schools. Firstly he proposes that university teacher education present mathematics as sense-making, rather than the learning of set procedures and rules which is common to most university mathematics and mathematics education programs.

Secondly, Battista (1994) believes it is necessary to design inserviceing that helps teachers better understand mathematics and how to implement new reforms. The typical one or two day workshops are ineffective as they fail to "address underlying pedagogical philosophies, their knowledge and beliefs about mathematics, or the processes by which students come to understand mathematical ideas" (p. 470). Extensive inserviceing, lasting at least several weeks, is needed that provides comprehensive sets of curriculum materials in combination with instruction in mathematics and mathematics learning (Battista, 1994). Burns (1994) agrees that
Instructional materials must be provided, giving classroom-tested lessons and assessments consistent with the new reforms.

It is also seen as important that the teachers are involved in the content and format of the professional development sessions, allowing them to become owners of the programs (Bos, 1995; Ball, 1996).

Long (1996) sees great value in large scale reform practices. She believes that to reduce the probability of short lived fads, systemic reform needs to be implemented.

"Systemic reform is fundamental, comprehensive, and coordinated change that occurs when all essential elements of a system—human resources, curriculum and instruction, assessment and evaluation, management, policy, governance, finance and external relations—are engaged and acting in concert." (Long, 1996, p.584)

Sergiovanni and Starratt (1993) suggest a healthy climate for systemic reform is typified by high staff morale, autonomy and sufficient stability and stress tolerance to adapt relatively easily with change. In conjunction with systemic reform are professional development practices that address all components of the system. It also needs to be realised that this change will take a considerable amount of time and time needs to be structured to allow for reflection to occur (Cohen, 1993; Hargreaves, 1997). Time needs to made for assessing, redesigning practices and for getting back on track when other issues have taken precedence (Adelman & Panton Walking-Eagle, 1997).

Wilsey and Killion (1982) believe that different structures need to be established to facilitate change, depending on the stage of readiness of the teacher. They suggest that if a teacher has a right-wrong orientation and believes that there is no need to seek new knowledge due to their present effectiveness, it is likely they will require a highly structured learning environment. They will not respond to theory but good practice would be to provide them with practical models and practical examples, to allow time for consolidation and provide regular follow up. However, if the teacher recognises that a variety of alternatives exist for a situation and accept different points of view through critical analysis, Wilsey and
Killion (1982) suggest they be given opportunities to discuss and share viewpoints with others and have their say in the planning and delivery of the new initiative.

Sergiovanni (1988) suggests similar approaches to implementing change. He claims that different people are to have different learning cycles, some learning best by dealing with concrete examples whilst others prefer to read about it or become more cognitively orientated before experiencing it. Another teacher may prefer to observe new learning experiences in action, reflect upon it and then experience it themselves at a concrete level.

Fullan (1993) believes that the main problem in education today is that too many innovations are mandated and adopted superficially in education. He believes that,

"If there is one cardinal rule of change in human condition, it is that you cannot make people change. You cannot force them to think differently or compel them to think differently or compel them to develop new skills." (p.23)

These development practices have the potential of addressing and changing the beliefs on mathematics and learning that teachers have developed. Only by learning mathematics properly can teachers become convinced that mathematics consists of sense-making and learn the skills and pedagogy necessary for teaching mathematics as sense making (Sykes, 1996).

2.5 Conclusion

The review of related literature presented a theoretical framework for understanding the beliefs held by teachers of mathematics and gave a preliminary understanding of the factors that tend to influence the process of educational reform.

The research conducted in this study occurred in the naturalistic paradigm and details of the methodology are outlined in the following chapter.
CHAPTER 3

METHODOLOGY
3. Methodology

3.1 Introduction

In this chapter I shall present the methodological framework for the research. The methodology is located within the bounds of the naturalistic paradigm (also called the constructivist, hermeneutic or interpretive paradigm with slight shadings in meaning). Guba and Lincoln (1989), who suggest a methodological approach well suited to this inquiry, chose to label the paradigm 'constructivist' but to avoid confusion with my discussion of constructivist theories of teaching and learning mathematics, I feel 'naturalistic' paradigm will suffice.

3.2 Choice of the Naturalistic Paradigm for Inquiry

This research study has the aim of exploring the beliefs of teachers with regard to the teaching and learning of mathematics. More importantly the research attempts to understand the process of mathematics educational reform in the current socio-political context. In broader terms, the study is interested in gaining an understanding of what the teachers think and what influences their thinking, rather than the general quantitative aim of proving a cause-effect relationship. Further, the data are rich and thick in description which lends itself to qualitative study (Bogdan & Biklen, 1992; Glesne & Peshkin, 1992).

As Guba and Lincoln (1989; p.67) indicate, knowledge is a human construction and cannot be taken as ultimate truth.

"... it is plain that knowledge emerges as a product of an interaction between humans or (in the physical sciences) between human and non-human objects. Different interactions will yield different findings. Strange as it may sound to ears socialised by the conventional paradigm, the results are literally—we stress literally-created by that interaction; they are not "discovered" as if they had always been "out there"."  

Further, as Guba and Lincoln indicate (1989), the constructions through which people make sense of their situations are significantly shaped by the values that they hold and thus a methodology claiming to be value free
would have little utility in this inquiry. The constructions are also inextricably linked to the particular physical, social and cultural context within which they are developed and refer. This inquiry will understand and describe the important contextual information as it relates to and influences the inquiry.

This study also uses non-intrusive methods in that it attempts to collect data from relatively non-contrived, non-experimental situations, such as informal conversations, non-structured interviews and normally occurring staffroom experiences. These methodological approaches are undeniably suited to the naturalistic paradigm, especially because it acknowledges the inextricable and critical influence of values and the context of the inquiry on the constructions that develop.

3.3 Presuppositions

I have made several presuppositions about research of this type which I shall make explicit. Kaplan (1964) comments,

"We presuppose, in every inquiry, not only a set of data but also a set of generalisations, both about our materials and about our instruments by which they are to be transformed in the cognitive enterprise. We draw our presuppositions from earlier inquiries, from other sciences, from everyday knowledge, from the experiences of conflict and frustration which motivated our inquiry, from habit and tradition, from who knows where." (p.87)

I believe making my presuppositions explicit is one way of enhancing the credibility of my research. This process makes me consciously aware of what my biases are and thus, puts me in a better position to control them. I assume as I am dealing with teachers as professionals and have established a relationship with them, that the information they give will be their concept of reality. I also assume I have enough background as a teacher of mathematics to be able to analyse the data from a mathematics teacher’s perspective. In addition, I have brought to the study a range of presuppositions concerning mathematics and the learning of mathematics.
I believe that students' mathematics education should provide them with an understanding of the concepts and processes behind solutions. This learning should be prolonged and should provide students with skills and knowledge that empowers them to understand the world and how it works. It is my opinion that the most effective way for achieving these goals in mathematics education is to teach using constructivist approaches. I find that behaviourist type approaches such as 'drill and practice' enable students to achieve high results in exams that involve questions that are rigid in keeping with those learned as rote. However, I believe this approach fails to provide students with a rational understanding of mathematics and the knowledge is short lived.

In my limited 4 years experience as a mathematics teacher in the NSW DOSE system, I have witnessed attempts to promote strategies that follow constructivist principles. I have generally agreed with the thinking behind the new initiatives but have witnessed considerable resistance from many. However, classroom management has been a significant concern in the schools I have taught at and I feel that certain strategies were avoided as they reduced the control the teacher had on the class. However, I believe there may be other factors that enable or inhibit the acceptance of new initiatives and these need to be considered in further attempts at educational reform.

3.4 Site & Participants

Although already introduced in the first chapter, the importance of the site and participants necessitates further mention at this point. As Guba and Lincoln (1989; p.142) suggest,

"The major task of the constructivist investigator is to tease out the constructions that various actors in a setting hold and, so far as possible, to bring them into conjunction—a joining-with one another and with whatever information can be brought to bear on the issues involved."

This study involves six teachers of mathematics, male and female and ranging in experience from less than 3 years to more than 20 years. There are teachers with experience in overseas education systems and teachers
with head teacher experience. For anonymity purposes, pseudonames were given to the participants. The teachers were chosen as a purposive sample to obtain a range of beliefs, ideas and experiences. However, details of the sampling will occur in the next section and details of the participants will be elaborated in the next chapter.

The sites for data collection primarily involve two high schools, in the Illawarra and South-West Metropolitan areas. These sites were discussed in some detail in the Introduction Chapter.

3.5 Research Design

It was difficult to decide on the research design before this inquiry due to it being of an emergent design. Thus it was important to complete the research before the description of methodology could be completed. Lincoln and Guba (1985) indicate the complex nature of the naturalistic inquiry in the following statement,

"...naturalistic studies are virtually impossible to design in any definitive way before the study is actually undertaken. But naturalistic studies do have a characteristic pattern of flow or development. Naturalistic inquiry is always carried out, logically enough in a natural setting since context is so heavily implicated in meaning." (p.187)

The methodology employed in this inquiry follows the Guba and Lincoln (1989) 'Methodology of Constructivist Inquiry' model following.
3.6 The Flow of Naturalistic Inquiry

The following includes a discussion of the most important elements and processes involved in the inquiry design. Further, an explanation of the models adaptation to this particular inquiry occurs as part of the discussion.

As Guba and Lincoln (1989) explain, the model cannot be simplified to a two-dimensional understanding, with lines shown having a tenuous quality and the hermeneutic dialectic circle representing a sphere,
extending out of the page front and back. The entry conditions, shown in
the stable triangle as the natural context, human instruments, qualitative
methods and tacit knowledge, must be met for the naturalistic process to
occur.

3.6.1 The Natural Context

The study must occur within the 'natural context'. As ultimate truth is
rejected and multiple realities assumed, and they are dependent on the
time and context of the participants who hold them, it is essential that the
research occurs in the time and context the researcher wants to
understand (Guba & Lincoln, 1989).

"Contexts give life to and are given life by the constructions that are held by the
people in them." (Guba & Lincoln, 1989, p.175)

• In this inquiry, data collection occurred mainly in the natural setting of
the high schools where the teachers were most comfortable with
discussing their views. This study was not contrived as a traditional
experimental experiment so all variables were an important and
essential part of the context. The inquiry employed non-intrusive
methods in collecting data from relatively non-contrived, non-
experimental situations. The methods included informal
conversations, non-structured interviews and observations of normally
occurring mathematics staffrooms.

• The interviews with Dan, Arnold, Jan and Violet occurred in their
classrooms during lunchtimes, free periods and after school. The
interview with Frank occurred at my home. Frank was comfortable in
this environment as he was a close friend and he was able to discuss his
opinions freely over a drink. Due to time constraints at work, Leo was
more comfortable to have a list of the broad interview questions and to
write down his ideas and feelings at home. As I was a participant in
these settings I was able to make further observations as a member of
the mathematics faculties.
3.6.2 The Human Instrument

The researcher enters the inquiry as a learner, with little to no understanding of what is salient. The human instrument is adaptable and without prior programming can begin to discern what is important and then focus their inquiry. Further, the argument that humans are subjective, biased and unreliable is irrelevant as no other option exists that has the same infinitely adaptable qualities (Guba & Lincoln, 1989).

- In this inquiry, the human instrument, namely my mind, enabled me to respond to the various environmental cues that existed in the 'natural setting'. It also enabled me to comprehend multiple inputs with the one instrument. Further it allowed me to generate hypotheses on the spot and to test them with the respondents in the 'natural setting'. However, as the use of human-as-instrument techniques can lead to a lower degree of trustworthiness (Guba & Lincoln, 1985), I attempted to combat this factor in part by making explicit my own beliefs, assumptions and values that relate to this study.

3.6.3 Qualitative Methods

The methods that are most readily available and accessible to humans are qualitative methods. As Guba and Lincoln (1989, p.176) express,

"Humans collect information best, and most easily, through the direct employment of their senses: talking to people, observing their activities, reading their documents, assessing the unobtrusive signs they leave behind, responding to their non-verbal cues, and the like."

- Methods used in this study included participant observations, informal conversations and semi-structured interviews which are typical qualitative methods. Due to the time limitations on the participants and myself, it was necessary to follow an interview schedule that considered their commitments. The methods will be discussed further in the section on data collection.
3.6.4 Tacit Knowledge

Tacit knowledge includes the beliefs, values, opinions, attitudes, ideas and knowledge that a person cannot make explicit (Guba & Lincoln, 1985). As the researcher begins with very little idea of what is important, they are able to bring their tacit knowledge to bear in understanding the constructions. As Guba and Lincoln (1989) profess, without the use of tacit knowledge it is very likely that the naturalistic inquiry would be severely constrained.

- In this inquiry, tacit knowledge was the base upon which many of the insights and hypotheses were developed. The reflective journal was also an effective tool for making my tacit knowledge more explicit and for making intuitive decisions during the research.

3.6.5 The Hermeneutic Circle

The above four specifications need to be met for the naturalistic inquiry to have any level of success. The next process, the hermeneutic dialectic process involves elements that continuously interact, cycling and recycling until consensus emerges (Guba & Lincoln, 1989). Purposive sampling for maximum variation is the mode of choice for naturalistic researchers. The sample is selected so that each element is chosen to be as different from preceding elements as possible and serve the particular needs of the inquiry at that moment. As Guba and Lincoln (1985) state,

"In naturalistic investigations, which are tied so intimately to contextual factors, the purpose of sampling will most often be to include as much information as possible, in all of its various ramifications and constructions." (p.201)

- This study sampled with the purpose of capturing as rich a vein of the data as possible given the time and resources available for the study. Therefore the participants were those who were enthusiastic to be involved in the study, who lived or worked close enough to visit, could communicate effectively and whose commitments allowed time for some in-depth interviewing and observations. As I had worked with these people, I had some degree of knowledge of their ideas and beliefs
and also chose teachers that would provide a contrasting variety of experience, ideas and beliefs.

Guba and Lincoln (1989) purport that the hermeneutic circle involves an interwoven process of data collection and analysis that occurs as the inquiry proceeds. Further, part of the hermeneutic circle concerns grounding the findings that emerge in the respondents' constructions. As the data collection and analysis informs further data collection and analysis, a joint construction begins to emerge which is grounded in all the individual respondent constructions. The grounded constructions or grounded theory is the most informed and elaborate construction that can be developed in the natural setting and is inextricably linked to the natural setting (Strauss & Corbin, 1990). The grounded construction may be accepted when it accounts for the data the research encompassed, it provides a level of understanding acceptable and credible to respondents and it deals with the core questions, problems and constructs that emerged from the inquiry (Guba & Lincoln, 1989).

- In this inquiry, the conclusions to this study provided the grounded constructions for educational reform in the current socio-political climate as they emerged from the research. It is intended that this grounded theory would then inform a model of change for teachers of mathematics.

The final element in the hermeneutic circle is the emergent design. As the inquirer does not know their research focus to any significant extent at the beginning of the inquiry, they also have little preliminary understanding about an appropriate research design. As the research proceeds, the researcher seeks to refine and extend the design, becoming more structured and defined in their approach through cycles of the hermeneutic circle. Bogdan and Biklen (1992) use the metaphor of a funnel to describe this process, where the research question is quite open at the beginning of the study but is gradually refined through the human instruments to a more specific focus.
3.6.6 The Case Report

The multiple iterations of the hermeneutic circle result in a case report. It does not provide a depiction of the true state of affairs or a series of generalisations that can be applied to other contexts. Rather the case report is the grounded joint construction that helps the reader understand the state of affairs that is believed by the respondents to exist, with the underlying motives, feelings and rationales that influence those beliefs (Guba & Lincoln, 1989). It provides 'thick description' that clarifies the context and makes it possible for the reader to 'vicariously experience' it. The vicarious experience is crucial as it provides many of the opportunities to learn that are provided by actual experience and can lead to reconstruction by the reader. As Guba and Lincoln (1989, p.181) state,

"The case report is thus a major vehicle for the dissemination, application, and (individual) aggregation of knowledge."

- In this inquiry, the case study reports enabled me to give an explanation and understanding of the teacher's personal theories on teaching and learning mathematics and the factors that influenced a change in their pedagogy. This occurred as thick description, giving intricate details of the beliefs, ideas, knowledge and experiences of the participants.

Further, the two circles to the left and right of the model impinge on the research. The left circle shows that the inquiry is continuously shaped and tested by negotiation between the researcher and the respondents. Similarly the right circle shows that discovery and verification processes are interactive and interwoven processes that occur continuously throughout the inquiry.

- In this inquiry it was necessary to discuss my constructions and understanding of realities with the participants throughout the data collection and analysis. This enabled me to correct misconceptions and to add new understandings.
3.7 The Quality or Goodness of the Inquiry

Guba and Lincoln (1989) believe that there are three approaches to considering the quality or goodness of any naturalistic inquiry: trustworthiness, the contribution by the nature of the hermeneutic process and authenticity criteria.

3.7.1 Trustworthiness

The trustworthiness of rationalistic research is governed by the factors of internal validity, external validity, reliability and objectivity. However, these criteria bear little relevance in the naturalistic paradigm. Guba and Lincoln (1989) assert that naturalistic inquiry is based upon the different but parallel criteria of credibility, transferability, dependability and confirmability. To most effectively satisfy these four criteria, certain processes were incorporated into the study and will be elaborated in the following discussion.

Credibility

Guba and Lincoln (1989) define credibility as the establishment of consistency between the constructed realities of participants and those realities as represented by the researcher. Prolonged engagement at the site is one way of gaining credibility. It involves the investment of sufficient time to learn the culture, test for distortions in the information and to build rapport with the participants. Further, persistent observation enables the researcher to identify elements and characteristics that are most relevant to the problem being explored and to focus on them in detail.

As I was a work colleague and friend of the participants I had prolonged engagement at the sites and was fortunate to have built a considerable degree of trust with them. I was also familiar with the specific culture of mathematics teaching in these schools as I had taught in the schools and had enjoyed many discussions with them as a member of the faculties. Further, I was interacting with the participants on a work and social level during the process of data collection and analysis.
Another way of establishing credibility is through peer debriefing. This process involves engaging with a peer, removed from the inquiry, in extensive discussions of findings, conclusions, analyses and problems (Guba & Lincoln, 1989). Further, negative case analysis, where working hypotheses are revised until it accounts for near to all cases, provides credibility to the inquiry.

My wife fulfilled the role of peer debriefing well. She enabled me to express ideas and acted as a sounding board for hypotheses. She also had no hesitation in providing constructive criticism when it was needed. Further, my research supervisor helped in keeping my findings and conclusions credible and in line with the collected data. Further, massaging the data for each participant a number of times enabled me to refine my understanding of their constructed realities.

Progressive subjectivity or the process of monitoring my own developing constructions was made easier by recording my own beliefs, attitudes and presuppositions before the inquiry began. As this process occurred at the beginning of the inquiry, I was better aware of the bias that I may bring with me into the study. Member checks were employed to allow all data, coding categories, interpretations and conclusions to be tested with participants. Copies of collected data were distributed to respondents and opportunities provided for them to correct any errors or misinterpretations and add further information. Near the completion of the study one participant, Arnold, read through the study and provided some salient feedback on the results.

These processes were employed and added significant credibility to the research.

Transferability
Transferability, in the naturalistic paradigm, is always relative and depends on the degree to which the important conditions of context and participants overlap. However, the responsibility of the researcher is not to provide transferability but to provide the database so that transferability judgments are possible to be made by potential appliers (Guba & Lincoln, 1985). The process of 'thick description' created the potential for the inferences of this research to be applied to another context.
**Dependability**

Dependability is concerned with the stability of the data over time. It is expected that due to the emerging design, methodological changes and shifts in constructions will occur, providing more mature reconstructions. This is the hallmark of a successful inquiry (Guba & Lincoln, 1989). However, there needs to be a data trail that enables reviewers of the inquiry to explore the process, judge the decisions and understand the important factors of the context that led to decisions and interpretations.

The dependability audit is the technique for documenting the logic of processes and methods employed and thus the quality and appropriateness of the inquiry. This audit was conducted separately by my research supervisor and myself at the same time as a confirmability audit.

**Confirmability**

"Like objectivity, confirmability is concerned with assuring that data, interpretations, and outcomes of the inquiries are rooted in contexts and persons apart from the evaluator and are not simply figments of the evaluator's imagination." (Guba & Lincoln, 1989, p.243)

The naturalistic paradigms' assurances of integrity of the findings are found in the actual data. Thus, constructions and inferences can be linked back to their sources and the path of interpretation is explicit and implicit in the narrative of the case report. Thus, in this inquiry the data and the processes used to interpret them are made obvious and are found in the body of this thesis and associated appendices.

A confirmability audit however was used to confirm the data and interpretations of the inquiry by tracing all constructions to their original sources. For this inquiry, the study's results, interpretations and conclusions were traced back through the use of a clear and definite audit trail. As mentioned, audits were conducted by myself and my supervisor to ensure dependability and confirmability were achieved.
3.7.2 The Hermeneutic Process as its Own Quality Control

Due to the nature of the hermeneutic dialectic process, data were analysed immediately on receipt. They were reflected back for comment immediately, especially during interviews, which formed the main method of collecting data in this inquiry. Further, those data were incorporated into the grounded joint construction that emerged and formed the base of the conclusions chapter. Thus, in this process, opportunities for errors to go unnoticed were quite limited.

Furthermore, as Guba and Lincoln (1989) argue, the possibility that the presuppositions of the researcher can shape the results is virtually zero given that they follow the hermeneutic dialectic principles. As mentioned, my presuppositions were made explicit before the inquiry and I followed the principles of the hermeneutic dialectic process, thus adding integrity to the final conclusions.

3.7.3 Authenticity

Guba and Lincoln (1989) believe it is also necessary that a naturalistic inquiry satisfies further authenticity criteria to ensure the goodness of the inquiry. To achieve authenticity, the inquiry needs to satisfy criteria including fairness, ontological authenticity, educative authenticity, catalytic authenticity and tactical authenticity. Fairness refers to the extent that different constructions and their underlying values are accounted for in a balanced way. To achieve fairness these different constructions were all displayed and conflicts were discussed.

Ontological authenticity, which refers to the extent that the participants' constructions are improved, elaborated and expanded, was achieved through the provision of vicarious experience. As previously discussed, this inquiry used 'thick description', which detailed the realities of the participants and gave them opportunities to apprehend the interpretations. Further, participants claimed to have a much better understanding of their own realities after the inquiry process.
Educative authenticity refers to the extent that participants' understanding of the constructions of others are enhanced. Some participants had no concern in their case studies being shared with others in the study. It was claimed by some that they had a better understanding of the constructions of others through this process and by making their own constructions explicit. Catalytic authenticity, where understanding of their own and other constructions leads to some form of action or decision making, was evidenced by two of the participants. Arnold and Frank claimed to discuss their beliefs and practices more with other mathematics teachers. Lastly, tactical authenticity, where the participants are empowered to act, was not obvious. However, participants were involved in the negotiation of direction of the inquiry.

3.8 Data Collection

3.8.1 Introduction

Various data collection techniques were employed to capture the 'slice of life' in the 'natural context'. These techniques included participant observation, semi-structured interviews, informal conversations and a reflective journal. It should also be noted that the data collection and data analysis were interwoven processes, which is a typical procedure in naturalistic inquiry (Lincoln & Guba, 1989). The same data collection techniques were used with each teacher, but these will be further discussed in the following.

3.8.2 Participant Observation

Participant observation involves the researcher becoming immersed in the setting to experience the world as the subject sees it. It allows the researcher to grasp the motives, unconscious behaviours and actions in the natural environment (Bogdan & Biklen, 1992). The participant observation was a major source of data collection in this study and involved interviews and non-intrusive observations of staffroom culture.
3.8.2.1 Interviews

"In all of these situations, the interview is used to gather descriptive data in the subject's own words so that the researcher can develop insights on how subjects interpret some piece of the world." (Bogdan & Biklen, 1992, p.135)

The interviews were an essential part of the data collection process. Tuckman (1972) claims the purpose of interviews is to gain access to what goes on inside a person's mind. It is used to find what the person knows, what they like and dislike, and what they think (cited in Cohen & Manion, 1992). Thus, it seemed that the interview was the ideal method for collecting data concerning the mathematics teachers' ideas and beliefs.

The interview schedule for the teachers was fundamentally the same with only minor variations. They involved a semi-structured interview followed by more structured follow-up interviews. The nature of inquiry meant we began with some general issues and then became more focused in the follow-up interviews. As Guba and Lincoln (1989) show, the grounded constructions developed as a cycle of redefining and revising. The types of interviews will be discussed in the following:

Semi-Structured Initial Interview

The purpose of the semi-structured interviews was to raise some broad issues and allow the teachers to then present what they saw as relevant (see Appendix A). This gave me the freedom to probe or pursue unexpected leads and emphasise points of interest. The broad questions had the purpose of illuminating the teachers' beliefs on the effective teaching of mathematics and the important processes and elements in the acceptance of new DOSE initiatives.

The teachers seemed to have little difficulty in expressing themselves and were only restricted only by the time constraints. The participants were either given a list of the broad interview questions a week before the interviews or questions were briefly introduced during discussion so they would begin reflecting upon the issues. I believe this made it easier for them to make their beliefs explicit during the interviews. The interviews
for Arnold, Jan, Frank and Dan were recorded and transcribed whilst Violet was more comfortable for me to record only fieldnotes. However, Violet allowed me to record certain quotes in my fieldnotes when specifically asked. Due to Leo's role as head teacher he was limited in time and preferred to write responses at home to the broad interview questions when he had more time. A wealth of data were collected from these interviews (See Appendix B). The analysis of the data enabled the salient points to be extracted and used as a focus in the follow-up interviews.

Structured, Follow-up Interviews

Often the follow-up interviews involved general discussions with the participants, clarifying and extending their previous initial interview responses. They were informal interviews in that they were largely discussions of points that emerged from the initial interviews. I had specific questions that emerged from the interviews which were asked either in discussions at the site or through phone calls. These interviews also allowed me to clarify the findings. The discussions were mostly written as fieldnotes and incorporated into the case studies (See Appendix C).

A number of probing questions were used to get 'inside their heads'. The teachers found this to be a difficult process but were able to make their thoughts explicit. Furthermore, the high degree of rapport was important as it enabled the teachers to feel comfortable in expressing themselves.

3.8.2.2 Staffroom Observations

By the term 'staffroom observations I make reference to my observations of the participants at the sites, but which largely consisted of conversations in staffrooms. As I was a permanent member of staff in the Metropolitan South West Sydney high school for 3 years and the Illawarra high school for 1 year, I was able to make observations during this time. Obviously during the research these observations became more intense. As these observations were largely built up over time, fieldnotes were not taken. Rather, these constructions were written straight into the body of the thesis and altered where necessary at each subsequent reading.
3.8.2.3 Reflective Journal

In addition to all the observations and interview data, separate summaries, inferences, speculations, considerations and problems were recorded using a reflective journal. This was used more or less on a random basis but especially when I needed to understand the data. The journal enabled me to articulate my thoughts and make sense of the research. It was also effective in keeping an account of the methodological decisions, especially in the area of data analysis and the formulation of coding categories. It was further helpful in the development of the grounded theory (See Appendix D).

3.9 Data Analysis

3.9.1 Introduction

The data analysis was not an inclusive phase that occurred at a certain stage in the research. It began at the same time as the data collection and was a continual thread throughout the research. However, this is typical of naturalistic inquiry (Guba & Lincoln, 1989). The purpose of the data analysis was to reconstruct the data in some meaningful way. The reflective journal was an effective tool during the analytical process, especially in the construction of coding categories and their applications.

3.9.2 Overview of Data Analysis

The main analytic steps that were employed in the data analysis were:

(i) To transcribe and accumulate the relevant data.

(ii) Construction of various coding categories.

(iii) Application of these coding categories to the data.

(iv) Tests for goodness/integrity/trustworthiness of constructions.
(v) Description and interpretation of the coding categories.
(cases studies)

(vi) Development of a grounded theory.

It is worthwhile to note that the construction of the categories, their application and the tests for trustworthiness were a cyclical process that involved a number of iterations. This will be discussed under the heading of “theme generation” in the following:

3.9.3 Theme Generation- Interviews

Over a period of approximately six months, a considerable amount of interview data were collected. The first task in the analysis of the data were to listen to the audio recordings of the interviews with the purpose of gaining a holistic perspective and to jot down the main salient points. It was then necessary to transcribe the interviews. This was a laborious task but I was further able to gain a detailed view of the interview contents. The next step involved reading and re-reading the transcripts. During this process, I formed some tentative categories by writing down what seemed to be the main elements.

The coding was done on two separate levels. Firstly for the individual case studies the interview data were organised into the following categories;

(i) Background & Experience (B)
(The experience, positions, type of schools, education systems and personal attributes of the participant)

(ii) Influence of the DOSE (D)
(The degree to which the participant has taken notice of and accepted into their practice, past DOSE initiatives)

(iii) Influences on Forming Beliefs (F)
(The factors that have influenced the development of the participants beliefs about teaching and learning mathematics)
(iv) Factors Enabling Change (E)
(Those factors that better enable a teacher to change their practice)

(v) Factors Inhibiting Change (I)
(Those factors that act as barriers to changes in the teachers practice)

It was then important to examine the interview transcripts and code by assigning the categories to the relevant sections of text. However, through the development of the individual case studies, further categories became apparent. Thus, when contrasting the case studies, especially in the area of inhibitors and enablers in the change process, it was important to construct the following categories from the data in the completed case studies, firstly label them according to the name of the participant.

(a) Arnold (A), Dan (D), Frank (F), Jan (J), Leo (L), Violet (V)

(b) Influence on beliefs from:
   (i) Own Schooling / Education (E)
   (ii) Parents (P)
   (iii) Beginning Teaching (B)

(c) Influence of the DOSE on teaching (D)

(d) Willingness to Change (W)

(e) Congruency between own Beliefs & Reform (F)

(f) Influence on Practice from:
   (i) The School Culture (C)
   (ii) The Assessment Structure (A)
   (iii) The School Textbook (K)

(g) Improvements in Staff Development Practices through
   (i) Staff Support Structure (S)
   (ii) Reflection Techniques (G)
The following model shows how the coding of the data occurred.

Using a word processing program, each transcripted and fieldnoted interview were given the above codes. Then using the 'sort' tool the data were organised into their various categories (See Appendix E). This enabled for the development of each participant's personal story, discussed as case reports in the following chapter.
3.10 Conclusion

As the methodology of this naturalistic research was largely emergent, the methodological processes often needed adapting to suit the purposes of this study. Hence, it was impossible to outline the methodology until the data were collected and analysed. However, the methodology enabled the formation of some illuminating case studies and the development of grounded constructions.
CHAPTER 4.

RESULTS
4. Findings

4.1 Introduction

The aim of this chapter is to illuminate the personal stories of the participants as six separate case studies. In essence I shall highlight,

- Their Background
- The Influence of the DSE on their Practice
- Their Beliefs on the Teaching & Learning of Mathematics
- Their Beliefs on Factors that Influence Changes in Practice

The findings provide the basis of the conclusions to the study and the development of a grounded theory for mathematics education in the current socio-political context. As part of the conclusions to the study I shall draw together the case studies and discuss the similarities and differences that emerged.
4.2 Arnold's Story

4.2.1 Background

Arnold was a relatively inexperienced teacher. He was still classified as a beginning teacher according to the NSW Department of Education definitions as he was within his first three years of teaching. He had remained at the same South-West Metropolitan Sydney school for two and a half years, teaching an equal share of computing and mathematics classes. Arnold claimed to be less enthusiastic about teaching mathematics and was "moving more and more away from maths towards computing" (12/8/97). He was pleased at recently being assigned the school role of computing coordinator.

On a personal level, Arnold was married with two infant children and had a strong commitment to his local church. He travelled to work by train, often taking one and a half hours each way.

4.2.2 Learning Mathematics

Arnold suggested that teaching for understanding was an essential element of the teaching practice. He suggested that many logical errors were overcome when the students had a real understanding of the mathematics and its applications. This belief can be evidenced by the comment,

"I think also because the kids quite often don't have an understanding of what they are doing, that once you give them an understanding... you suddenly solve a lot of the problems as far as them getting the right answer or not getting the right answer."

(12/8/97)

Although Arnold had suggested the necessity of teaching for understanding he also saw value in drill and practise learning procedures. He suggested that after efforts were made to teach for understanding, "you can decide whether you really want to hammer something home, you know do it one hundred times over". Arnold believed that the students' understanding could be reinforced by repetitive practice of the mathematics learned.
Arnold further supported this belief by claiming that the students were more likely to retain an understanding of the mathematics if lessons involved "hands-on experience rather than just going through it in theory". He was of the opinion that students would remember the mathematics if they could relate it to a practical experience.

"I've found you get much more recognition off people when you can actually relate it back to the thing they have actually done." (12/8/97)

Making the learning of mathematics relevant to the students through real life applications was central to Arnold's beliefs on teaching and learning mathematics. This is evidenced by the statement,

"I think the important thing is that it needs to be made real to the kids. So if you can actually show them a situation where 'this is where we could actually use maths and maths could actually help us to get the right answer here and that is something that I would want to do as opposed to something that the teacher might suggest to me', then I see that as one of the main ways of getting people to learn." (12/8/97)

This belief was further supported by Arnold's comments on groupwork.

"Just the idea of the way society is and that we tend to specialise in one thing and rely on other people for other things... You know, you specialise in what you are going to do. I think group work has the potential for doing that really well." (12/8/97)

He felt that groupwork had value in that it encouraged students to work "interdependently" in the "way the real world works". This belief was congruent with his stated objective for teaching mathematics, that,

"The whole reason we are trying to do it is because we think it is going to be useful to them in later life." (12/8/97)

One further belief that emerged strongly from Arnold's interview was that the learning experience should be enjoyable for the students. It was obvious also from my own experience working with Arnold that he
attempted to make the classroom an environment where the students felt comfortable and enjoyed the mathematics.

Arnold probably summed up many of his beliefs on teaching and learning mathematics by the statement,

"If we give them practical stuff, interesting stuff and relevant stuff, if they don't get it now, in ten years time they may look back and go, 'I remember it being explained like this' or 'I remember when we did this and now I know how it works and I remember it.'" (12/8/97)

4.2.3 Factors Influencing Change

Arnold was questioned on the influence DSE initiatives had on his teaching and what factors make it easier or more difficult to implement these initiatives. He commented,

"I used a few things from the syllabus. Now that I don't teach junior years as much, I haven't put as much emphasis on how the department thinks I should be teaching." (12/8/97)

Arnold believed that the DSE had not influenced his teaching of mathematics to any significant extent.

He was also asked about the factors that could, or already had, affected his teaching of mathematics. His father was suggested to have had an influence on his teaching. As mentioned previously, Arnold believed that effective mathematics teaching would use real life applications. He claimed that his father helped him understand mathematics by showing him where the mathematics had uses.

"I remember that my dad would come and reinforce all that stuff by trying to show me real life situations." (12/8/97)

Arnold also talked of how his own education may have affected the way he teaches mathematics. His experiences of mathematics as a student were largely through a traditional pedagogy. As Arnold describes,
"But at school I was taught very straight down the line. I don't remember a lot of that, sort of creative stuff."

(12/8/97)

At the beginning of his full time teaching appointment at Egg Vale he claimed that he tried a similar pedagogy.

"Yes, I think I might have tried some things like that. 'Here's a page of the textbook. It's straight forward, you should be able to do it.' If I said to them now I expect it done at the end of the lesson then I could just hold them responsible."

(12/8/97)

However, Arnold soon arrived at the understanding that the same way he was taught mathematics was not going to be as successful for him as a teacher at Egg Vale High School.

"And that would have worked at my school no worries. But here unless you wander around and tap kids on the shoulder and pick up their pen for them and start writing, it won't actually get done... So I think I had to make a conscious effort to change it totally as to how I was going to do it."

(12/8/97)

"Because the school I went to was so different, I've had to go, 'Well I'll need to throw all that out the window and look around for something else that works."

(12/8/97)

It seemed that Arnold's practice was effected on two levels. Firstly by what I shall classify as 'trial and error', he trialed a certain method and found how successful or effective it was. It seemed that at the beginning of his teaching it was necessary to experiment with different methods to find which were most effective. He reflected upon his teaching experiences throughout the interview and it seemed this trial and error process had helped him to decide on the practices he currently used. An example can be shown by,

"The times when you can actually draw it back onto something, if you can say 'Remember when we went down the oval and measured out the big football field is' or something like that, I've found you get much more recognition off people."

(12/8/97)
In later conversations, Arnold indicated that he used multiple sources for ideas on improving his teaching effectiveness. He said that he observed other teachers that seemed to be successful and selected those practices that may work for him. He also read books by Bill Rogers on classroom management to gain ideas on improving his student management techniques. Arnold claimed that inservicing for beginning teachers also provided him with ideas he could use. All these ideas were again part of a process of trial and error to discover what worked best for himself.

As suggested, the culture of the school seemed to be a significant influence in Arnold's choice of teaching practice. Arnold emphasised the limitations that the school's culture and student expectations had on his teaching.

"I don't know whether it's a cop out or not but I think this school is so different from a lot of schools so I'm not sure that what works in a lot of schools does work here... Doing things creatively, you have really got to be careful, because the kids can't quite often handle that, the fact that it's different from their normal routine."

(12/8/97)

"In maths especially I think you have, and the kids still really have an expectation, 'You will test me on this and you will make sure that nobody else talks to me at the time'."

(12/8/97)

In later conversations Arnold claimed that the expectations of other staff also forced him to look for ways to improve his practice. He said that now, after three years of teaching, he felt comfortable with how teachers would perceive him and was more concerned with his self perception and own expectations. So it seems at the important initial period of teaching, Arnold was experimenting with new teaching methods. However, the success and effectiveness of these methods was largely influenced by the behaviour and expectations of the students and staff.

Arnold was asked what factors he believed were necessary for changes in his practice to occur. The interviewing centred around DSE initiatives and recent attempts to implement policy. According to Arnold there were some inherent problems with the way new policy, initiatives have been
implemented in the past. He likened the DSE's implementation process as "pieces of paper floating down from above."

"I don't think it is a very good way of handing down these policies. They just kind of appear."  

(12/8/97)

He commented that it was much easier to accept new teaching methods when they were consistent with the beliefs he already held. While discussing the practical and real life applications that were the impetus of the most recent Year 7-8 syllabus, he said,

"And that kind of fitted in nicely with my idea of things needed to be real life and stuff like that."  

(12/8/97)

With DSE initiatives and policy, such as that conveyed in the Curriculum Directorate Support documents (see Department of School Education, 1996A), Arnold would only look through them for the activities and questions that were consistent with his beliefs on teaching mathematics. He did not seem as interested in the beliefs and theories conveyed by the DSE. He reflected,

"I know those little mathematics things they hand out now and then, those little blue things, they're not bad... Quite normally I look at the questions and go 'That's good. Yeah, I like that' but I never quite remember it when I get around to teaching it. But hopefully I've still got those little pieces of paper. I can dig them up." 

(12/8/97)

While discussing 'Agenda 97' he stated that new policy or initiatives should be accompanied by questions and activities that can be easily implemented.

"It seemed like a big picture, sort of up there in the clouds thing and without concrete things I'm not sure that teachers are going to put it into practice straight away. They might keep it in the back of their mind and when they decide to rework some topic they might pull out a few ideas from it but I don't think it will be incorporated as a unified whole unless there is someone there to help go through it."

(12/8/97)
Arnold seemed to suggest that teachers can accept new initiatives on different levels. At the surface they can take from it those teaching ideas and strategies that are consistent with their own beliefs. However at a deeper level, for teachers to make a significant change to their beliefs on teaching mathematics, at the least it needs to be explained to them face to face.

When asked about the other factors that influence the acceptance of new reforms, Arnold said "the biggest one is probably time". Arnold expressed on a number of occasions that time to was essential to "evaluate it and decide how you are going to implement it". He later stated,

"It tends to be all part of teaching. This policy appears and it is going to be incorporated in three months time or something. You’re not really given any time to work on it and you certainly can’t stop to do what you are doing at the moment. I think that’s a problem and I think that would be something that would make it easier."

(12/8/97)

As well as not being given sufficient time to understand a new policy, Arnold suggested that time be set aside at a later stage to evaluate and provide feedback on what had been done in implementing a new policy.

"With the year nine syllabus, we spent a bit of time at the beginning of the year on it... and that kind of got off the ground and I think we made some progress but then we were never really given any extra time after that to look at it. So I don't think anybody really went anywhere with it."

(12/8/70)

Arnold further believed that the structure of support in the mathematics faculty had a considerable bearing on the implementation of changes to teaching practice. He claimed that if a new initiative or change in practice was accepted as a whole by the head teacher and mathematics faculty, it established the foundation for sharing the workload involved, sharing ideas and experiences, giving and receiving feedback and "peer modelling". His comments included,

"So you need to know that they are on side with it or they are going to be doing the same thing and especially if you are developing something new you need to be able to share the workload or something. And so you need to get together with other
teachers to talk through, 'So how do we do this' or 'I'm really uncertain how to do this' or whatever." (12/8/97)

"It comes down to little policies kind of like 'Agenda 97' or something and I'd say that is largely ignored, certainly by the general teaching people unless of course the head teacher decides it is going to be their little baby and they are going to work on it." (12/8/97)

Arnold claimed one of the major obstacles to accepting and implementing some of the new DSE initiatives was ironically due to the DSE assessment system. The structure of the Higher School Certificate for mathematics placed limitations on his teaching practice. He commented,

"The biggest thing I think is that, especially the seniors, you're gearing them up to the HSC. So although groupwork may be fun along the way, in the end you are going to be by yourself doing an exam with no one around you. So until the HSC changes there is not going to be a lot of reason to change to anything like that." (12/8/97)

4.2.4 Concluding Comments

Arnold discussed the beliefs he held about the teaching and learning of mathematics. He felt that mathematics should be taught for understanding but also saw value in rote learning procedures. He further believed that students would learn more effectively if they were involved in practical experiences and the mathematics was connected to real life experiences.

Arnold's story of teaching mathematics also gave an insight into the factors that may influence a beginning teacher as they look to learn their trade. A kind of cognitive conflict seemed to occur as he experimented to find the most effective methods for teaching the mathematics. As Arnold conveyed, he entered teaching with certain beliefs and ideas for teaching mathematics. He then tests these beliefs in practice. However external factors such as the school culture, expectations of the students and the DSE assessment structure place constraints on how these beliefs were put into practice.

Influences through the DSE in the form of new policy, agendas and initiatives had minimal affect due to problems in their implementation.
He commented that it was much easier to accept and employ practices that were consistent with his own beliefs. Arnold also perceived that more time was necessary to understand, evaluate and develop practices consistent with the new initiatives. He further saw importance in having a supportive circle of teachers who discuss, share and work together in the implementation.
4.3 Frank's Story

4.3.1 Background

Frank lived his life in the Illawarra region, attending a local high school and then "with no break onto Wollongong University with a Bachelor of Mathematics for four years." He also completed a Graduate Diploma of Education to give him qualifications for teaching in the education system. He also was involved over the previous five years with the Circuit Breaker Program which was "designed as a non-English speaking background course for high school students improving them in literacy, numeracy, vocational skills, TAFE and University appointments". Although a casual teacher he had taught "since third term 1995 full year blocks all in the Southern Illawarra area in the public secondary school system".

On a personal level, Frank had a wife and baby and had recently purchased a new house in the area he had grown up. He also worked part time as a salesman at a local department store. He had a love for mathematics and enjoyed teaching students of a high ability. However, Frank had recently discussed his disillusionment with the education system and a desire to find a career where he could more greatly apply his mathematical knowledge and skills.

4.3.2 Learning Mathematics

Frank was adamant that teaching mathematics for understanding was essential as it minimises the errors that occur due to a lack of logic and thus enables students to apply their knowledge to various situations. He commented,

"...because usually with an understanding of the question, one has enough logic to see whether the result is correct given the situation or incorrect." (22/8/97)

He illustrated this belief with an example of algebra being applied to time and displacement. He mentioned that calculations will give answers of time equal to 8 seconds and -2 seconds. A student who understands the question and the mathematics will know "time equals -2 seconds is a
totally illogical result". Whilst discussing the value of understanding the mathematics he claimed,

"To me it should be a case of yes I’ve done the question but I also understand the question. Now I am a good mathematician. I think the understanding of it is so important." (22/8/97)

However, he maintained that "there are things in mathematics that do not require understanding”. He used the example of times-tables and claimed "you don't really need to have an understanding of why four times five is twenty”.

Frank was asked how he perceived mathematics was learned by the students and answered with a building metaphor. He suggested that mathematics was a subject where new knowledge and skills had to be built from what the students already know.

"I've always believed that mathematics is an accumulative subject. You have to know your basics, build on that and that becomes your new basics per se." (22/8/97)

In congruence with his theory of learning mathematics, Frank suggested that mathematics should largely be taught through investigating the mathematics and constructing an understanding through the experience. The teacher acts a guide, steering the students so that they "are on the right track". This understanding, he believes, makes it easier to apply the mathematics to a variety of applications. In his words,

"Investigations are usually remembered better because the child remembers the theory part coupled with the experience of finding the theory part as opposed to just having it thrust down their throat" (22/8/97)

"If an understanding had been gained through an investigation or what have you, then they have a much higher chance of being able to adapt that situation to the mathematical concepts needed." (22/8/97)

Although investigations were an important part of Frank's pedagogy, he understood that a variety of methods were necessary for teaching mathematics.
"You can't give lessons in the same manner over and over and over again because then the students become very, I wouldn't say bored, I would say intellectually numbed by the way lessons are projected and hence once that happens, the information really isn't being absorbed." (22/8/97)

He also believed that language was integral in learning mathematics.

"I strongly believe that you can not have effective learning of mathematics unless literacy is already there... You need to have a strong literacy base for the understanding of concepts and relationships between different facets of mathematics." (22/8/97)

The importance of having a strong understanding of the language of mathematics was further emphasised when Frank was questioned about his perception of mathematics. He said,

"Every situation has qualitative and quantitative aspects to it occurring simultaneously... They work hand in hand. They are simultaneous. You cannot separate them unless you are going to go through life looking at situations that can be solely explained by four times five. It doesn't happen." (22/8/97)

4.3.3 Factors Influencing Change

It was necessary to illuminate where Frank's beliefs on teaching and learning mathematics had originated. He suggested that his experiences tutoring mathematics and watching other teachers had enabled him to "see what was effective and what wasn't effective through all the different levels of mathematics". Frank was also questioned about the influences that his own schooling may have had on the methods he employs to teach mathematics. He thought that there was a subconscious influence and likened it to the experience of learning to tie shoelaces.

"You get to the stage in life where you have lost the conscious knowledge of the process of how to tie your shoelaces but you subconsciously still do them the way you were taught. I think it's the same in maths and in everything else." (22/8/97)

Frank emphasised this point further with the statement,
"If you have been taught a certain method, then when you come to reteach, if that method was effective for you, you will do it in that same effective method. Now and then trying different methods as an experiment but you will always fall back to the comfort zone of how you were taught."  

(22/8/97)

Once his personal theories of teaching and learning mathematics were more explicit, he was questioned to find out the factors that were more likely to facilitate a change in his practice. He claimed to be a willing agent of change and believed those that were not willing to change were "very closed minded, very egotistical" and should find another career.

"If you are not open to change and being able to analyse yourself in a realistic way then you have got to get out."  

(22/8/97)

He also suggested that teachers may be negative to change because they are afraid to admit that their teaching could be improved. Frank believed for change to occur in this person they must first change their mindset.

"...if someone should be egotistical it's very hard for outside influences to change the personal viewpoints of that person."  

(22/8/97)

If a teacher came to the realisation that "perfection was impossible to achieve" and thus improvements could also be made, Frank believed they were more likely to analyse other points of view and experiment with their teaching. Frank seemed to perceive teaching as a continual process of evolving and developing which had no ceiling.

He suggested that to evolve as a teacher it was necessary to experiment with teaching approaches and reflect on the experience. He said,

"Of course another major influence would be, I hate saying it as a teacher, trial and error."  

(22/8/97)

However he was uncertain whether he would try a new teaching strategy if it was unsuccessful in the first instance. He said that even though it may be successful afterwards, "because of the first instance of using it, it was atrocious, you are very hesitant".
As it is unlikely that on the first occasion of trialing a new teaching strategy, it is effective, it seemed unlikely that Frank would adopt new teaching strategies easily. He added to this discussion that if the faculty were supportive and had accepted the changes in practice as a whole, he would be more likely to try it again. He commented,

"If that openness was there with my peers then yes I would try it again."

(22/8/97)

Frank claimed that if the faculty were supportive he would discuss his practice with them, analyse their lessons and "reconstruct the lesson and redeliver it after the analysis". Frank suggested that this peer support network was important if changes in practice were to occur." He further suggested that the word "change" could be substituted for "experiment" to remove the threatening connotations that are attached to the change process.

"The other way of getting teachers to change might be to not bring in the terminology of change."

(22/8/97)

When the DSE attempted to implement new initiatives or policy changes, Frank believed it was far simpler to accept and incorporate it into his practice if it was congruent with his own beliefs. He suggested that a teacher who had the objective of teaching for high results may not see as much importance in teaching for understanding.

"Going right back to where I said good behaviour, total silence but no understanding, to me that's a lesson that's failed. To some it isn't. To some that is a pleasurable experience. They see that having high marks as being great."

(22/8/97)

Frank believed the structure of the DSE enabled teachers to experiment and take risks with their lessons due to "the lack of quality control". He suggested that due to the lack of supervision or evaluation, teachers were given "the freedom of being able to fail in your teaching".
Frank also highlighted that the culture of the school placed constraints on the teaching methods he employed. He expressed this point succinctly using the following example,

"Let's go to class, lets just do it. What's little Jimmy doing? Little Jimmy is hanging from the fans. Chalk and talk today kids. Sit down. Shut up. Write the work. (he laughs)"

(22/8/97)

It seems that the behaviour of the students had a considerable influence on the teaching methods chosen. If "the student body just goes haywire" then he sees it as necessary to revert back to the method that maintains the greater class control.

4.3.4 Concluding Comments

Frank had some strong opinions regarding the teaching and learning of mathematics but essentially believed that students should be taught for understanding of the mathematics through investigative techniques and with a significant focus on the language aspects of the subject.

He saw difficulty in achieving change in teachers practice, especially if their beliefs were inconsistent with the new policy or initiative. Frank believed teachers were often fearful of change as this often meant them teaching outside the comfort zone. He suggested that change could be more successful if they had the right mindset, the support of the faculty and the teachers reflected on their experiences. Further, the structure of the department allowed teachers freedom to experiment with their pedagogy but the behaviour of the students can place constraints on their practice.
4.4 Jan's Story

4.4.1 Background

Jan had experience teaching in both country and inner city New South Wales schools over the past 22 years. This experience included schools with relatively small populations to schools with approximately one thousand students. She also spent some time as acting head teacher of mathematics, acting head of administration and year adviser. I found her to have a good rapport with the students and staff.

On a personal level Jan was married with three daughters and travelled a considerable distance to her place of work, currently a metropolitan Sydney high school.

4.4.2 Learning Mathematics

As can be evidenced by her discussion of effective teaching methods, Jan saw teaching for understanding as central to her role as a mathematics teacher.

"They need to understand where they are going and what it means." (12/8/97)

This statement also suggests that giving the students a holistic understanding of the mathematics was also important to her teaching. Jan further believed students should be given experiences where they are manipulating concrete materials to achieve an understanding. She commented,

"The best way for students to learn mathematics is through hands on, concrete experience and practical activities." (12/8/97)

Jan was also of the opinion that "you can do some excellent things with discovery techniques". So it seems ideally Jan believed that the most effective way of learning mathematics involved the students constructing their own understanding of the concepts through the use of concrete materials.
"When they can discover something for themselves and they can actually see it practically, then they get a better understanding of what it means." (12/8/97)

Involved in this whole learning process was an understanding of the language of mathematics. Jan claimed that she "always taught with a lot of literacy base" and stated that an understanding of mathematics "comes from understanding what the words mean". Although Jan believed this pedagogy to be the most effective she also clarified this by commenting that "it doesn't always click with all students because all students learn in different ways". It seemed that Jan held perspectives on learning mathematics similar to the Constructivist perspectives that have achieved recent popularity from many educators.

4.4.3 Factors Influencing Change

Jan had developed her beliefs over the many years of teaching. She placed significant importance on understanding how the DSE believed students most effectively learned mathematics. Her reasons were expressed in the following,

"Because the department is responsible for the whole. If I'm working in a particular state, as in Australia, it is important for me to know what the department feels because we are supposed to be getting the same results out of a lot of children."

(12/8/97)

It seemed that her beliefs on teaching mathematics were quite consistent with the DSE because she felt a responsibility to her employer and for the outcomes of the students. Jan had read, analysed and incorporated the beliefs of the DSE into her practice. This was further emphasised by her statement,

"It's also the belief of the department that that's the best way to teach mathematics. All the theory I've read says that's the best way to teach mathematics. The primary syllabus works that way with an emphasis on concrete stuff."

(12/8/97)
Thus when the DSE attempted to implement new policy or initiatives, Jan would more readily accept them into her practice. She saw it as her responsibility.

She also found it easy to incorporate new strategies if they were consistent with her beliefs. Jan was asked about the new literacy push and how easily she accepted it.

"I don't find it difficult because I basically agree that literacy is the most important thing you can do." (12/8/97)

Although Jan found it easy to accept new policies and initiatives, she indicated that the attitude and behaviour of students placed certain constraints on whether she put it into practice. Jan explained,

"In practice it doesn't always work that way. This year in particular, I'm finding it very difficult to do that with the classes I have. But if you had students that were basically motivated and interested, then yes, you can do some excellent things with discovery techniques." (12/8/97)

Jan was also asked why she believed some teachers found it more difficult to accept changes in their practice. She believed that teachers often were comfortable with their teaching and either saw no need for change, were scared of failure or were too lazy to make the required effort. She conjectured,

"Laziness. Not in all situations by any means. I think it could come down to being unsure, being scared of something new. Scared of failure. I think it comes down to your beliefs. They have a belief that there is nothing wrong in what we are doing." (12/8/97)

However, Jan was unsure of how these teachers could be led to change their teaching. She accepted that "change is very awkward". Jan suggested that a cautious role should be played in suggesting approaches to the teachers involved. She further suggested "sharing your resources and asking them to observe your lessons if you are comfortable with that" as examples of strategies that may be tried to affect change.
One common method used to affect change in line with DSE policies and initiatives is inservicing. Jan was critical of this method, claiming it was an inefficient use of time and money. She said,

"You can always use time and inservicing but I don't think that is a very good use of resources at all, financial resources. Because people either take it on board and use it or they just forget about it. They say that it's a good idea but can't be bothered doing anything with it. It is very limiting as to who it gets to. Inservicing is very limiting to who it gets to.”

(12/8/97)

4.4.4 Concluding Comments

Jan was an experienced teacher who accepted change easily as she believed it was part of her responsibility as a teacher. Her beliefs were congruent with the beliefs promoted by the DSE. She thought that students learned mathematics most effectively when they were given practical experiences using concrete materials and were allowed to construct an understanding from it.

She was a little uncertain to how a change in practice could be encouraged in a teacher. Jan suggested the sharing of resources and having teachers watch other lessons as approaches they could facilitate change. However she was aware that the attitude and behaviour of students could place constraints on whether beliefs were put into practice.
4.5 Dan's Story

4.5.1 Background

Dan had a wealth of experience, teaching mathematics in Fiji and Zimbabwe as well as the Australian states, West Australia, Tasmania and New South Wales. He had also taught in country and city schools. Thus he had experience working in different education systems but was currently employed on a full time casual basis in an Illawarra school. He had taught mathematics in this school for the past two years.

4.5.2 Learning Mathematics

It was firstly important to illuminate Dan's understanding of how mathematics is constructed in the minds of the student. He chose the metaphor of a jigsaw puzzle.

"I think that often they are like different bits in a jigsaw puzzle and that at certain points kids may connect bits together and realise that these bits go together to give part of a bigger picture."  

(26/8/97)

Dan made explicit a number of contrasting strategies that he believed were effective for teaching mathematics. He saw "a lot of value in activity based work" and "working with concrete materials". Dan believed effective learning was likely to occur when the students were experiencing the mathematics in a practical sense. He also saw importance in guiding the students to "bridge from the concrete into the abstract".

Dan also suggested that traditional, teacher centred instruction was "hard to replace". He commented,

"I actually still believe that there is an important place for traditional, chalk and talk expository lessons... So I guess on the one hand I'm saying lets have some exploratory, hands on type lessons but you also need the straight expository lessons."

(26/8/97)
Dan believed that by presenting the mathematics to the students they were able to follow the process and model themselves on the teacher. He also saw importance in using resources that were "a little more light hearted and fun", to motivate the students in their learning.

Further, Dan agreed with the push for literacy that had recently occurred across the curriculum in his school. He believed that as a mathematics teacher he should be helping the students improve their mathematical vocabulary.

"It's emphasising again that every teacher is a teacher of literacy and I think that is something I've always believed." (26/8/97)

4.5.3 Factors Influencing Change

Dan claimed that his beliefs on the teaching and learning of mathematics were "an accumulation of experience over the years". However he later questioned whether he actually did reflect on his practice.

"I wonder, to be honest, whether I do reflect on my own practice." (26/8/97)

Further, he recognised that the various departmental policies had little effect on his beliefs and practices. He was unsure of current policy and DSE beliefs on teaching and learning mathematics and believed that it would not have a significant influence on his practice. This may be evidenced by the statement,

"To tell the truth, I don't know what the Department of New South Wales really believes on these things. But as I think I said before, I don't know how much impact that would have on the way I practice teaching." (26/8/97)

Dan was questioned on a number of recent policies and DSE initiatives that had been implemented in high schools. After some discussion he concluded that he would only accept those practices that were consistent with his beliefs. He commented,
"I think what tends to happen is, if there is a new faction or a new practice that's pushed forward, you tend to adapt the kind of things that you do anyway and ignore those that don't suit what you have been doing most of the time." (26/8/97)

Dan seemed to suggest that his belief system acted as a filter for new policies and initiatives. He would only adopt practices and strategies that were consistent with the beliefs he held.

When questioned about the factors that may lead to a change in his practice, he commented that,

"I think for someone trained in mathematics, statistical evidence is something that can lead to modifications in belief and behaviour." (26/8/97)

Dan discussed an example where he "became aware of studies on how teachers respond to male students as opposed to female students and how they tend to interact more and ask the boys more in a classroom environment". However after further discussion he began to question whether this had actually impacted on his practice. He claimed,

"Now whether my beliefs have actually changed, I'm not really sure because I think that the reason why those issues have become important to me is perhaps for my whole career I've had the belief in the equality of males and females and so because of that belief, I actually seek out... I'm not sure whether I seek out statistics on that issue or it's when I become aware of those things. It becomes a way where I can put my beliefs into practice by trying to address imbalances." (26/8/97)

Dan could suggest things that had an impact on his practice but he found it difficult to make explicit those things that had effected his values and beliefs. He also understood that changing the beliefs or practices of teachers was a difficult proposition. He stated,

"I think that once people have established a pattern of behaviour it really is difficult to get them to change." (26/8/97)

During the course of the interview Dan was able to indicate a number of factors that had influenced his teaching of mathematics. On numerous occasions he made reference to the culture of the classroom as an inhibiting factor. He made the following comments,
"I think one of the major difficulties that I find as a teacher these days is dealing with basic courtesy and manners. That seems to be a far more difficult issue these days. You just can't expect good behaviour."

"Now I guess the practicalities of doing that don't work out when you have got bigger classes and students aren't really committed or cooperative." (26/8/97)

The behaviour of the students placed significant limitations on the teaching strategies that Dan employed. He had certain ideas on how he could teach the mathematics but the successful implementation was largely dependent on the culture of the students.

The established structures of the school also had an impact on Dan's choice of teaching practice. He discussed the success he had with a small class of talented students in Fiji and claimed that NSW "schools have to have some kinds of flexibility in them to allow things like that to happen". The concrete resources that the mathematics department holds also influenced the teaching strategies that could be employed. He discussed the school in Zimbabwe where the mathematics department actually had a person wholly responsible for making resources were available. He believed this encouraged the teachers to employ teaching practices they would not previously have entertained.

Dan felt that the person responsible for the mathematics resources gave teachers more time to prepare adequately for their lessons. He believed more time was needed to think about constructively about how the lessons were to be conducted.

Dan claimed the mathematics textbook that was chosen for use in the school was a resource that had a large influence on teaching. He tended to "follow the style and presentation of the textbook that is currently in use".

### 4.5.4 Concluding Comments

Thus there seemed to be numerous factors that influenced Dan's pedagogy. Things such as the culture of the school, behaviour of the
students and available resources had a significant impact on the teaching strategies chosen. However, he could not define factors that had a direct influence on his belief system. It seemed that Dan's beliefs were deeply rooted and DSE policy could only have effect if initiatives were congruent with these beliefs.
4.6 Leo's Story

4.6.1 Background

Leo had a wealth of experience as a mathematics teacher working in the NSW Department of Education system. He completed his Bachelor of Science and Diploma of Education in the mid 1970s. The late 1970s and 1980s were spent as a mathematics teacher in Southern Sydney, Canada and Illawarra schools. He was promoted to head teacher of mathematics in 1993 and has since worked in inner Sydney and Illawarra schools. Leo had further experience teaching evening classes at TAFE.

Leo had a wife and two teenage sons and had lived in the Illawarra for most of his adult life. My perception of Leo as a teacher of mathematics was someone who enjoyed teaching, had a good rapport with the students and was extremely organised in his approach. As a head teacher of mathematics he led by example and nurtured a supportive framework in the faculty for sharing ideas and practices. He also had a good rapport with the teachers in his faculty and kept open lines of communication between himself, the staff and the executives in the school.

4.6.2 Learning Mathematics

Leo began his discussion of teaching strategies by stating that they are "dependent on the best ways for learning mathematics". He claimed that any effective teacher must be enthusiastic about the mathematics, be fair and genuinely care about the students. He believed that if the students were comfortable and had confidence in the teacher they were more likely to learn. Leo also suggested that students were motivated if the work was fun and they were "not threatened but are challenged".

Leo was adamant that students should have a "command of the language of mathematics". He believed this was facilitated by providing opportunities for students "to explain concepts and to help each other" understand the mathematics.
4.6.3 Factors Influencing Change

Leo had developed these beliefs on teaching mathematics through his experience as a mathematics teacher. He claimed that success, gauged by the students results, had provided feedback to the effectiveness of his teaching. Further "feedback" from students had helped him to evaluate his teaching and decide on effective practices.

When questioned about his knowledge of current mathematics policies, Leo was able to provide a detailed discussion of the latest syllabi. He claimed the importance of knowing about current ideas and strategies was "because as educators we need to be prepared to learn and to remain enthusiastic about our craft". Leo seemed to value DSE policy and initiatives primarily because of the variety it provided, igniting his enthusiasm for teaching.

Leo was motivated to implement new strategies as it provided variety and challenge but he further highlighted extraneous factors that influenced change. He claimed that certain approaches were chosen "to suit the students" showing that the personalities of the students had an influence on the teaching pedagogy. He further indicated that some teachers are uncomfortable with change as it may upset the classroom dynamics and behaviour management. He commented,

"Instead we all like our comfort zones and particularly if we are working hard at classroom management we quite often will use our most familiar approaches for fear of losing control and for fear that our students won't achieve the desired outcomes that we feel our tried methods achieve." (September 97)

Another obstacle to change Leo believed was "the suspicion that the policy is not necessary". He claimed that some teachers saw little worth in some initiatives and thus it was important to help them see the worth in it. He believed it was each easier to accept and implement new ideas if teachers learned as much as possible about them. Leo suggested attending workshops to learn about the policies.
Leo believed change and acceptance of new initiatives would also be made easier if teachers were given more time to reflect upon new approaches and were provided with the resources necessary. He said,

"Then it is made easier if I have the resources available, the time to learn further and the enthusiasm to implement." (September 97)

4.6.4 Concluding Comments

Thus it seemed that change for Leo was made much easier because he valued change. It equipped him with new approaches to implement, thus igniting his enthusiasm for teaching. However he also believed that there were other factors that also had a considerable influence on the implementation of policy and initiatives. He claimed that apart from the teacher's attitude and belief in the worth of the new pedagogy, external factors such as lack of time and resources and the personalities of the students influenced the practice of teachers.
4.7 Violet's Story

4.7.1 Background

Violet was trained at Wollongong Teacher's College and had been teaching for 23 years, all in the Illawarra area and all in two schools within ten kilometres of each other. She had enjoyed teaching in the area and felt it had enabled her to build a "good reputation" in the community. She felt she was perceived as a well organised, strict and fair teacher who had success with her classes. As well as limiting herself to the two schools in the same area, she chose to avoid teaching the advanced classes, concentrating on middle to low ability students.

In a conversation following the interview, Violet mentioned that she was not overly interested in mathematics. This was also evident when faculty discussions centred around mathematical concepts and applications. Violet would roll her eyes in a gesture suggesting no interest. It seemed that Violet enjoyed teaching and mathematics was simply content that enabled her to teach.

I perceived Violet to be very organised in her approach to teaching. She spent a large amount of time preparing work for classes at home and had her lessons recorded in a book that she used each year. Her students were extremely well behaved and seemed to like her as a teacher. At a staff level, Violet had a tendency to express her views on teaching and the school structure. Recently she had expressed annoyance at the increased workload and responsibilities in the school due to policy initiatives. Violet refused to participate in policy initiatives that she believed were unproductive.

4.7.2 Learning Mathematics

Violet believed that her teaching was most effective when it followed the traditional behaviourist type style. She commented,

"Kids like a structured lesson where they know what to expect". (18/8/97)
Integral to her teaching was a structure that began "with a demonstration." The students then "copy down the notes" and Violet takes them through the examples. The students then copy down the examples and she goes "around the classroom providing assistance". She was also an advocate of "drill and consistency". She believed the best results were achieved when the students did many questions of a similar nature.

This teacher centred style was also important to Violet as it enabled her to maintain control over the students' behaviour. Whilst discussing the structure of her lessons she commented,

"You look at some of my students and they are getting in trouble in other lessons but do not cause a hassle in here."  (18/8/97)

Violet was of the opinion that students would learn more when they were having success and "a sense of achievement". She claimed this was the reason why she would provide them with all the steps, methods and hints to solving questions. She further stated that it was important to remove the "uncertainty" that students may have when solving a problem. It seemed that Violet did not encourage constructive thinking in her students. She was more concerned with them learning to follow a procedure and achieve high numerical results in assessments. This belief is further evidenced by the statement Violet made about the outcomes for the students,

"It all boils down to scoring."  (18/8/97)

Violet claimed that the "bottom line" was the exam. She believed that it was unreasonable to teach the students using groupwork techniques when at the end of the teaching the students are forced to "face exams by themselves". Violet believed groupwork was an ineffective teaching method anyway. In a discussion of the value of groupwork she exclaimed,

"What a load of crap."  (18/8/97)

She discussed her experiences with groupwork techniques and claimed that it is usual that one student dominates the group "while the others bludge". The noise that occurs during groupwork was disconcerting to
Violet as she needed to have quiet and control through teacher centred approaches. This belief was further suggested by the comment,

"No interaction means no distraction."  

(18/8/97)

A recent policy initiative was the use of investigations that involved the students working on open-ended type questions. She was not enthusiastic about investigations either as she believed the students had a tendency to get confused.

Considering Violet's beliefs on groupwork her response to the new focus on literacy strategies in the teaching of mathematics was at first surprising. She claimed that she was enthusiastic about incorporating literacy strategies into her teaching as her students seemed to enjoy it. However, Violet had only incorporated those strategies that could be implemented within her classroom structure, with work on an individual basis and no discussions directly between the students.

4.7.3 Factors Influencing Change

It seemed that Violet's beliefs on teaching mathematics may have stemmed from when she was a student of mathematics. She talked of experiences in mathematics where her mathematics teacher would not provide a thorough enough explanation of the work. She was often "in tears trying to complete mathematics homework". There seemed to be a strong relationship between her experiences and her current teaching methodology.

Violet claimed to have an understanding of the DSE policy and initiatives but disregarded much of what she saw and read in that respect. She said that her methods had always led to success for the students so she saw no reason to change her teaching. In discussing new policy initiatives she commented,

"Success for the majority and harmony in the classroom do not come from those sorts of things."  

(18/8/97)
As new initiatives did not fit her beliefs on teaching mathematics she was unwilling to adopt them as part of her practice. She compared the results of her students with the results of other teachers who made frequent use of new strategies and recent initiatives. She claimed that her classes were most often more successful in examinations and thus proved that her methods were more effective. It seemed that to Violet, the numerical results of students from individualised examinations and process based questions were the ultimate guide of the students learning.

As Violet had considerable experience as a mathematics teacher she had been witness to various policy changes and initiatives. Further she had built quite a cynical opinion of the policy initiatives that were attempted to be implemented. She claimed many initiatives were being implemented for the second time although they proved to be unsuccessful previously and that some initiatives were the response of departmental consultants attempting to justify their salary rather than for the value of mathematics teaching. She spoke of those involved in the development of departmental policy,

"They probably got out of the classroom because they couldn't handle it." (18/8/97)

It seemed that Violet's mindset made it quite difficult to facilitate significant change in her teaching practice. She saw no reason to change as her methods led to successful results and those attempting to change her practice had ulterior motives for doing so.

Violet suggested that those attempting to implement change needed to give teachers the resources to get started. She believed that new syllabi needed to be accompanied by programs and new textbooks with appropriate exercises. It seemed that this would provide a process to follow and would thus lead to a more successful implementation. Violet believed that if these resources were provided it would largely decrease the workload that a faculty faced. She claimed that this base could be modified later but initially it made the implementation "a whole lot easier".
4.7.4 Concluding Comments

Violet provided the study with an alternate viewpoint. She strongly advocated teaching centred teaching methods with a habit formation learning theory and believed that change was only necessary for those who were not having success with their classes. To Violet, success was measured by results in exams and not by the deep understanding of concepts and their application to various contexts. Violet was also openly unwilling to adopt policy initiatives that were inconsistent with her beliefs. However she believed that policy implementation would be more successful if teachers were provided with the resources to use and a structure for putting it into practice.
4.8 Conclusions

The personal stories of the participants provided the basis for the development of a grounded theory. By analysing the personal stories for similarities and differences, some important conclusions could be drawn. The following chapter will show the development of these conclusions through a grounded joint construction and will suggest outcomes for mathematics education and the improvement of reform processes.
CHAPTER 5.

CONCLUSIONS
5. Conclusions

5.1 Introduction

Before conclusions may be drawn from the research it is important that I reiterate the focus of the study. As the Introduction Chapter suggested, significant and wholesale changes were necessary to bring mathematics teaching in line with current theories. It also explained how past reform efforts have met only limited success. Thus it was the aim of this study to understand these factors inhibiting and facilitating change in the current socio-political context and to provide a basis for future programs of staff development. A reintroduction of the Model 'Context of the Study' is useful for understanding the process used to achieve this aim.

Fig. 6. Reintroduction of the Context of Study
The model shows how the study aimed to understand the agents of change within the context of the NSW Education system. To reach this understanding it was first necessary for the study to contrast the beliefs on teaching and learning mathematics expressed by the DSE policy, research literature and teacher training programs. This discussion formed much of the 'Review of Related Literature' Chapter. Using qualitative methods data were collected and via the process of thick description, formed six individual case studies. These case studies illuminated the beliefs, ideas and knowledge constructed by the mathematics teachers. In essence these mathematics teachers provided their grounded constructions within the current socio-political context of the NSW public education system.

The Conclusions Chapter contrasts the similarities and differences between the beliefs of the teachers and current theories expressed by the DSE, the research literature and teacher training programs. More importantly it highlights the factors that seem to influence the process of reform in mathematics education according to the teachers working within the current socio-political context. This discussion, with references to the related literature forms the grounded theory for reform in mathematics education as shown in the model above.

5.2 A Discussion of Personal Stories

Firstly it is necessary to form a grounded joint construction where the individual constructions discussed in the previous chapter are brought together, compared and contrasted. Following this discussion is the formulation of a model and comparisons drawn between findings and the related literature.

5.2.1 Backgrounds

Although the sample used in the study was relatively small, the mathematics teachers came from a wealth of backgrounds and experiences. The following table provides a brief summary.
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<thead>
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<th>Participant</th>
<th>Sex</th>
<th>Experience</th>
<th>School Area</th>
<th>Further Experience</th>
</tr>
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<td>Frank</td>
<td>Male</td>
<td>&lt; 3 years</td>
<td>country</td>
<td>NESB Course Coordinator</td>
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</tr>
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<td>&gt; 20 years</td>
<td>outer city, country</td>
<td>Acting Head Teacher, Administration</td>
</tr>
</tbody>
</table>

**Table 1. Teacher Backgrounds**

5.2.2 Learning Mathematics: Contrasting Beliefs

The participants in the study had varying beliefs on how students best learned mathematics. Arnold, Frank and Jan held the strong belief that mathematics should be taught for relational understanding. They expressed importance in the students understanding the processes and reasoning behind the mathematical solutions that resulted. Arnold and Jan also believed the students could construct an understanding more effectively when engaged in practical, 'hands-on' activities. Corresponding to this view on teaching and learning, Arnold and Frank expressed that the learning experiences should be made real and relevant to the students. Frank was also a strong advocate of a student centred approach to teaching mathematics.

Leo was quite similar in his beliefs on teaching and learning mathematics. In his written discussion he did not mention understanding as important to the learning process but the strategies he outlined were typical of this view of learning. Amongst other things he believed students learn more effectively "when they are doing", "they have the opportunity to explain concepts and to help each other" and "know where they are heading".
In contrast to these views on teaching and learning mathematics, Violet was adamant that students learned more effectively using a more didactic approach. She expressed a distaste for the holistic, constructivist type approaches, mainly because they did not suit the high level of control she wished to maintain in the classroom. Her pedagogy was strictly teacher centred and involved approaches typical of a habit formation learning theory such as drill and practice. Dan seemed to share this viewpoint, favouring teacher centred lessons where the teacher acts as demonstrator and instructor but could also see value in the students engaging in practical activities.

It should also be noted that Frank and Arnold saw importance in employing drill and practice techniques. They saw value in a variety of approaches that included both behaviourist and constructivist approaches. However, it seemed that they chose approaches based on the needs of the students. The more the students were likely to misbehave, the more likely the teachers would advocate a traditional drill and practise approach.

Although it is quite one-dimensional to place the teachers views on a continuum it provides some illustration of their beliefs on teaching and learning mathematics.

All teachers saw significance in applying literacy and language based approaches to learning mathematics. During the period of data collection the DSE had been pushing literacy across the curriculum and had been encouraging teachers to incorporate strategies that involved student discussion, both written and verbal in the process of learning.
mathematics. It seemed that this initiative had been successfully implemented. However, as Hargreaves (1997) suggests, significant change needs to be prolonged and it would be an apt study to determine where these strategies remain part of the teacher's practice.

5.2.3 The Influence of the DSE

As mentioned previously, the DSE had largely moved away from habit formation approaches to teaching mathematics and currently promoted a more constructivist learning theory. Jan, Leo, Frank and Arnold held beliefs quite consistent with current DSE thinking whilst Dan and Violet held beliefs similar to the DSE beliefs that were prevalent when they began teaching during the 1960s and early 1970s.

The DSE had varying influences on the participants in the study. Leo and Jan seemed to have a considerable knowledge of current DSE beliefs on teaching and learning mathematics and shared many of those beliefs. Jan saw it as her responsibility to employ methods that the DSE were promoting. Arnold said that he had "used a few things from the syllabus" but this was the extent of the influence of current DSE policies and initiatives on his practice. Violet had some knowledge of the DSE's beliefs but claimed that she disregarded most of it whilst Dan was not interested in what the DSE currently believed and suggested that it would have little impact on his practice in recent times.

5.2.4 Factors that Influence Change: Contrasting Ideas

The results of the research illuminated factors that were critical in the success of educational reform. It seems that they may be categorised as intrinsic and extrinsic factors. The intrinsic factors are those related to the personal beliefs held by the teachers whilst the extrinsic factors are those external to the individual and a result of the socio-political context of the mathematics teaching.
5.2.4.1 **Intrinsic Factors**

The participants suggested that the effectiveness of change is largely dependent on the mindset of the individual. Frank and Jan suggested that teachers need to first see a need to change their practice. They claimed that some teachers believed their methods to be successful and thus saw no reason to change. Jan and Leo also suggested that teachers become comfortable with their pedagogy and are fearful that change may significantly reduce this comfort. Violet seemed to fit this representation. However, she also seemed to hold quite a cynical view of the DSE and believed many initiatives were the result of incompetent teachers attempting to justify their salary as mathematics consultants and developers of syllabi.

Another factor influencing change in teachers' practice and intrinsic to the individual was the degree that DSE initiatives corresponded with the teacher's beliefs. Arnold claimed that he would not often accept new initiatives as a whole but would rather sift through new initiatives for teaching strategies that corresponded with his beliefs on teaching and learning mathematics. Dan, Frank and Jan claimed that they adopted a similar practice. Violet had the belief that facilitating success, in the form of high numerical results was the primary aim of her teaching. It seemed that in consequence the DSE push to teach for understanding would have less relevance for her. It seemed that the congruency between the teachers' beliefs and the new reforms was highly important in achieving significant change.

As the beliefs held by teachers seemed an integral factor in achieving change, it was also important to investigate their background to find where these beliefs had developed. The participants found it difficult to express how they had formed their beliefs on teaching. Both Arnold and Violet suggested that their own schooling had influencing their beliefs on teaching and learning mathematics. Arnold claimed that he was "taught straight down the line" at high school and thus believed this to be an effective pedagogy. Frank believed that his own schooling had a subconscious influence on his current teaching. He suggested that especially when strategies were not effective, he would "fall back to the comfort zone of how you were taught". Violet recalled her negative
experiences, over 20 years ago as a student of mathematics, where explanations were poor, causing her grief in achieving high results. Although she now taught in a very similar way, she had made adjustments to ensure her demonstrations were thorough.

Arnold believed that his father had also influenced his teaching. He claimed that his father explained the mathematics using real life applications which was now integral to his own beliefs on teaching and learning mathematics. Dan, Frank and Leo claimed that their beliefs were formed through their experiences as teachers. Leo further saw the results and feedback from the students as important in assessing his teaching and deciding on future practices. Frank claimed that he also reflected upon his observations of other teachers to "see what was effective" in the mathematics classroom. On the whole, the beliefs of the participants in the study seemed to have been influenced by their own schooling, the attitudes and beliefs of their parents, their observations of other teachers and through evaluation of the experiences they had as teachers of mathematics.

The first few years of teaching seemed to be a highly significant period in the evolution of the teachers' beliefs and practices. As Arnold explained, he entered his first teaching appointment with certain ideas and beliefs on teaching mathematics. However he soon found that he needed to change these ideas to be successful in his role. It was thus necessary to look for new ideas and strategies. He used whatever resources were available but mentioned observations of other teachers and reading as important influences on his teaching. He then went through a period of trialing practices and finding those that were successful.

5.2.4.2 Extrinsic Factors

All participants suggested that the culture of the school places considerable limitations on the chosen teaching practice. Violet especially based her teacher centred pedagogy on maintaining control over the students. The teachers suggested that the behaviour of many classes forced them to disregard methods that gave students freedom to discuss or work in a collaborative manner. Dan claimed that in general he found that students behaviour was considerably worse and a much larger concern at present
day. As Arnold further stated, the students also had an expectation that mathematics was to be taught using methods they were accustomed to and thus were less willing to accept new teaching methods. Even Leo, a head teacher of mathematics, claimed that he chose practices depending on the behaviour and expectations of the students.

The textbook chosen to be used by the mathematics staff was also suggested to influence the teaching. Dan claimed to often follow the style and presentation of the textbook. Thus it seemed that careful consideration of the choice of textbook for the staff was important as it could often govern the teachers practice.

It seemed ironic that the assessment structure in place in NSW DSE schools placed limitations on the teacher's practice. As Arnold informed, especially the senior students are being prepared for the Higher School Certificate Examination which, in mathematics, consists of an individualised pen and paper test with closed questions. He therefore found it difficult to see relevance in collaborative learning and investigative lessons.

The factors mentioned previously had a significant influence on the teachers' practice but the participants also suggested factors more specific to the process of educational reform. They were quite critical of past attempts by the DSE to implement new initiatives. Jan believed that inservicing was an inefficient process as funding was expensive in the form of course costs and replacement teachers and often those inserviced failed to share it with other staff members.

Many of the participants claimed that greater time and supply of resources was necessary to improve the acceptance of new reforms. Arnold and Leo believed that extra time was needed to understand the theory behind the new initiatives and decide on appropriate methods for implementing the theory. Arnold also suggested that time be later made available to evaluate and discuss the success of the implementation. Violet believed that less time would be needed if resources were provided in the form of textbooks and programs that could be used as a base that teachers could build on. Arnold suggested similarly that it would be much easier to incorporate the initiatives into his practice if "questions", "activities" and
"concrete" resources were provided together with a trainer to assist in understanding the theory. He believed this would greatly increase the chance of teachers incorporating it as a "unified whole" rather than just adopting parts that suit their own beliefs.

The structure of support amongst the staff received mention as an influence on the successful implementation of new reforms. Jan believed that a staff that shared resources and even observed each others lessons would adopt new practices easier. Frank and Arnold believed that a "peer support network" was important in the staffroom so teachers could reflect upon and discuss their experiences in trialing new practices. This, they believed, enabled teachers to feel non-threatened and comfortable with the change and to receive valuable feedback. Arnold also saw the head teacher as having an important role in encouraging teachers to adopt new practices. It was suggested that these structures needed to be established to improve the implementation of new practices.

5.3 Towards a Model as a Basis for Educational Reform

Although only six participants were used in the study, the conclusions drawn are tentative but inform a grounded theory on educational reform in the field of mathematics education. As previously stated, reform in mathematics education has been relatively unsuccessful for many years and it is thus important to understand the process and the factors that hinder or enable this process (Battista, 1994). It is important to note that the study attempts to understand this change from the perspective of the individual teacher which hopefully sheds light on how reform practices may be improved.

Through an analysis of the educational research literature coupled with the results of this study, a grounded model is developed that helps understand educational reform processes in the current socio-political climate. A discussion of the important elements and processes inherent in the model shall occur in the following.
Fig. 8. A Model of Educational Reform in the Current Socio-Political Context

**Teachers Attitude to Change & the DSE**

The first barrier to acceptance of a new initiative seemed to be provided by the teacher's attitude to change and the degree of value they placed on the ideas and beliefs of the DSE. Some teachers perceived it as necessary to continually evolve their pedagogy, with experienced teachers such as Jan and Leo quite enthusiastic about new initiatives. They believed they had a responsibility to improve and evolve as teachers. Jan believed that as an employee of the DSE she had a responsibility to accept and implement changes to her practice that followed DSE beliefs whilst Leo enjoyed change as it provided variety for his teaching. It seemed that as the younger beginning teachers were experimenting in search for successful
strategies, they were generally willing to accept new ideas from a variety of sources also.

However, other teachers such as Violet were quite resistant to changing their practice in most instances, believing it seems that their methods were already effective and did not require modification. Leo and Jan suggested that some teachers were comfortable with their pedagogy and were fearful that changes to their practice would upset this balance. As Burns (1994) suggested of many teachers, Violet believed many reforms were just another educational bandwagon that was soon to pass. It may be suggested that some teachers such as Violet, who have established an effective pedagogy, may choose to resist change and maintain the same pedagogy for many years.

Therefore change seemed largely influenced by the teachers' opinion of the necessity of the change and whether the teacher saw importance in understanding and accepting the ideas and theories of the DSE.

**Teachers' Beliefs on the Teaching & Learning of Mathematics**

Even before the teachers had taught their first class they had developed a deeply rooted belief system regarding the teaching and learning of mathematics. This observation is shared by many in the research literature (e.g., Ball, 1996; Grant et al, 1996). Some of these influences at this pre-service stage were made explicit through the course of the interviews. The younger teachers especially, could suggest that they had initially moulded their pedagogy on their own schooling experiences. However, even Violet with over 20 years experience as a mathematics teacher, claimed strong links between her current practice and the teaching she received as a student. This observation is shared by Battista (1994) who suggests that teachers' own schooling experiences have perpetuated habit formation theories of learning mathematics.

"Teachers who are asked to teach the reformed mathematics curriculum are products of an old curriculum that developed in them beliefs so incompatible with those of the new curricula that they can understand many of the innovations only with great effort. We are caught in a pernicious cycle of mathematics mislearning."

(Battista, 1996, p.468)
Battista (1994) further suggests that teachers such as Violet, who are accustomed to teaching procedures rather than meaning, actually lack the knowledge about mathematics and student learning that is necessary to implement many of the constructivist principles that currently underlie much of the recent reform movements. Frank had the opportunity to observe teachers whilst completing University training and believed that he formed some of his beliefs from reflecting upon these observations. The influence of parents also received mention as important in the development of the teachers' beliefs.

It seemed that acceptance of DSE initiatives was heavily dependent on the congruency between these beliefs and the theory behind the new reforms. This observation is consistent with the findings of similar studies (eg. Fennema, Carpenter and Peterson, 1989). The participants believed that teachers would only wholly accept and adopt new reforms as part of their practice if the new reforms were consistent with the beliefs they held about teaching and learning mathematics. Otherwise it seemed, the teachers would ignore the reforms or sift from it only those ideas that fitted with their beliefs.

This seemed to suggest important repercussions for the process of educational reform. As this study and other research literature suggest, to achieve significant and enduring change, staff development programs would need to address the beliefs of the teachers involved (Ernest, 1989; Thompson, 1992). Making explicit and discussing their beliefs would improve the chances of altering their beliefs and achieving acceptance of the new initiatives (Thompson, 1992).

**Constraints Imposed by the Socio-Political Process**

As well as the barriers to changes in practice provided by the beliefs, values and attitudes of the mathematics teacher, the socio-political context tended to have a considerable influence on the acceptance of new reforms. The teaching environment placed considerable limitations on the teachers' practice thus limiting the effectiveness of DSE initiatives. All teachers suggested that the behaviour and expectations of the students influenced the choice of teaching strategy. To illustrate this point, Violet refused to
accept and adopt initiatives that required a change from her teacher centred approach as this approach enabled her to keep discipline in her classroom and she also believed the students wanted a consistent approach. Some participants believed that students would be resistant to changes in the teachers' practice as they had certain expectations about the methods to be used to teach them mathematics. Stein et al (1996) similarly believes that students unfamiliar with teaching for understanding would resist new reforms. Similar findings were also evident in studies discussed in the section on related studies (eg. Fennema, Carpenter & Peterson, 1989; Ernest 1989).

It was also suggested that the assessment structure in NSW DSE schools hindered the acceptance and adoption of policy initiatives. Arnold believed that the exam format, especially in the Higher School Certificate encouraged teachers to use strategies that were teacher centred and limited collaborative work. The available textbook for use by the mathematics staff was also recognised as influencing teaching, as teachers would often follow the instructions and questions promoted in the textbook. Similarly, Hargreaves (1997) stated that reform is made near impossible when pursued in isolation, where unchanging structures, such as textbooks or standardised tests, create a conflict in direction.

Lack of time to discuss, reflect upon and design new teaching approaches was a further constraint provided by the socio-political context. Most teachers claimed that much greater time needed to be structured to facilitate the acceptance of new reforms. Similarly, this inhibiting factor is recognised in the literature by Adelman and Panton-Walking Eagle (1997), who suggest that the time pressures can weigh heavily on the minds of teachers and distract them from their reform goals.

Articulation & Reflection

Arnold suggested that he chose to observe successful, established teachers to gain ideas on effective teaching strategies. Reading educational literature and attending beginning teacher inservices also seemed to be influential in the development of a beginning teacher's pedagogy. These findings, with the suggestions in the literature of Aitken and Mildon (1991) and Feldt (1993), seem to suggest that a supportive structure needs
to be established where beginning teachers are given further opportunities to observe other teachers and discuss their beliefs and practices as they attempt to establish an effective pedagogy.

The teachers were also quite critical of past attempts by the DSE to implement new initiatives. Arnold suggested they were often "pieces of paper floating down from above". The inservicing of teachers was suggested as an inefficient use of staff development funds as it only provided access to a few teachers. Battista (1994) suggested similarly that one or two day inservicing was futile and needed was significant engagement through inservices over much wider time frames.

Most of the participants suggested that more time needed to be set aside to allow teachers to understand the theory behind the initiatives and to decide on how they are going to adopt it as part of their practice. The teachers required time to then try new approaches and discuss them with their peers in a supportive environment. This point is also made in the research literature, with Wilson et al (1996) suggesting that time is essential for teachers to articulate and reflect on their beliefs and practices. The participants also suggested that time be allocated at a later date to assess the success of the implementation. This is also a suggestion in the literature by Adelman & Panton Walking-Eagle (1997).

To combat this lack of time, the participants suggested that new initiatives could be accompanied by resources, such as questions, activities, textbooks and programs. They believed that these resources would provide teachers with a basis for implementing the new initiatives that could later be developed further. The participants believed this would largely increase the probability of teachers accepting and adopting new initiatives into their practice. Battista (1994) also believes reforms would meet greater success if teachers were provided with comprehensive sets of curriculum materials in combination with instruction in mathematics and mathematics learning.

Teachers were also more likely to change their practice if a supportive structure was established in the staffroom. Participants claimed that when teachers were able to share ideas and resources they felt more comfortable with changing their practice and had more time to decide on how they
could best implement the reforms. Jan believed that teachers could learn how to implement reforms by actually observing peers in the classroom. It is suggested that the head teacher needs to take the responsibility of encouraging this non-threatening and supportive atmosphere. Long (1996), amongst many reported in the literature, agreed that a collaborative learning atmosphere was important for teachers in facilitating the acceptance of new reforms.

**The Change Process as a Whole**

Therefore as the model suggests, the introduction of a new initiative is affected by numerous factors. Acceptance of the initiative is largely affected by whether the teacher perceives it is necessary to change and the degree of importance they place in the theories of the DSE. Further, the teachers possess deeply rooted beliefs on the teaching and learning of mathematics and seem only to accept new reforms when they correspond with the theories behind the new reforms. The socio-political context also provides constraints that hinder the acceptance of a new initiative into the teachers' pedagogy.

The model also shows that the process of articulating beliefs and reflecting upon them in relation to practice is an important process in facilitating the acceptance of new initiatives.

It is unlikely that the teacher initially accepts the new initiative whole heartedly as part of their pedagogy. As Frank suggested, it was necessary to trial the new initiative in practice and then reflect upon the experience, either individually or in a peer group. This process seemed to have a degree of affect on the beliefs the teacher held about the teaching and learning of mathematics. Further attempts to adopt the reform as part of the teacher's practice led to either a change in beliefs or the reinforcement of beliefs already held. Similarly iterations of this cycle led to either the acceptance or rejection of the initiative as part of the teacher's pedagogy.

**Further Comment**

It is interesting that the years at university or teachers college rarely gained mention as a considerable influence in the evolution of the teachers
beliefs and practice. The teachers could generally not explicitly recognise their teacher training as having a significant influence on their beliefs. This is the period obviously where beliefs and practices regarding mathematics teaching are supposed to be developed and shaped. It may be suggested that University courses need to focus further on nurturing the beliefs and practices of beginning teachers. However, before this occurs, as DEET (1989) suggests, it would be necessary for tertiary institutions to bring their thinking in line with the current theories on teaching and learning mathematics.

Although it is impossible to obstruct the influences of their parents and own schooling experiences, it could be important for training to encourage trainee teachers to make these beliefs explicit so that they can more easily be addressed and changed (Boomer 1986). Further it could be important for trainees to observe model teachers that use strategies consistent with current thinking and DSE beliefs. This process may better combat the chance of the trainees perpetuating the beliefs and practices of the mathematics teachers they were taught by.

The model made explicit the dynamics and influences in the implementation of a new initiative in the current socio-political context. I believe it provides a useful perspective on reform and food for thought for reformers and researchers. Further, it has the potential to provide a basis for the development of staff development programs and the improvement of mathematics education in the NSW Education system.

5.4 Recommendations for Further Study

I also feel that this study raises new questions and creates new opportunities for research. The conclusions of this study are based on a wide cross section of teachers. However with only six teachers involved, it only provides a general understanding of the processes involved in the acceptance of new initiative by a mathematics teacher. The scope of the research was also limited by time and resources.

It would be valuable to focus more closely on certain elements of the model that formed a basis for reform in mathematics education in the
current socio-political context. For example, a significant study would look at the development of the pre-service teacher's belief system and the factors that influence these beliefs. It seems logical to then decide on appropriate training strategies that would give these teachers more controlled and appropriate stimuli and encourage them to articulate and reflect upon their beliefs. It would also be worthwhile to focus on beginning teachers and experienced teachers as separate groups and contrast the factors that influence the development of their pedagogy at the different stages of professional growth.

The conclusions that emerged from the research have the potential of informing the establishment of staff development programs. These programs can address the intrinsic and extrinsic factors that influence a teacher's acceptance and adoption of new reforms. For example it would be important to illuminate the support structures necessary to facilitate professional growth and educational reform. A further recommendation would be to trial these staff development programs to explore their effectiveness in improving educational reform in mathematics faculties.

Furthermore, this inquiry has benefits for mathematics teachers as it presents 'food for thought' and the mode through which change will occur, in the form of reflections of mathematics teachers, students and their parents. Thompson (1992) believes there is a genuine need for descriptive studies which actually make explicit a mathematics teacher's perceptions. Hence, this study seems to have the potential to inform a number of important avenues for further research.
REFERENCES
REFERENCES


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APPENDICES
APPENDIX A

SEMI-STRUCTURED INTERVIEW SCHEDULE

*** purpose of interview is to investigate what hinders and what helps the implementation of DOSE reforms.

- Can you provide me with a brief background of your educational and teaching history?

- What do you believe are the best ways for teaching mathematics? Why? (note that this is a very full question)

- What experiences have led to you forming these beliefs?

- Can you name some examples of what you do in the classroom in line with these beliefs?

- Do you know what the DOSE believes is the best way for teaching mathematics? Is it important to know?

- Why do you think teachers do not want to change and accept new DOSE initiatives?

EXTRA (Reserve Questions)

- Two recent policy initiatives are the encouragement of literacy strategies across the curriculum and investigations (year 9/10 syllabus). Have you made either of these approaches a part of your practice? Why? Why not? (talking in class?)

- What things make it easier for you to implement new policies?

- What things make it difficult to implement new policies?

*** mention that I'd like to follow-up the interview in a few weeks after I've analysed the transcript and come up with more questions.
APPENDIX B

Excerpt from Interview with Arnold

I: Sure. The first real question is; What do you believe are the best ways for teaching/learning mathematics?

A: I think the important thing is that it needs to be made real to the kids. So if you can actually show them a situation where hey, this is where we could use maths and maths could actually help us to get the right answer here and that is something that I would want to do as opposed to something the teacher might suggest to me, then I see that as one of the main ways of getting people to learn. And I think also hands-on experience rather than just going through it in theory, 'we could use this to do this', actually using it to do something I think makes a lot of difference probably to how much people are going to remember. It may not change much to how much they are interested in it, and it may be hard to organise it but, it will then help them to remember it.

I: So there are mainly two main points you have talked about there.

A: Yes, to show that it is practical, that it can be used and to actually use it.

I: OK. Great. Alright, so they are the main things, you would say?

A: I think so. I tend to emphasise creativity over just rote and practicing stuff. And I think I also tend to jump pretty quickly to the conclusion if somebody's understood something, but I think the important thing is to get those other things right and after that you can decide whether you really want to hammer something home, you know do it one hundred times over. But certainly, when you are trying to give people the ideas, you need to give them the big picture and then work down to the little things.

I: OK. The next part of the question is, What has made you form these beliefs? What experiences, or knowledge, have led you to believe that?

A: I think just part of the reason is just getting continually frustrated with the fact that you teach something and you understand it, and you taught it in a way you think other people will understand, and you turn around an hour, a day, three weeks later, and they suddenly don't know it anymore. And you can quite often say to them, 'Hey remember we did this' and they sort of look at you blankly. The times when you can actually draw it back onto something if you can say, 'Remember we went down the oval and we measured out how big the football field' is or something like that, I've found you get
much more recognition off people, when you can actually relate it back to the thing that they have actually done.

I think also because the kids quite often don’t have an understanding of what they are doing, that once you do give people an understanding and say things like, 'Well, this can’t be the right answer because we’re trying to find the shortest side of the triangle from this real life situation'. You suddenly solve a lot of the problems as far as them getting the right answer or not getting the right answer.

Also I think the fact that I’ve found that by just doing… that for a lot of the kids here especially I think, because they tend not to do very well at anything, and particularly in maths or whatever the subject is, its kind of better to actually give them positive experiences of maths, so much so that, if you assume they are not going to do very well in exams anyway, you might as well at least let them enjoy the ride, kind of. So, to really bludgeon them with something which they won’t learn anyway, it’s far better to give them a positive thing. 'Here’s something interesting we can do with maths' and 'I can show you where the maths comes into something like that', they may end up only getting the same marks in an exam but at least they’ll enjoy it along the way.

I think probably when they look back on it in a couple of years time, they might actually remember, they might actually realise how it all fits together. Maybe not. But especially with a lower group, maths in practice or something, I mean they are not doing it because they are trying to get into uni, and they want to study Actuarial studies, but it is going to be useful. The whole reason we are trying to do it is because we think it is going to be useful to them in later life. If we give them practical stuff, interesting stuff and relevant stuff, if they don’t get it now in ten years time they may look back and go 'I remember it being explained like this' or 'I remember when we did this and now I know how it works and now I remember it. They may not remember it for the HSC but it slowly sinks in afterwards.

I: When you were at school, how did you learn the mathematics, or at university?

A: I tend to remember little stories, little quirky things. I think I remember the maths very well but I think I especially remember the little quirky things. So for instance, with trigonometry, I always remember the sine, cos and tan and where they are and what they mean and stuff like that, but, it’s an example of how you might use, what the use of that is. And once I remember what the use of it is, I find it easier to remember the sine, cos and tan, blah, blah, blah. Just the idea of, … being able to think of real life situations where this does work, or something. And I think, maybe it’s being a maths
teacher, but I tend to look for maths in things, you know, you suddenly notice that two numbers add up to one hundred and try and work out why those two numbers add up to one hundred. Does it always work? Is there something about those two numbers that it will always add up to one hundred.

But I think at school I was taught very just straight down the line. I don't remember there being a lot of that, sort of creative stuff. I remember that my dad would come and reinforce all that stuff by trying to show me real life situations. That's some of the stuff that I remember. I've always been big on, well that can't be right because that could never happen, kind of thing, but I don't think I got that from school. We weren't really taught to estimate all that much I don't think. Maybe because we were up higher in a maths class and didn't need that sort of thing.

I: Yes, I'm just trying to understand where your beliefs have come from. Would you say there is a relationship between how you learnt at school and how you teach?

A: I think there probably could be but I think because the school that I went to was so different, I've had to go, 'Well I'll need to throw all that out the window and look around for something else that works.

I: That's what you were saying earlier.

A: Yes, I think I might have tried some things like that, 'Here's a page of the textbook, it's straight forward. You should be able to do it. If I say to you now, I expect it done at the end then, I could just hold you responsible'. And that would have worked at my school no worries. But here unless you wander around and tap kids on the shoulder and pick their pen up for them and start writing, it won't actually get done. They just have no idea of the fact that what I do now affects what happens in ten years time. Eventually what happen is detention tomorrow at lunch or something. So I think I had to make a conscious effort to change it, totally as to how I'm going to do it.

I: That's interesting.

A: Yes. I don't think there is a strong correlation because there is such a difference between my old school and where I am now.

I: Do you know what the department believes is the best way for teaching maths? Is it important to know what the department thinks in your situation?

A: I remember at uni, the lecturer we had in maths, because I only did a Dip.Ed. and he made a big deal that there was a new year 7-8 syllabus and stuff like that, even though it was not that new at the time. And
how there was practical things and things were meant to be done using real life situations and it was all meant to be problem solving and stuff like that. And that kind of fitted in nicely with my idea of things needed to be real life and stuff like that. I kind of thought that was interesting and good, although I'm not sure I really appreciated the fact that there were maths people up there who worked on these things, who might implement these things. So I used a few things from the syllabus. Now that I don't teach junior years as much, I haven't put as much emphasis on how the department thinks I should be teaching. I know those little mathematics things they hand out now and then, those little blue things, they're not bad. Although a lot of it is aimed at either junior years that I don't teach or 3-4 Unit years that I don't teach, so I quite often find there is not a lot of relevance in there. Quite normally I look at the questions and go 'that's good, oh yeah I like that' but never quite remember it when I get around to teaching it but hopefully I've still got those little pieces of paper. I can dig them up. I think, yes I'm not sure, I don't know whether it's a cop out or not but I think this school is so different to a lot of schools and so I'm not sure that what works in a lot of schools does work here. Once again I'm not sure if that's a cop out or what the story is but it certainly doesn't seem to work. Doing things creatively you have really got to be careful because the kids quite often can't handle that, the fact that it's different to their normal routine. I don't know if that answers your question or not?

I: Yes it does. That was good. Probably the guts of the interview is looking at, if change needs to occur, if the department pushes through a policy or a new initiative, what makes it difficult to accept that and take it in, make that part of your practice? And what makes it easier? What are those factors?

A: I think the biggest one is probably time. I think that it's not like a policy gets introduced. A don't think there is a very good way of handing down these policies. I think they just kind of appear and I can imagine if you were sick on one day you would never hear about it and so you wouldn't even know if that was there to some certain extent. I think that also it's not like everything stops and this policy comes in and you are given time to evaluate it and decide how you are going to implement it and then the kids suddenly come back again. It tends to just to be all just part of teaching, this policy appears and it is going to be incorporated in three months time or something. You're not really given any time to work on it. And you certainly can't stop what you are doing at the moment. I think that's a problem and I think that would be something that would make it easier. I don't think it is very practical though. I don't know... I think it's a problem because you can say 'obviously we need to set aside time', so some sort of inservice or something, but most people are so negative about inservices anyway that I'm not sure you would actually get a lot done there either. It's kind of a catch 22 situation.
A: So just looking at me OK, I think time, being told told this is time that I could spend on this or somebody making it obvious to me to something had become a lot easier and that easiness was meant to be filled up by looking at this policy and working out what to do with it. And I think also just, I think there needs to be time with other teachers as well, where you can share ideas and stuff like that as well because especially as most of our classes have two classes in the one stream, and so if you are going to do anything radical you need to make sure you are not going to fall behind the others or whatever. And so you need to know that they are on side with it or they are going to be doing the same thing and especially if you are developing something new you need to be able to share the workload or something and so you need time to get together with other teachers to talk through, 'So how do we do this' or 'I'm really uncertain how to do this' or whatever it is. So, with the year 9 syllabus, we spent a bit of time in the beginning of the year on it, or was it last year? It was last year wasn't it? And that kind of got off the ground and I think we made some progress then but we were never really given any extra time after that to look at it. So I don't think anybody really went anywhere with it. That's the only really big change in policy that I've kind of been through I think.

I: It seems that now they are trying to encourage things such as literacy. They are at the school I'm at. Things such as getting the students to talk about the maths and write about it.

A: Stuff like that I think, it comes down to little policies kind of like 'Agena 97' or something and I'd say that is largely ignored, certainly by the general teaching people. Of course if the head teacher decides that is going to become their baby and they're going to work on it or something...

I: Why do they ignore it?

A: I'm not sure that it is made to be all that relevant. Like I'm not sure that, ... maybe I did get a copy of Agenda 97... I don't remember getting a copy of Agenda 97. I certainly don't remember saying that this is something I could put into general teaching practice. It seemed like a big picture, sort of up there in the clouds thing and without concrete things I'm not sure that teachers are going to put it into practice straight away. They might keep it in the back of their mind and when they decide to rework some topic they might pull out a few ideas from it but I don't think it will get incorporated as a unified thing unless there is somebody there to help people go through it. And even though teachers admit to be innovators and stuff like that, there the one's trying to teach people things, I'm not sure that we do tend to do that a lot.
Excerpt from Initial Interview with Violet

Vicki
Initial Interview
18/8/97

V: Veejay I: Interviewer

NOTE: Veejay was given a copy of the broad interview questions. She reflected upon them over the weekend and decided she would take part in the interview. However she asked that it would not be taped. The interview occurred in her home room in privacy. The following fieldnotes were taken.

V: She was three year trained at Wollongong Teacher's College. All her 23 years of teaching have been spent in the same area in the Illawarra and have included two schools. She's enjoyed teaching in the area and feel that it has enabled her to build up a good reputation.

V: She believes that the most effective way of teaching mathematics is to begin with a demonstration,. They then copy down the notes and go through the examples together. They then copy down the examples and she walks around the classroom providing assistance. She has found that this is the best way. Then again she says she has never taught an advanced class or 2 Unit or 3 Unit mathematics. It has always worked for the middle and low ability students.

I: Why do you teach this way?

V: She thinks it's best for students to work individually on the maths. It also makes it easier to monitor behaviour and keep control in the classroom. "No interaction means no distractions." She has always done it this way because it has been effective from the start.

V: She has tried groupwork. "What a load of crap". She's found that one kid does all the work while the others bludge. It may be a great lesson for five or six of the students but the others are missing out. She also can't stand all the noise that groupwork generates also. She needs to have quiet in the classroom. The same thing goes for investigations. She's not going to do it if it loses the kids and they get confused.

V: For example, when she's teaching something like a to the power of zero, she said she could muck around with investigating it and the kids would tune out and lose attention when they don't understand. If she just tells them that anything to the power of zero is equal to one, especially with the lower groups, they have no confusion and don't lose confidence.
V: She also claims you need to eliminate the uncertainty that the kids have, the unknown stuff. Kids like a structured lesson where they know what to expect. You look at some of my students and they are getting in trouble in other lessons but do not cause a hassle in here.

V: Also her students get the good marks. The good results don't come for the teachers who like to have students do the investigating, playing, etc. She's really not convinced. She believes that more often than not, investigations lead to chaos in the classroom.

V: "It all boils down to scoring." She believes that it is most important that the students are happy about the mathematics and are successful. She provides the students with all the steps, methods and hints. She was quite upset while going through high school when the maths teacher would not provide a thorough enough explanation and would often be in tears attempting to complete homework. She said "They have got to have a sense of achievement." This was the most important outcome for students in her mathematics classroom.

I: Are you aware of the departments viewpoint on teaching and learning mathematics? Is it important?

V: She was aware but did not really take much notice. Her methods have always worked so she did not see reason to mess with it. In discussing the new initiatives and policies she said, "Success for the majority and harmony in the classroom do not come from those sorts of things."

V: She claimed that the bottom line is the exam. You can do groupwork and all those things but at the end they face exams by themselves. She gives them the best opportunities to be successful in these exams.

I: Why do you think teachers do not want to change their practice?

V: She firstly said that she was in total agreement with the literacy strategies. (Veejay provided an extensive list of literacy strategies to the faculty when it was requested by the head teacher.) She said that the students enjoyed learning with the literacy strategies such as finding the double meaning to certain words in mathematics.

V: She claimed that many of the new initiatives she has seen before and they never worked the first time. Further, there are some things that people in the department push to gain equality but it does not promote better mathematicians. (Her school is largely anglo-saxon and male and female achievement is relatively equal anyway. It seems that she sees little need for these strategies in her environment.) Also, there are people in the department that paid dollars for their input and thus push things unnecessarily. "They probably got out of the classroom because they couldn't handle it."
Excerpt from Lou's Written Response to Interview Questions

Interview with Leo
August, 1997
Completed in written form with a list of the broad interview questions due to his time constraints. He was also given a brief overview of the research study and its objectives. Leo is the head teacher of the mathematics faculty which also includes Dan, Frank and Vicki.

• Can you provide me with a brief background of your educational and teaching history?

During the mid seventies, completed a Bachelor of Science and followed it with a Diploma of Education. Late seventies and eighties spent as a classroom mathematics teacher in southern Sydney, Illawarra and Canadian schools. Then employed as a head teacher of mathematics at an inner Sydney and Illawarra school since 1993. Also completed some teaching at TAFE from 91-93 with evening classes.

• What do you believe are the best ways for teaching mathematics? Why?

The best ways for teaching maths are dependent on the best ways for learning maths. Students will learn any subject from a teacher who is enthusiastic, fair and caring. Students learn maths if it is fun, if they are doing, if they are not threatened but are challenged, if they have a command of the language of maths, if they are motivated, if they know where they are heading, if they feel comfortable, if they have confidence in the instruction, if they review, if they apply their concepts to varied examples, if they have the opportunity to explain concepts and to help each other.

• What experiences have led to you forming these beliefs?

Experiences- success with classes which has been assessed through results and through feedback. Over the years I have tried changing my approach to suit the student and to ignite my enthusiasm. These beliefs are also formulated through research both active and passive. These beliefs are also formed through observation.
• Do you know what the DOSE believes is the best way for teaching mathematics? Is it important to know?

The Dept of Education views are expressed through the Board of Studies Syllabus committees. The latest syllabus clearly states what is current in mathematics learning. They state hands on development of concepts, the importance of cooperative groupwork, the importance of problem solving skills, the importance of being able to read, understand and communicate mathematical ideas. They also state the importance of technology in mathematics learning. The department also states that students have individual learning styles and that teachers should be endeavouring to cater for all learning styles by employing various teaching strategies. There is a strong emphasis on teaching through openendedness and investigative methods. It is important to know what is current because as educators we need to be prepared to learn and remain enthusiastic about our craft.

• Why do you think teachers do not want to change and accept new DOSE initiatives?

I don't believe this is necessarily the case. Instead we all like our comfort zones and particularly if we are working hard at classroom management we quite often will use our most familiar approaches for fear of losing control and for fear that our students won't achieve the desired outcomes that we feel our tried methods achieve. We are quite often fearful of quantitative 'evidence'. Another obstacle is the inadequate time and provision for learning new approaches. Change should be stimulating and envigorating.

• What things make it easier for you to implement new policies?

It is easier to implement new policies if I find out as much about them as possible. If this means that I attend workshops in my own time then so be it. Then it is made easier if I have the resources available, the time to learn further and the enthusiasm to implement.
ARNOLD  (Phone Conversation)  3/1/98

* beginning teaching looked at teachers that seemed successful (eg Martin) who could control a class without the shouting and screaming.

* also reading 'Bill Rogers' books on classroom management when things weren't working.
  He suggested consistency is not great as students are then controlling the teacher.  
  Eg response to swearing need to decide on the outcome you want before leaping into action.

* claims that beginning teacher inservice (term 3) was also influential in some respects, especially 'Bill Rogers' video (whole assortment of influences took what he could)
  ➡ Asked whether now (3rd year) he is changing/evolving by same degree.

* said that earlier on more concerned with expectations of other staff & students but now he's more comfortable in that respect he is trying more strategies for own motivations, the pressure is not as great so he can do it at own pace.

* change now at smaller scale but he believes the change in students results (learning) is still just as great, ie. subtle change leading to greater learning.
APPENDIX D

Excerpt from Reflective Journal

April 8
I’ve found lots on DOSE viewpoints on t & l maths. It seems to follow suit with that I have found in the literature. I am now unsure of how to present the 2 viewpoints in the literature review. I do not want it to be repetitive like my hons thesis got. Maybe I could discuss the theories under sub-headings and occasionally comment on the congruence. eg. The DOSE viewpoint was in accordance with the literature. This is evidenced by the quote...(evidencing it could be optional or necessary?) Sounds good to me. I’m now to look at the DOSE on the net to see what’s available.

April 13
I’ve retrieved the Curriculum Support document from Leo. There aren’t any others. However there are some items that supposedly arrived with the new 9-10 syllabus (hassle Leo for support documents). I’m thinking about having a brief mention of general learning theories and a more thorough discussion of mathematical theories of learning. Further, I don’t wish to look greatly at pedagogy if at all. I would rather focus on the principles behind the learning theories.

I’m also not finding in the 9-10 syllabus much mention of the role of language as the medium through which learning occurs. It is more focused on communicating as gaining practice using math terminology.

With my thesis this year I’m thinking of actually researching in two separate phases. I would like to focus on looking this year at the relationship between the experts and the socio-political context

One other point is that the studies have shown a gap between the knowledge and practice of teachers. Should my study go then to explore the triangular relationship between expert theories, teacher (personal theories) and the actual practice??

April 19
Spoke to Jan and she suggested the following things;
- Ring the Board of Studies and ask them for any relevant literature that I haven’t already come across. (Write a list of what I have already). Also
ask who are the authors they read when they put a list together (can they send a list?)
- it is necessary to comment on the general learning theories (including Vygotsky, Piaget, Constructivism)
- look at the outcomes based education research (especially the work of Spadey) Don't just look at the maths curriculum but how it is actually presented.
- The viewpoint of the educational theorists and university educators can be called the academic perspective.
Also need to look at the document;

April 20:

Purpose is to develop a solid base and structure for the professional development for mathematics teachers in New South Wales Schools. A secondary purpose is to create an important resource for teachers to use in reflecting upon their practice.

How? Synthesis of the literature that focuses on the viewpoints of educational theorists (general and mathematics), the DOSE and Board of Studies, and tertiary educators.
Then to interview the teachers, survey students and parents on effective teaching and learning of mathematics.
Then to write it up looking at the relationships and questioning why the relationship occurs as it does.

One more thing. Don't forget to mention the little bro (Paul) in this thesis because he was pretty distraught when he didn't get a mention in the undergrad thesis.
APPENDIX E

Excerpt from Coded Interview (Frank)

FF If you have been taught a certain method then when you come to reteach, if that method was effective for you, you will do it in that same effective method. Now and then trying different methods I suppose as an experiment but you will always fall back to the comfort zone of how you were taught.

FF Understood. Thankfully before I got into teaching for the school, like I said I was teaching my Circuit Breaker and I was also tutoring since I went to University. I’ve got to see many teachers many styles through the eyes of the students and it was through that experience that I could see what was effective, what wasn’t effective, through all the different levels of mathematics. Of course another major influence would be, I hate saying it as a teacher, but trial and error. You try something, it might work fine one day, and actually that did happen to me. I had parallel HSIE classes so I was giving them the same material in the same method. Some times it worked well with one class and not the other, sometimes it worked brilliantly, sometimes it failed horribly with both of them. Hence, using my mathematics background with analysing and what have you, you had to just try and rationally think of an explanation why a certain method worked, why it didn’t, what were the different factors and it even could just come down to time of day, something happened within the student body, etc.

FI But unless you ask the questions you don’t really think about it. You just... lets go to class, lets just do it. What’s little Jimmy doing? Little Jimmy is just hanging from the fans. Chalk and talk today kids. Sit down. Shut up. Write the work. (laughs) But yeah, you just don’t think about it, really.

FI Conversely if you use a method and the very first time you use it is an absolute horrible one, you’re very reluctant to try it again even though the four times after that it may be a very pleasurable one. But because of your very first instance of using it was atrocious you are very hesitant.

FI Exactly. When I say the self realisation that someone is deficient in a certain area, in a very simplistic way you are admitting to yourself that the method you were using could be wrong. It’s very hard for some people to admit to themselves that ‘hey, that’s wrong. What I have done is wrong.

FI Going back to what gives good results and what gives bad results, there is a member of our faculty that does that, but then that comes down to, I would assume how that teacher was taught. It’s very hard
for someone who has been taught everything rote learning, and more than likely has never gained an understanding, to then turn around and teach a class the understanding of it. It justy doesn't happen. You can fall very easy into the trap of, yes I've done the question, yes I know how to do the question, yes I did do it correctly, so I must be a good mathematician. Which to me isn't true.

FI Going back, using myself and using the other teacher as the example that did the rote learning, the teacher that did the rote learning, her capability for changing the style of lesson will be very difficult because if they changed it to an investigating type of lesson, then the probability of getting a question that was not preconceived is very high and hence she can be caught out. Doing rote learning and doing rigid examples on the board, etc, then the chance that a child can conceive a question that wasn't thought of by this teacher before would be very, very low because they have got all the information. Me on the other hand, since I see myself as having a very high understanding of mathematics at a high school level and at a tertiary level, I have no hesitation in going in and any student on the spot asking me any question about the material or even about any other topic thats contents might cross the path of the problem that we're on.

FI Hence, for the people who put up a fight against change, are in themselves saying either (1) I am egotistical enough to think that the job that I am doing at the moment is 100% perfection or (2) are scared to admit the contrary, which is maybe I am defficient in a certain area. Now, let's be honest, no one is perfect. Everyone can always better themselves. When someone has reached a level of being very good there's still the margin of making themselves better. These days we are trying to teach people to look at the positive things which is fantastic. Yes, people should look at the positive things but by reducing the negative things is also an incredibly positive aspect. For example, you get 95% in an evaluation, fantastic, well done. You shouldn't come away thinking why did I lose 5%, you should be saying I got 95%, fantastic, now how can I reduce that 5%. Hence change. You are very good but how can I reduce that slightly defficient aspect of my teaching to make very good change to very, very good. I know there is a lot of terminology, I'm harping on the words but, that's what I think.

FI It's all up to the personal discretion of the acting maths master at the time whether or not they feel a teacher is able to cope with a certain subject. That's another structure in the school that allows for bad situations or good situations to happen again and again. It seems, like I said, very unstructured. It's too open to bias, opinions and biased decisions. It's far too autonomous in my opinion. It's probably why I'm a little disenchanted with the whole concept of teaching. I see so many teachers being appointed that were in my
class at University who can't do basic fractions. Now, here I am being able to do high level maths, high level university and these dopey gits get the job before those people that can do the job which is a shame, which is a shame. But let's be honest, the end result, since a teacher gets a job, being good or bad, they've got the job until they retire if they want it. The only way they can get out is through types of assults, criminal activity. If every one of their kids fail year after year, tough. It doesn't matter. The kids are not relevant in the processes of deeming whether a teacher can or cannot do a job. Does that answer your question?

FI No, it's not the same thing, actually it's very much opposite ends of the scale. If you use two extremities, one is perfection, one is totally incorrect. The people that perceive themselves at the perfection end, hence egotistical, for them to admit that they are deficient would be for them, moving one step closer to the incorrect extremity. For that seemingly small step, it's inconceivable for them to do. They want to stay at the point of perfection.

FI Yes. There is and that's just simply by preparation. In the sense of the quantity of presumed knowledge changes. Higher classes yes you can presume they have the skills and what not that's needed for the investigation. With the lower kids that level of assumption changes so the preparation needed would be, for the Pythagoras example, maybe ten to fifteen minutes could be spent on, "What does doubling mean? What does tripling mean? What is halving? How do you square a number?", and then you progress onto the investigation knowing that you might still have half the class trying to concentrate on the process of squaring a number instead of what you would like the class to be concentrating on, what the final outcome is.

FL (long pause after being asked if the process is more important than the result) Yes, actually yes because usually with an understanding of the question one has enough logic to see whether the result is correct given the situation or incorrect. You find that the people that don't have an understanding will get an answer, and then say "My answer is this, end of story". One's with an understanding and I am now going into say, applied mathematics; example, x is the origin, from a cliff a ball is thrown in a parabolic fashion, when will the ball hit the ground? If the ball starts off in mid flight you can get the answers time equals 8 seconds and time equals -2 seconds. The people that have been taught rote learning will write down both answers which shows they don't have an understanding because logically there is no such thing as -2 seconds. Consequently in a student that does understand it, when they do get the question they can say time is part of the Natural Number set which is 0, 1, 2, etc so time equals -2 is a totally illogical result. That is where I see understanding of the concepts of mathematics to be very important.
Excerpt from Combined Coded Interviews

DV Violet claimed to have an understanding of the DOSE policy and initiatives but disregarded much of what she saw and read in that respect. She said that her methods had always led to success for the students so she saw no reason to change her teaching. In discussing new policy initiatives she commented, "Success for the majority and harmony in the classroom do not come from those sorts of things."

EA Arnold also talked of how his own education may have affected the way he teaches mathematics. His experiences of mathematics as a student were largely through a traditional pedagogy. As Arnold describes,"But at school I was taught very straight down the line. I don't remember a lot of that, sort of creative stuff." (12/8/97)

EV It seemed that Violet's beliefs on teaching mathematics may have stemmed from when she was a student of mathematics. She talked of experiences in mathematics where her mathematics teacher would not provide a thorough enough explanation of the work. She was often "in tears trying to complete mathematics homework". There seemed to be a strong relationship between her experiences and her current teaching methodology.

FA He commented that it was much easier to accept new teaching methods when they were consistent with the beliefs he already held. While discussing the practical and real life applications that were the impetus of the most recent Year 7-8 syllabus, he said,"And that kind of fitted in nicely with my idea of things needed to be real life and stuff like that." With DOSE initiatives and policy, such as that conveyed in the (Curriculum Directorate little blue things), Arnold would only look through them for the activities and questions that were consistent with his beliefs on teaching mathematics. He did not seem as interested in the beliefs and theories conveyed by the DOSE. He reflected,"I know those little mathematics things they hand out now and then, those little blue things, they're not bad... Quite normally I look at the questions and go 'That's good. Yeah, I like that' but I never quite remember it when I get around to teaching it. But hopefully I've still got those little pieces of paper. I can dig them up." (12/8/97)

FD Dan was questioned on a number of recent policies and DOSE initiatives that had been implemented in high schools. After some discussion he concluded that he would only accept those practices that were consistent with his beliefs. He commented,"I think what tends to happen is, if there is a new faction or a new practice that's pushed forward, you tend to adapt the kind of things that you do anyway and ignore those that don't suit what you have been doing most of the time." Dan seemed to suggest that his belief system acted
as a filter for new policies and initiatives. He would only adopt practices and strategies that were consistent with the beliefs he held.

**FF** When the DOSE attempted to implement new initiatives or policy changes, Frank believed it was far simpler to accept and incorporate it into his practice if it was congruent with his own beliefs. He suggested that a teacher who had the objective of teaching for high results may not see as much importance in teaching for understanding. "Going right back to where I said good behaviour, total silence but no understanding, to me that's a lesson that's failed. To some it isn't. To some that is a pleasureable experience. They see that having high marks as being great."

**FJ** She also found it easy to incorporate new strategies if they were consistent with her beliefs. Jan was asked about the new literacy push and how easily she accepted it. "I don't find it difficult because I basically agree that literacy is the most important thing you can do."

**FV** As new initiatives did not fit her beliefs on teaching mathematics she was unwilling to adopt them as part of her practice. She compared the results of her students with the results of other teachers who made frequent use of new strategies and recent initiatives. She claimed that her classes were most often more successful in examinations and thus proved that her methods were more effective. It seemed that to Violet, the numerical results of students from individualised examinations and process based questions were the ultimate guide of the students learning.

**FV** It seemed that Violet's mindset made it quite difficult to facilitate significant change in her teaching practice. She saw no reason to change as her methods led to successful results and those attempting to change her practice had ulterior motives for doing so.

**GD** Dan claimed that his beliefs on the teaching and learning of mathematics were "an accumulation of experience over the years". However he later questioned whether he actually did reflect on his practice. "I wonder, to be honest, whether I do reflect on my own practice."

**GF** He suggested that his experiences tutoring mathematics and watching other teachers had enabled him to "see what was effective and what wasn't effective through all the different levels of mathematics". Frank was also questioned about the influences that his own schooling may have had on the methods he employs to teach mathematics. He thought that there was a subconscious influence and likened it to the experience of learning to tie shoelaces. "You get to the stage in life where you have lost the conscious knowledge of the process of how to tie your shoelaces but
you subconsciously still do them the way you were taught. I think it's the same in maths and in everything else." Frank emphasised this point further with the statement, "If you have been taught a certain method, then when you come to reteach, if that method was effective for you, you will do it in that same effective method. Now and then trying different methods as an experiment but you will always fall back to the comfort zone of how you were taught."

GF He suggested that to evolve as a teacher it was necessary to experiment with teaching approaches and reflect on the experience. He said, "Of course another major influence would be, I hate saying it as a teacher, trial and error." However he was uncertain whether he would try a new teaching strategy if it was unsuccessful in the first instance. He said that even though it may be successful afterwards, "because of the first instance of using it, it was atrocious, you are very hesitant".

GL Leo had developed these beliefs on teaching mathematics through his experience as a mathematics teacher. He claimed that success, gauged by the students results, had provided feedback to the effectiveness of his teaching. Further "feedback" from students had helped him to evaluate his teaching and decide on effective practices.

HA "It comes down to little policies kind of like 'Agenda 97' or something and I'd say that is largely ignored, certainly by the general teaching people unless of course the head teacher decides it is going to be their little baby and they are going to work on it." (12/8/97)

IA According to Arnold there were some inherent problems with the way new policy, initiatives have been implemented in the past. He likened the DOSE's implementation process as "pieces of paper floating down from above." "I don't think it is a very good way of handing down these policies. They just kind of appear." (12/8/97)

JD "I think for someone trained in mathematics, statistical evidence is something that can lead to modifications in belief and behaviour." Dan discussed an example where he "became aware of studies on how teachers respond to male students as opposed to female students and how they tend to interact more and ask the boys more in a classroom environment". However after further discussion he began to question whether this had actually impacted on his practice. He claimed,

PA His father was suggested to have had an influence on his teaching. As mentioned previously, Arnold believed that effective mathematics teaching would use real life applications. He claimed that his father helped him understand mathematics by showing him where the mathematics had uses. "I remember that my dad
would come and reinforce all that stuff by trying to show me real life situations."

RA While discussing 'Agenda 97' he stated that new policy or initiatives should be accompanied by questions and activities that can be easily implemented. "It seemed like a big picture, sort of up there in the clouds thing and without concrete things I'm not sure that teachers are going to put it into practice straight away. They might keep it in the back of their mind and when they decide to rework some topic they might pull out a few ideas from it but I don't think it will be incorporated as a unified whole unless there is someone there to help go through it."

RD Dan claimed the mathematics textbook that was chosen for use in the school was a resource that had a large influence on teaching. He tended to "follow the style and presentation of the textbook that is currently in use".

RD The concrete resources that the mathematics department holds also influenced the teaching strategies that could be employed. He discussed the school in Zimbabwe where the mathematics department actually had a person wholly responsible for making resources were available. He believed this encouraged the teachers to employ teaching practices they would not previously have entertained.

RJ She further suggested "sharing your resources and asking them to observe your lessons if you are comfortable with that" as examples of strategies that may be tried to affect change. One common method used to affect change in line with DOSE policies and initiatives is inservicing. Jan was critical of this method, claiming it was an inefficient use of time and money. She said,"You can always use time and inservicing but I don't think that is a very good use of resources at all, financial resources. Because people either take it on board and use it or they just forget about it. They say that it's a good idea but can't be bothered doing anything with it. It is very limiting as to who it gets to. Inservicing is very limiting to who it gets to."

RV Violet suggested that those attempting to implement change needed to give teachers the resources to get started. She believed that new syllabi needed to be accompanied by programs and new textbooks with appropriate exercises. It seemed that this would provide a process to follow and would thus lead to a more successful implementation. Violet believed that if these resources were provided it would largely decrease the workload that a faculty faced. She claimed that this base could be modified later but initially it made the implementation "a whole lot easier".