Department of Education

Multiple Intelligences Learning and Equity in Middle School Mathematics Education

Brian Edward Young

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ABSTRACT

This study offers a new approach to raising mathematics achievement through the synthesis of Multiple Intelligences theory and Self-Efficacy theory. It proposes that the opportunity to learn through intellectual strengths will raise mathematics achievement both directly from students' increased understanding and indirectly through raising students' self-efficacy for mathematics.

A mathematics learning program was developed for year eight students in a rural secondary school based on tasks resonating with their intellectual strengths. Both quantitative and qualitative indicators were used to compare the effects of the Multiple Intelligences learning program with the standard delivery of the mathematics curriculum to year eight students over their first term of study.

After nine weeks participation in the Multiple Intelligences learning program, students demonstrated improved engagement and more positive attitudes in mathematics classes relative to their peers receiving standard instruction. The expected gains in mathematics achievement and self-efficacy were not demonstrated within the one-term span of the study.

Assessment of the fidelity of implementation of the principles of Multiple Intelligences theory was confirmed through assessment of the classroom learning environment. Analysis of the reasons for the lack of differentiation revealed limitations in the traditional measures used for assessing the mathematics learning outcomes gained within the Multiple Intelligences program. The loss of available year eight classroom instruction time from institutional assessment requirements and school policy decisions were found to be higher for the class receiving the Multiple Intelligences program than for the comparison class, and this is a significant confounding variable.

It is concluded that significant changes to school organisational structures and assessment procedures are required before the cognitive and affective advantages of Multiple Intelligences learning may be realised optimally in the mathematics classroom.

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[1] Refer to CD-ROM, attached. Please note this is a pdf file (420Kb) and can take a few minutes to load. Adobe Reader 6 is required.

CHAPTER ONE

INTRODUCTION

Low achievement is a significant problem in mathematics education. It has been an ongoing cause for concern and a major factor in mathematics education reform (Lewis, 2002; McNair, 2000; Reys, Robinson, Sconiers, & Mark, 1999). Both nationally and internationally, the lens of public scrutiny is firmly focussed on mathematical achievement with a wide range of countries reporting low levels of mathematical skills in their student populations (Afrassa & Keeves, 1999; Caldwell, 1999; Forgione, 1998; Jakwerth et al., 1997; Macnab, 2000; Stedman, 1997). The problem of low mathematics achievement has been shown to be particularly evident during the transition from primary school (Fullarton, 1996), and during progress through secondary school (NCES, 1997b). For many students who have proceeded through schooling a trend of decreasing mathematics performance has been shown (Afrassa & Keeves, 1999; Hoff, 2000; NCES, 2000a), coupled with a significant decline in student interest in mathematics (Schiefele & Csikszentmihalyi, 1995; Mitchell, Hawkins, Jakwerth, Stancavage, & Dossey, 1999). Much of the stagnation of student achievement, fall in student attitude and reduction in student enjoyment has been noted as occurring in the Middle School years of schooling (Midgley & Edelin, 1998; Vale, 1999). This junior secondary school period is also important for establishing relationships between attitude and achievement in mathematics (Ma & Kishor, 1997), suggesting the transition point in education should receive particular attention.

There is large-scale avoidance of advanced mathematics when the option is available for students at the transitions between years eight and nine (Ma & Willms, 1999) and when moving to year twelve or graduation level (Ingleton & O’Regan, 1998). This avoidance of mathematics may begin in the classroom, but the effects extend beyond it. Literacy and numeracy performances have been indicated to be better predictors of subsequent educational participation than socio-economic characteristics (Marks, Fleming, Long & McMillan, 2000). Mathematics is therefore a key “gatekeeper” to further education and employment opportunities (Riley, 1997; Schoenfeld, 2002) but many students are leaving school with poor functional skills in mathematics and frequently require support in acquiring mathematics competency after they leave school (Battista, 1999). Decreasing performance in mathematics over the school attendance years appears to have associated effects. In addition to having poor functional skills, a number of students progress through school feeling increasingly anxious about their capability to learn mathematics (Hembree, 1990) and when confronted with using mathematics in daily functioning and the workforce (Burrill, 1998). The practice of mathematics testing from an early age has been shown to cause progressive nervousness and anxiety (Gierl & Bisanz, 1995) with children becoming increasingly concerned about their results over time at school. The broader community would empathise with these attitudes towards mathematics, which often has a negative public image as difficult and accessible only to the clever (Lim, 2002; Scott, 2001).

A common admission from people is that they were not good at mathematics in school or could not understand mathematics (Trafton, Reys, & Wasman, 2001) with many expressing a dislike of their school mathematics experiences (Battista, 1999; O'Brien, 1999; Pasztor, Hale-Haniff, & Valle, 1999; Scott, 2001) and anxiety with mathematics use (Jackson & Leffingwell, 1999). Mathematics anxiety is also experienced by educators, and is common among pre-service teachers (Hembree, 1990) and Elementary teachers (Peterson & Barnes, 1996; Zevenbergen, 2000). Those educators who have a higher anxiety and dislike of mathematics can be more likely to teach mathematics in traditional and rule-bound ways (Sloan, Daane & Geesen, 2002), with traditional methods of bookwork and the same instruction for all acting as causes of student anxiety in mathematics (Furner & Burman, 2003). The casual acknowledgement of poor mathematical skills is contrasted with the social stigma attached to an admittance of an inability to read (Battista, 1999). While literacy is considered within the reach of most of the population, difficulty with mathematics and low mathematics achievement appear to be viewed as a common experience, with success expected to be reserved for the brighter students.

These negative descriptions of Western or "Anglo-American" (Zabulionis, 2001) mathematics achievement and image may be attributed to how mathematics is commonly taught and assessed in schools. At the root of much of the difficulty found in mathematics education are inappropriate ideas about what represents mathematics understanding, and inadequate opportunities for students to integrate mathematics into personal mental models of what to do and why (Skemp, 1987). The learning of mathematics has usually been treated as memorisation and practice of rules, and continues to be so in many classrooms (Geist, 2000). The traditional mathematics classroom has been described as mechanistic, isolating mathematics both from its applications and other fields of knowledge (Nickson, 1992) and in turn leaves no room for surprise, discovery, or individual flair (Romberg & Kaput, 1999). This description applies to many classrooms where mathematics is taught using textbooks and discussion, is explained through verbal and written instructions, is worked by mental and written mathematical tasks, and is applied in decontextualised settings drawn from the dominant cultural environment.

Traditional mathematics teaching is seen as both the instructional norm and a cause of failure in school mathematics (Battista, 1999). Traditional mathematics is a particular form of mathematics, "school math" (Richards, 1991), where a collection of facts and figures is structured into an information-transfer relationship between teacher and student. It is a teach and test situation where students receive verbal and written instruction in concepts, practice working through applications of laws and rules and then indicate their understanding by a proficiency in their problem-solving accuracy in the same types of problems used to gain understanding, usually with pencil-and-paper tasks. The mathematics curriculum in schools appears driven by a pedagogy centred on the belief that mathematics is a fixed, static body of knowledge which is mechanistically manipulated using symbols and numbers (Romberg & Kaput, 1999), learned for its intrinsic value, as an end in itself (Scott, 2001).

Yet mathematics capability is an essential utilitarian skill of considerable personal, social and economic value (Scott, 2001; Wilkins, 2000). Given the diversity of students' environments in many schools, the rituals of traditional mathematics instruction may not be readily allowing all students to use their personal experiences to become skilled in recognising when and how to apply mathematics (Draper, 2002; NCREL, 2002) or to experience using mathematics successfully (Stanley & Spafford, 2002). The understanding of mathematics has sometimes been considered to be dependent upon a "gift" for mathematics that is then used to explain success or failure, when the nature of teaching itself should be examined (Piaget, 1972).

Reforms in mathematics education call for learning that is student-centred, drawing upon the individual's socio-cultural background to create fertile opportunities for meaningful mathematics understanding (McNair, 2000; Stanic, 1989; Strutchens, 1995) in order to equip students with a mathematical competence. Immersing students in innovative environments that differ from traditional practices can allow students to develop realistic ideas about representations of mathematics, and how their mathematics learning is connected to the world (De Corte, Verschaffel & Greer, 2000).

Promoting learning in such non-traditional or informal settings and building connections that allow individual experiences to contribute to school achievement is a national research priority in the United States (US Department of Education, 1997).

1.1 Equity and mathematics pedagogy

Society has become increasingly mathematically oriented and mathematics is widely utilised in daily living, in the workplace and in social and civic undertakings (AEC, 1990). The capability to meet the requirement for everyday mathematics has been referred to as a "quantitative literacy" (Steen, 1999; Wilkins, 2000) and is defined in this thesis as *numeracy*. Being numerate has become a cultural necessity in the Western world. Two major components of numeracy are competence in doing mathematics, and a confidence for using mathematics (Perso, 1998). From a professional educators' perspective (Australian Association of Mathematics Teachers, 1997), numeracy involves the ability to use mathematics effectively across personal and public needs, and involves the disposition to use mathematics skills and concepts in context. Under a national numeracy policy, Australian schools are charged with ensuring all students are numerate and have a willingness to engage in situations requiring mathematics (Department of Education, Training, and Youth Affairs, 2000).

The acquisition of this mathematical literacy needs guided instruction and engagement with mathematics. While teachers do make a difference (De Corte, 1995; Haycock, 2001), it has been easy to allow numbers of students to leave school with poor numeracy (Scott, 2001), aided by factors such as segregation or tracking that allow students in lesser paths to take general courses of little mathematical growth (Wilkins, 2000) or because there may be no requirement for minimum mathematics competence to graduate from secondary school, as with Western Australian education (Curriculum Council, 2002). In the past, many students who were not achieving success in mathematics simply stopped enrolling in the subject. Often their future employment requirements did not emphasise the need for mathematics skills much beyond a basic numeracy achievable at primary school level. Traditional teaching and learning structures suited societal needs in terms of identifying those students with mathematical ability who could and would further their education, and partitioning them from the students who were "ready" for the workforce. Schools have been described as having hidden curricula (Garaway, 1997), driven in part by external requirements about "how much, how well and for how many" mathematics learning should be pursued to meet social needs.

Altered social and economic directions and an increasingly complex society has changed in its expectations about the kind of mathematics knowledge needed, now requiring a quantitative capability for varied and open-ended situations (Wilkins, 2000). The rapidly changing society precludes anticipating what will be needed as skills, suggesting that an understanding of mathematics concepts rather than a mechanistic application of mathematics knowledge will better prepare mathematically literate students for the new century (Carpenter & Lehrer, 1999). Within this knowledge-shift in expectations about school mathematics over the recent decade, reforms have altered mathematics education (Romberg & Kaput, 1999), drawing upon evidence such as the Third International Mathematics and Science Study (TIMSS) to indicate the need for learning that involved hands-on and real-world thinking, conceptual understanding, and co-operative learning (Geist, 2000). Under a growing consideration of cultural, socio-economic and demographic diversity a particular emphasis has been placed on the need to make stronger connections between mathematics and students' lives outside the classroom as well as creating a knowledge-construction classroom environment (McNair, 2000) in order to increase understanding of mathematics concepts. Educators interested in teaching for mathematics understanding in their diverse pool of students can enrich these opportunities for connections by making equity factors a consideration in the curriculum, classroom practices, assessment and research (Secada & Berman, 1999).

With growing diversity in student populations at school, increased mathematics understanding represents a continuing challenge for educators in order to provide better life-skills preparation for low-achievers in mathematics. The fact that formal schooling appears crucial to the development of cognitive processes underpinning these skills (De Corte, 1995) suggests a profitable focus may be in the design of powerful learning environments in mathematics. Despite reforms there remains a persistent achievement gap in mathematics, particularly within minority and low-income sectors (Haycock, 2001; NCES, 2001). This is not because the normal child cannot achieve numeracy through learning development (Bowman, 1994). Although there is rich mathematical knowledge and mathematics experience it is held differently by individuals (Stanley & Spafford, 2002), suggesting traditional mathematics education with its dependence on memorization, number manipulation, skill development, and lecture-style teaching (Riordan & Noyce, 2001) may not be providing learning opportunities for all. Schools have been described as powerful sites of social pressures where practical and expedient interests have played a determining role in past educational policy with respect to the consideration of who learns mathematics, how mathematics should be learnt, and how much mathematics learning is deemed necessary (Apple, 1995; NCTM 1998; Stanic, 1989; Steedman, 1991). As a result, differences or inequities have been created in the opportunities for all students to benefit fully from mathematics education (Grouws & Cebulla, 2000). The inclusion of equity principles into the development of pedagogical practices, curriculum content, assessment and research has been suggested as the paradigm under which mathematics low-achievement may be overcome (Meyer, 1989; Secada & Meyer, 1989; Secada & Berman, 1999).

The redress of differentiated learning opportunities through equity has played a significant role in education reform, factored into mathematics education curriculum under the umbrella of social justice (Smith, 2000). The majority of reforms in mathematics education that are designed to address low achievement have responded to particular and well known demographic factors that have been associated with poor educational opportunity and poor student progress, such as social class, race, ethnicity, language background and gender (Diezmann, 1995). There have been clear, definite, positive gains from specific equity programs such as increasing opportunities in access to mathematics (Green, 2001; Ma, 2000; Riley, 1997).

However, examining teaching for understanding from an equity perspective may establish other issues that have been missed as relevant and important to successful achievement in mathematics (Secada & Berman 1999). A major goal of mathematics reform efforts is to assist all students to learn with understanding (Smith, 2000a) because understanding increases the ability to learn, remember and use mathematics (Trafton et al., 2001). Yet the continuing lack of attainment of satisfactory mathematics achievement across all groups of students (Stanic, 1989; Olson, 1996; Sadowski, 2002) represents a great challenge to teaching and learning research and practice to deliver learning in equitable ways. Much education theory and research suggests that a student-centred, constructivist approach that actively engages students in learning best develops understanding (De Corte, 1995). The importance of creating equitable opportunities for personalised understanding requires the recognition and inclusion of individual differences into teaching and learning mathematics.

According to Eisner (1985), the recognition of cognitive differences makes creating equitable school programs essential:

> If students are to understand phenomena in the variety of ways they can be understood, they need to have the opportunity to encounter forms that express ideas about those phenomena in different ways. Furthermore, it implies that if teachers are to understand what students know about something, then students should be given options in the ways in which they can express what they know. (p.150)

Increased accountability and the use of Standards-based outcomes places obligations on teachers to find ways of teaching diverse students and of creating meaningful learning experiences (Gray & Waggoner, 2002). Mathematical learning is mediated by the social and cultural elements of each student (McNair, 2000). Cognitive diversity suggests that mathematics understanding can also be mediated by differences in students' intellectual profile. Allowing children to use their own ways of thinking to solve problems is a powerful tool for making sense of mathematics and for connecting students' everyday informal knowledge with new knowledge (Trafton et al., 2001). This is the educational implication of Multiple Intelligences theory

(Gardner, 1983). In this thesis, equity-perspective differences are considered at the level of the individual's cognitive states and it is proposed that children need more diverse opportunities to learn mathematics through these individual intellectual potentials.

Educational approaches derived from Multiple Intelligences theory provide more diverse opportunities to learn because the fundamental principles of the theory emphasise the alternative strengths that individuals bring to the learning experience. Briefly, Multiple Intelligences theory proposes that intelligence is a culturally dependent construct, is flexible in different contexts, and the functioning or performance of individual intellects is affected by the individual's interactions with the contextual environment (McInerny & McInerny, 1998).

The traditional approach to mathematics education mostly emphasises logically-approached decontextualised schooling, particularly at secondary school (Archer, 1999), that appears to constrain some students from having successful, meaningful, and emotionally satisfying experiences from mathematics education (Kreinberg, 1989). Mathematics success appears tied to a verbal-linguistic and logical-mathematical instructional emphasis derived from Piagetian views of the development of intelligence (eg Inhelder & Piaget, 1958). Gardner (1983) challenges the culturally dominant emphasis on intelligence as a linguistic and logical facility and his development of the Theory of Multiple Intelligences is designed to broaden the Piagetian conception to a much more inclusive, equitable conception of cognitive abilities as intelligences. The theory proposes a plurality of intelligences that allows a framework for teachers to seat mathematics learning in a range of contexts, increasing the equitable opportunities for more students to make real-life connections with mathematics ideas. Multiple Intelligences theory sits within a range of Intelligence models that have been applied to education (Plucker, 2001).

Mathematics understanding is strengthened when meaning is made through connections between mathematical ideas, facts and procedures (Hiebert & Carpenter, 1992) and it is likely that mathematical ideas will be realised more quickly and held more strongly if they make personal sense. Context is an important guide for establishing meaning from mathematical symbols (Rubenstein & Thompson, 2001) and is better provided in instruction if the classroom mathematics being engaged are linked into a larger field of meaningful practices (Roth, 1996). Once the particular principles are understood within a concrete circumstance, it is also more likely that they can be successfully generalised or extended to other representations, with the potential for a growing construction of connections between these forms becoming available. Mathematical meaning therefore is advantaged if the opportunity for connections is diversified through a variety of representations, with understanding coming from connections made between forms, and within forms. The significance lies in the importance of building rich networks in personal contexts, which may then act generatively to form connections with new information (NCREL, 1995b).

The problem in school mathematics is that the initial contexts can be restricted to abstract symbols and written material that limit the availability of meaning for many students (Hiebert & Carpenter, 1992). Symbolism creates difficulties for students and unlike daily language is mainly confined to classroom use (Rubenstein & Thompson, 2001). Meaningful linkages between classroom mathematics and student experiences may be lost if mathematics concepts are taught only in the abstract form, and if mathematics classrooms assume that everyone organises experiences in the same way and everyone shares the same experiences (McNair, 2000). These restrictions on context and representation may create inequities in the opportunities for all students to understand concepts contained within tasks. Evidence of success in closing mathematics achievement gaps between students of different life experiences through contextual learning and mathematics with personal meaning has been demonstrated in the EQUITY 2000 project, building on the essence of Multiple Intelligences theory (Green, 2001). Multiple Intelligences theory offers both an explanation why mathematics classrooms continue to show persistent low achievement, and offers teachers a framework within which pedagogical decisions can be made that accommodate a student's cognitive profile (Goodnough, 2001), allowing equitable learning opportunities into diverse classrooms.

1.2 The effects of inequity on academic progress

Creating equitable learning opportunities is an important and necessary component of mathematics teaching under the Standards and Outcomes approach being introduced into US and Australian schools. A major premise for making mathematics education an integral part of general education is that “all students are capable of learning the mathematical ideas and skills that underpin a wide range of everyday uses and can benefit from doing so” (Curriculum Council, 1998, p. 178).

Equity infuses this goal yet the persistence of low mathematical achievement is at odds with the statement. Low mathematical achievement has continued to be found trans-nationally and is attributed to biased classroom practices, to disjunctive teacher expectations and values, and to school policies which cause students to be assessed and grouped such that their opportunities to learn mathematics under optimal circumstances is curtailed early in their schooling (Jones & Bouie, 2000).

Low mathematical achievement appears to grow with exposure to schooling such that the discrepancy between expected achievement and actual attainment widens for some low mathematics achievers over time (Bowman, 1994; Magne, 1991). This contradicts the effectiveness of policies of education systems aiming equitably for excellence in education. Despite continued reforms aimed at ensuring that the principle of equity is considered in programs, the question arises as to why many students have persisted in showing poor performance (Futrell, Lynch, & Hunter-Boykin, 1997).

This thesis argues that low achievement persists in mathematics because inequity continues to lie at the heart of the problem and equity-driven mathematics reforms do not consider the concept of differentiated student intelligences when devising learning programs. It is proposed that a new perspective on raising achievement in mathematics students through the use of a learning program based on Multiple Intelligences (MI) theory (Gardner, 1983) may provide an alternative more equitable approach. The application of Multiple Intelligences theory to create resonant learning between different cognitive abilities and the mathematics tasks is proposed to add depth to equity-based reforms that have concentrated on demographic characteristics of students. The idea of an “equity pedagogy” is applied in this thesis to the concept of opportunities to learn through differentiated and multiple forms of intelligence, at variance with the Piagetian trajectory traditionally assumed of students’ cognitive growth in school learning and assessment in mathematics.

1.3 The extension of equity to the concept of intelligence

Equity-based statements have been incorporated into recent frameworks for the delivery of education (Curriculum Framework, 1998; NCTM, 1991). Both US and Australian national statements express that the quality of a mathematics education is inextricably linked to the classroom experiences schools provide to students. Chapter one of the NCTM's "Principles and Standards for School Mathematics" opens with a vision for school mathematics where all students have access to high quality, engaging mathematics instruction, knowledgeable teachers have adequate resources to support their work, students confidently engage in complex tasks chosen carefully by teachers, drawing on knowledge from a wide variety of mathematical topics, sometimes approaching the same problem from different mathematical perspectives or representing the mathematics in different ways until they find methods that enable them to make progress (NCTM, 1991).

Yet this visionary description of a mathematics classroom made over a decade ago is still only a vision. The reality is that all children are not represented in this picture of a school mathematics classroom. Many children do not receive a quality education in mathematics and experience failure and alienation from mathematics.

There are many identified reasons for mathematics students' failure and alienation. Traditional mathematics presentation has contained such causes as memory-dependent algorithms; an inability for students to maintain pace; delayed diagnosis and assistance, an over-emphasis on rote-learning; inadequate feedback from assessment; and a presentation of facts in isolation (Cornell, 1999; Cordova & Lepper, 1996; Lim Chap Sam, 2002). Recent reforms in mathematics have focussed on the importance of students making connections with real contexts, which have been absent in much of traditional mathematics presentation.

This focus of mathematics learning on making meaning to a range of students requires a broad range of physical resources, the engagement of different experiences as settings for problem-solving, and the consideration of multiple student skills to cognitively embed mathematical principles. A concentration on particular modes of presentation and forms of response denies students the opportunity to display what they have learned in the forms that most suit their aptitudes (Eisner, 1985).

Mathematics education has recognised there are aptitude differences among students with respect to the knowledge and performance systems they use best (Secada, 1992), making the pedagogical argument for using diverse modes of representation and response highly defensible. Many children cannot readily find meaning in linguistic and symbolic representations (Rubenstein & Thompson, 2001). The link between student experiences outside the classroom and the mathematics instruction in the classroom is at its most critical for students whose life experiences are most distant from traditional mathematics curriculum experiences (McNair, 2000). In order not to perpetuate differences in achievement caused through traditional transmission models of mathematics education that emphasise manipulation of symbols in an “instruction–example–practice” delivery, it may be effective to offer a variety of contexts and representations for mathematics concepts allowing more opportunities for connections to experiences.

It is suggested in this thesis that a major reason for the persistence of low mathematics achievement is that schools limit this variety of classroom experiences. It is proposed that traditional mathematics classrooms emphasise linguistic and logical-mathematical skills as the means of teaching, learning and assessment in mathematics, introducing a bias against some students establishing understanding. Not all students have natural abilities in the culturally valued tools most used in mathematics education, which are those of verbal-linguistic and logical-mathematical skills. Students with alternative modes of intelligence need resonant new opportunities to learn, with a deliberate planning of curriculum delivery to bring diverse opportunities into play.

The thesis proposes that using Multiple Intelligences theory to create a personalised learning environment that meets diverse learning needs will assist mathematics students in two ways. The first is that an increased achievement in mathematics is proposed to result from the direct cognitive advantage given from representing mathematical concepts in more meaningful forms to different students. The second form of assistance to low achieving mathematics students is through the emotional or affective advantage from using classroom instruction that takes into account students' intellectual strengths to increase their opportunity for success.

Changes in students' beliefs about their capability to do well in mathematics are examined in this thesis in terms of the theoretical concept of Self-Efficacy, the confidence that individuals have in themselves to succeed in tasks (Bandura, 1997). More explicitly, the construct of self-efficacy is defined as "people's judgements of their capabilities to organise and execute courses of action required to reach designated types of performances" (Bandura, 1986, p391). There has been a recent shift in the field of self-efficacy research towards academic achievement and motivation, and particularly towards mathematics performance (Fouad & Smith, 1996). The value of synthesising Multiple Intelligences theory with Self-Efficacy theory is offered as a unique addition to research into low mathematics achievement in secondary schools.

1.4 The role of affect in low mathematics achievement

The problem of motivating children wanting to know "why" and "how" doesn't seem to be found in pre-school children (Cordova & Lepper, 1996), yet one of the most acknowledged characteristics about mathematics education is that after a short time at school, many students do not seem to be enthusiastic about mathematics. It is doubtful that these students begin their school experiences with such ingrained attitudes to mathematics, suggesting that schools need to recognise and accept responsibility that exposure to schooling might be playing a role in forming negative student attitudes in mathematics. For a subject that is commonly regarded as dispassionate and impersonal, mathematics seems to generate the most passionate emotions, of which dislike is frequently expressed (Ingleton & O'Regan, 1998).

This problem of liking or disliking mathematics at school has significance for achievement under the compulsory curriculum for students. It is an accepted human reaction to enjoy and participate in activities we like, and because people are good at different things, there is a natural inclination towards the things we feel good about doing, and away from those things that we feel not so confident in doing. A major NAEP (2000) finding was that across grades four, eight, and twelve, those students who agreed that they enjoyed mathematics and saw a usefulness in it outperformed those who disagreed with these attitudes (NCES, 2000b). Present curricular and pedagogical requirements of education do not sufficiently include the psychological factors of learning such as self-confidence and school attitudes in order to influence achievement in mathematics (Stedman, 1997), nor is there sufficient effort made to create intrinsic motivation in order to stimulate students' enjoyment in learning (Csikszentmihalyi, 1996). Affective variables – characterised as beliefs, feelings, moods, attitudes and emotions (McLeod, 1992; Owens, Perry, Conroy, Geoghegan, & Howe, 1998) – have a clear role in mathematics achievement research (Higbee & Thomas, 1999). Research confirms that a major reason for the lack of success is a lack of engagement, with low achievers particularly showing lower engagement in class (Kastner, Gottlieb, Gottlieb, & Kastner, 1995). Some students do not apply themselves to class-work, are not active in class, become frustrated with their lack of success and express the belief that they are not capable of doing the work. Frustration is not only on the part of students. There are many frustrated parents who have read students' school reports bearing teachers' comments that low student achievement is because the student "is not trying", "is not concentrating", "could do better" or "is not working to capacity".

Yet mathematics is an acquired component of human skills. The acquisition of mathematics is as subject to the combined influences of human efforts and innate abilities as is proficiency in golf, violin, ballet or languages. Competence in these things is influenced by "natural endowment, socio-cultural experiences and fortuitous circumstances that alter the course of developmental trajectories" (Bandura, 1997, p. 36). It is also influenced by how much effort is put in, how much practice occurs, how much support in the form of resources is given, and what expert help is provided. The more these latter variables are part of the learning experience, the more likely the learner will feel confident about taking part in learning. That is, their self-efficacy will be raised.

Mathematics self-efficacy is related to the activation of engagement with mathematics. Self-efficacy is the term used by Bandura (1986) to describe the degree of confidence that individuals have in their ability to undertake particular actions. Self-efficacy, and especially mathematics self-efficacy has been extensively researched, as demonstrated in the meta-analysis of Multon, Brown and Lent (1991). An established outcome of that research is the link between raised mathematics self-efficacy and a range of variables associated with mathematics achievement such as course selection choices (Betz & Hackett, 1983; Gainor & Lent, 1998; Lapan, Shaughnessy & Boggs, 1996), mathematics anxiety (Hackett, 1985; Malpass, O'Neil, & Hocevar, 1996), attitude (Hackett & Betz, 1989), improved performance (Hanlon & Schneider, 1999), teacher efficacy (Huinker & Madison, 1997; Midgely, Feldlaufer & Eccles, 1989) and motivation (Meyer, Turner & Spencer, 1997).

Mathematics is a socially constructed human activity with its own history, tradition and culture (Barton, 1996; Richards, 1991) and the participation in classroom mathematical activities are mediated by those socio-cultural experiences (McNair, 2000). Mathematics reforms have considered these factors in recommendations for change to curriculum and pedagogy (Adeeb & Bosnick, 2000; Joshi, 1995; McNair, 2000; Reys, Robinson, Sconniers & Mark, 1999; Stanley & Spafford, 2002; Stanic, 1989) and they have underpinned a number of new curricula (Bey, Reys & Reys, 1999; Green, 2001; Haycock, 2001).

As an additional component in raising mathematics achievement, Multiple Intelligences theory is used in this thesis to argue that mathematics concepts can be differentially represented, understood and demonstrated in many ways other than those requiring talent in logical-mathematical cognitive operations. The hegemonic position that logical-mathematical ability is a requisite quality for learning mathematics is refuted. Multiple Intelligences learning allows that people may legitimately be able to better understand concepts if other personal strengths are involved. This use of personal strengths is also proposed to encourage student self-efficacy in mathematics.

1.5 The context of mathematical reform

Mathematics education culture has a degree of inertia, an entrenched attitude persisting with "tried and true" traditional practices of modelling, symbolic manipulation and decontextualised representation (Archer, 1999). The success of traditional mathematics appears higher for those students with a natural strength in logical-mathematical abilities (Center for Talented Youth, 2002), which implies that many other students are disadvantaged in their opportunity to learn. Opportunities and incentives to participate in mathematics through course-taking are important predictors of future mathematics capability and success (Riley, 1997). In particular, Middle School students are a group at a point where alienation from mathematics is both potentially at its peak, and optimally alterable towards engagement (Ma & Kishor, 1997). A Multiple Intelligences program may offer particular benefits in mathematics learning for these students because it carries the promise of improvements in understanding, more successful experiences and a sense of capability for mathematics leading to increased engagement with and selection of mathematics courses. Research on Middle School mathematics teaching is not prevalent (Vale, 1999), a circumstance this thesis aims to address.

Mathematics reforms in Australia have included a move to “Middle School” models of learning. There has been strong interest in and adoption of this concept in Australian schools recently (Department of Education Services, 1999). This has been stimulated in part by a Curriculum Framework focus on Outcomes as an equity-based concept to give all students equal access to the curriculum. The relative autonomy given to Middle Schools readily allows a variation in the means by which those outcomes are achieved. One of the features contained in traditional mathematics delivery that need reforming in order to influence achievement are those organisational factors of curriculum, such as bureaucratic control (Stedman, 1997). A Multiple Intelligences program is well adapted to support the implied flexible delivery of a Middle School philosophy, building as it does a connectedness between mathematics and other areas of learning. In particular, the Middle School ethos offers support to the introduction of a Multiple Intelligences program because one of the guiding philosophies to its establishment is a move away from notions of uniform conceptions of intelligence in an effort to cater for increasing diversity among the student population (Department of Education Services, 1999).

Middle Schools offer an opportunity for increased personalisation and the application of cross-curricula activities. Some defining features exemplifying a Middle School are that students should be connecting learning to personal experiences, and that knowledge and skills should be acquired in authentic settings and contexts

(Department of Education Services, 1999). Pedagogical characteristics of Middle Schooling include self-directed learning, varied tasks leading to concepts, and the flexible use of materials. A recommendation is for "clear and meaningful tasks" (Department of Education Services, 1999, p. 61), which from the students' perspective is more likely if these tasks reflect their cognitive strengths. There is a strong connection between these tenets of the Middle School philosophy, the Curriculum Framework model of educational reform being incorporated in Western Australian schools, and Multiple Intelligences learning. This may be indicated by three beliefs associated with an Outcomes-Based Education pedagogy:

- all students can learn and succeed (but not on the same day or in the same way).
- Success breeds success.
- Schools control the conditions of success

(Willis & Kissane, 1995, p. 3).

These beliefs contain kernels of Multiple Intelligences theory and Self-Efficacy theory principles. Multiple Intelligences theory holds opportunities to increase understanding and achievement in low ability children through personalised cognitive pathways to learning content and skills. It offers affective consequences that are postulated to encourage confidence in doing mathematics and engaging in mathematical practices, factors that have been argued to be important both within the school environment (Cornell 1999; Greene, DeBacker, Ravindran & Krows, 1999; Higbee & Thomas, 1999; McNair 2000; NCTM, 1989; Reinholdt, 2001) and in the reduction of schools creating marginalised young adults (Spierings, 1999).

To summarise, it is argued that the students at risk of persistent low mathematics achievement are those who have failed to meet the school culture's requirements of strong linguistic and logical ability. These mathematics students may not have strong abilities in logical thinking, may have poor language skills and poor opportunities for supporting mental idealisation. Since mathematics is traditionally taught through such cognitive tools, possession predicates enhanced success in mathematics and it is argued that as a consequence not all students are equitably provided for in the classroom mathematics curriculum. Further, if the same mechanisms are used to assess the outcomes of students' mathematical understanding, the result could be interpreted as an inability to learn mathematics (Morgan & Watson, 2002). On the basis that school reforms have persisted with practices based on dominant intellectual forms of representation, low achievement appears to be built into many mathematics classrooms. The movement to Middle School models of learning provides opportunity to reform mathematics classrooms in ways that are resonant with diverse student abilities, to improve confidence and achievement among students who currently fail to acquire mathematical competence.

1.6 Rationale for the thesis

The rationale for the Multiple Intelligences mathematics program presented in this thesis is that it will increase the numeracy of low achieving mathematics students who have neither the proficiency nor the inclination to use mathematics in their daily lives. At present, although schools provide students' main experiences of mathematics, the school context contributes very little to these students becoming mathematically literate (Richards, 1991). It is proposed that as a result of Multiple Intelligences-based learning, the formal learning of traditional school mathematics will be diluted by tasks that are richly appealing in their contexts to the cognitive understanding of low-achieving students. As a result, the functional value of mathematics will be made clearer to students, they will be better equipped with mathematical understanding, and more disposed to use mathematics.

A major function of mathematics reform is to increase the numeracy of students. The Multiple Intelligences learning program described in this thesis operationalises numeracy as the active application and consideration of mathematics in multiple tasks. The curriculum program developed for this thesis seeks to influence students in engaging mathematically with a variety of tasks and to use that knowledge to confidently move towards raised achievement.

Low levels of numeracy have a strong negative effect on employment prospects, and coupled with an early exit from secondary education are prime factors in creating such "at risk" populations (Spierings, 1999). Literacy and Numeracy are key foundation skills, without which children are at risk of failing at school, yet while Australia nationally has a minimum literacy requirement on students to graduate from high school, no such numeracy standard yet exists. Numeracy in Australia has been acknowledged as a neglected area of policy development at the national level and because of this it is an Australian federal intention to institute projects to provide foundation work and research to support numeracy teaching in schools (School Insight, 1998). This thesis reflects these federal intentions and is capable of informing future policies and practices concerning numeracy.

The importance of numeracy lies in changed demographic requirements. Contemporary society has diverse needs. Economic changes in the workplace are rapid, mobility is high, student retention at school is both an Australian and international priority and the necessity of an education in mathematics has dramatically increased. Ironically, the valued emphases on verbal-linguistic skills and logical-mathematical ability are drawn from and driven by the same society that rejects and blames individuals who have not gained numeracy at school. Western culture provides few roles either socially or economically for those who do not engage in these favoured ways of learning (Resnick & Nelson-Le Gall, 1997). From the perspective of social justice, mathematics pedagogy should consider the implications of reconceptualising intelligence to recognise the diversity of its modes.

The National Statement on Mathematics for Australian Schools (AEC, 1990) notes "participation in mathematics in Australia has been too dependent on being a member of particular groups in society" (p. 8). In an admission that lends support to the underlying tenet of this thesis, the AEC states that past mathematical teaching practices and curricula have neglected the values, concerns, interests and cognitive skills of many students that may have disadvantaged their learning mathematics.

This neglect is suggested to account for the gradual but persistent decrease in some students' achievement in mathematics. Failure is a corrosive influence on motivation and if persistent is apt to alienate students. When students no longer expect to do well in their mathematics, it is not surprising that they will become disengaged and alienated from mathematics class-work. The mutual effects of disengagement and poor performance are likely to compound each other, and it is sometimes necessary to convince students they can be successful, are able to learn mathematics, and that mathematics has a meaningful role in their lives (Higbee & Thomas, 1999).

Therefore students need successful mathematics experiences. Multiple Intelligences theory holds opportunities to increase understanding and achievement in low ability children through personalised cognitive pathways to learning content and skills. Multiple Intelligences learning is proposed to have affective consequences which will encourage positive attitudes towards schooling and subsequent successes in life. These outcomes are important both within the school environment in the encouragement of active involvement, and in the reduction of schools creating marginalised young adults.

1.7 Purpose of the research thesis

The purpose of this thesis is to demonstrate a learning program that aims to raise mathematical competence in low achieving students and increase their self-confidence for engaging in mathematics.

The thesis introduces a course of teaching and learning which transforms the NCTM's (1991) vision for mathematics learning into reality. The vision of the NCTM is that all students in their mathematics classes should be engaging in high quality mathematics instruction, drawing on knowledge from a wide variety of mathematical topics, sometimes approaching the same problem from different mathematical perspectives or representing the mathematics in different ways until they find methods that enable them to make progress. The thesis program has the purpose of showing that the use of Multiple Intelligences theory can allow a mathematics classroom to function in this way.

This thesis proposes that by adopting programs utilising mathematics tasks in which children have an ability and interest, they may become engaged with the subject. Student interests are proposed to reflect, engage and strengthen students' intelligences. It is proposed that utilising student strengths will both encourage participation and assist the understanding of mathematics concepts. Both these influences are suggested to improve academic performance with attendant increased confidence in the student for personal success. This affective reaction by students to their improved cognitive ability is introduced into the study as the concept of *self-efficacy*, the belief in one's own ability to perform tasks (Bandura, 1986). The influence of self-efficacy in the field of mathematics education is discussed in depth in chapter four. In brief, raising student self-efficacy for mathematics has been widely researched and noted to be a significant force for achievement in mathematics. This thesis has a purpose of informing research on the influence of Multiple Intelligences learning on mathematics self-efficacy.

1.8 Significance of the thesis

This study aims to implement an innovative program that assists mathematics low achievers. It seeks to add to the inventory of replicable, validated programs required to guide mathematics reforms. Such guides should demonstrate effectiveness with targeted populations, be clearly defined, be implemented with reasonable effort and should use resources that typically are available in educational settings (Miller & Mercer, 1997). Because of its contemporary aim of reducing low mathematics achievement, the thesis has value for mathematics learning at the levels of individual students, the Western Australian education system, the national Australian education system and internationally.

At the student level, the significance of the thesis can be demonstrated in terms of the value to individuals of possessing mathematical knowledge. The effects of low mathematics achievement are well documented. They diminish the contributory value of individuals to society, inhibit engagement with a richer personal life, and carry financial and social burdens. The thesis offers new information on how students may be encouraged to feel confident about engaging with mathematics, and how a student's history of failure to achieve may be negated through the inclusion of their interests and strengths as media. This knowledge of the impact of Multiple Intelligences learning programs has not been evident in literature on low mathematics achievement and therefore contributes new knowledge on programs aiming to positively influence variables related to the success of students.

In the opinion of Bandura (1997), "Societies pay dear for the educational neglect of their youth" (p. 213) and even the well educated have to struggle to compete in the globalised workforce. The traditional practices of mathematics education no longer supply the mathematical needs of many students in the twenty-first century. Nor do they cater for the diversity of personal factors that children bring to school. Even the most literate and numerate students have difficulty coping with social and economic changes. The personal and social impacts of low mathematical achievement have been magnified in the last decade by these changes (NCREL, 2000, 2000a). Vocational and functional emphases such as the communication of ideas, shared solutions and the use of technology have influenced reviews of the mathematics curriculum and the mathematical skill requirements of students leaving school. The expenditure by governments on education has become increasingly accountable, and the moderate successes of educationally similar countries such as Australia, the US or Canada in international mathematics assessments have not been accepted as reflecting the economic resources placed into their education systems (McLaughlin, 1999).

Australia is undergoing many of the social and economic changes felt in the US. Low achievement in mathematics in Australia does not seem to be of the same level as that experienced in the US (American Federation of Teachers, 1999; TIMSS International Study Center, 2001; Way, 2002), perhaps because of a relatively uniform dominant culture and curriculum (within and between Australian states) yet Australia faces the same challenges to create opportunities as other countries. Technological change and a global economy mean skill requirements have evolved. The factors associated with changing conditions of work in Australian society, such as flexibility, ability to transfer skills to new settings, accommodation of new information quickly, and capacity to function cooperatively in exchanges with others are all similar to NCTM recommended skills acquisitions (NCTM, 1989).

A further significance is that the thesis meets the calls from within mathematics education for research into classroom learning. A major policy movement in both the US and Australia has been the call for improved pedagogical knowledge and relevant classroom practices (Forgione, 1998; Department of Education, Training, and Youth Affairs, 2000). Within the Australian education community, Australia's peak research organisation – the Australian Council of Educational Research (ACER) – has made the gaining of knowledge about the value of reforms in mathematics, and of how to improve numeracy both internationally and nationally, a major priority. The ACER organisation is currently undertaking research on numeracy guided by such questions as

- What programs have been implemented to improve numeracy learning?
- What needs do children have to improve numeracy and how can teachers help?

- What are the strategies, methods and contexts of classroom programs and how effective were they?

(ACER, 2001)

The direction of these questions suggests the need for research on increasing student achievement, improving engagement and raising productive behaviour in mathematics classes. This thesis is timely in that it addresses these factors that have been described as important areas of mathematics education to be researched (Doig, 2001; Keeves 1995), and is undertaken at a time when a number of Australian and international projects and reports into numeracy learning are becoming available (ACER, 2001). By situating the research in the Middle School transition year on an equity basis this study has the potential to inform the field of mathematics education on learning and student differences at a critical point in the educational pathway.

1.9 The research hypotheses

The research hypotheses are as follows

1. *Multiple Intelligences instruction will result in improved performance in mathematics for students.*
2. *Multiple Intelligences instruction will positively influence the performance attainment of low achievers to a greater degree than average and high achievers on measures of mathematics achievement.*
3. *Multiple Intelligences instruction will result in increased perceptions of self-efficacy for students*
4. *Multiple Intelligences instruction will positively influence the perceived mathematics self-efficacy of low achievers to a greater degree than for average and high achieving mathematics students.*

The hypotheses are based on the likelihood that Multiple Intelligences learning will allow more students to understand mathematics. In particular, low achievers should improve most because they have had fewer opportunities to gain a personally meaningful understanding of mathematics concepts under traditional teaching emphases. Because more students are provided with tasks matching their natural intelligence strengths, more students should experience success. Success builds a sense of capability for task performance, therefore it is hypothesised that students' mathematics self-efficacy will improve. Again, low achievers are the group that has least experienced success in mathematics, so it is hypothesised that this group will show the greatest gain in self-efficacy for mathematics.

1.10 Methodology

The thesis involves investigating the impact of a Multiple Intelligences learning program on the cognitive variable of mathematics achievement and the affective variable of self-efficacy. A particular focus is on those students who are low-achieving in mathematics.

In order to identify past and current literature on mathematics education, Multiple Intelligences theory, Self-Efficacy theory, and low achievement in mathematics a computerised search was made on major databases, combined with a search of major journals in mathematics education. This method of literature search has been used in the synthesis of research on mathematics interventions with low-achieving students (Baker, Gersten & Lee, 2002). The main databases used in this thesis were ERIC, PSYCINFO, PROQUEST, EXPANDED ACADEMIC, INFOTRAC, and AustROM (WebSPIRS). Keyword sets used included intelligence, multiple, mathematics, self-efficacy, low, achievement, research, and meta-analysis.

Based on the computerised searches, the use of Multiple Intelligences theory with low mathematics achievement in Middle School year eight classes had little research-based representation in the literature review at the time of designing this research (1998). The process of implementation of a Multiple Intelligences mathematics program presented a challenge to determine the most appropriate methodology to validly and reliably obtain the data, to select data instruments and to analyse the data. Little guidance on the methodology of research into this thesis problem of low mathematics achievement could be imputed from the literature on Multiple Intelligences theory apart from general principles of implementation. At the time of writing, the majority of Multiple Intelligences research within the environment of secondary schools has been into the Humanities (eg Beuscher, Keuer & Muehlich, 1997; Dare, Durand & Moeller, 1997; Layng, McGrane & Wilson, 1995) under the "Action Research" methodology (eg Ellingson, Long, & McCullough, 1997; Creagh & McHaney, 1997). Research into low mathematics achievement using Multiple-Intelligences interventions has appeared to have received minimal attention since then based on recent database reviews. Although there are many narrative descriptions of the application of Multiple Intelligences theory in mathematics (eg Willis, 2001), research using the experimental and quasi-experimental criteria of Baker et al. (2002) has appeared sparse. An ERIC search using the descriptors of 'Multiple Intelligences' and 'mathematics' returned 189 abstracts of which 9 specifically related to research in mathematics education, with the majority of those using "Action Research" methodology (Abbot & Warfield, 1999; Carver, Price, & Wilkin, 2000; Campbell, 1990; Goodnough, 2001; Pajkos, & Klein-Collins, 2001; Klein, Pflederer, & Truckenmiller, 1998; Schwarz, 1999; Kuzniewski, Sanders, Smith, Swanson, & Urich, 1998). One study (McGraw, 1998) used random assignment methodology comparing pre-test and post-test effects of Multiple Intelligences intervention on year seven mathematics students.

In the poor light of guiding methodologies for research into mathematics education under Multiple Intelligences theory, this study adopts a quantitative, quasi-experimental methodology. The major reason is to investigate a possible cause and effect relationship between the intervention program of Multiple Intelligences teaching and the outcome variables of mathematics achievement and mathematics self-efficacy. Further reason for the selection of the quantitative approach is that the nature of the research hypotheses allows a collection of data which can be analysed statistically and allow decisions to support or reject the research hypotheses.

In contrast to Multiple Intelligences literature, Self-Efficacy theory and its application to low mathematics achievement is well researched (Bandura, 1997). The majority of research in Self-Efficacy and low mathematics achievement uses quantitative methods, adding reason to select that methodology for this thesis.

Standardised assessments of student achievement in mathematics are used to establish equivalence between the groups involved in the study and to demonstrate progress over time. Similarly standardised measures of self-efficacy are utilised to demonstrate changes in students' self-efficacy over time (Mathematics Today Series, 1996; Pajares & Miller, 1995).

The constraints of access to the site are also significant for the length of the study's data collection period and were determined by institutional factors beyond the control of the researcher. From the point of view of student access, the intervention was limited to a nine-week school term. The problem of determining length of exposure to the intervention program in order for it to have measurable effects is not indicated from research literature on Multiple Intelligences learning. The question of whether differences associated with the contrast between the intervention program and standard mathematics teaching will emerge within the available time frame is empirical. The differentiated delivery of the intervention is guided by both Multiple Intelligences theory and the Curriculum Framework document (Curriculum Council, 1998) in that teaching practices will recognise individual interests and create opportunities for raising student engagement, and allow the assessment to include student work in relevant contexts. By contrast, traditional Australian mathematics classroom teachers strongly guide students and have a high degree of classroom control (Bourke & Smith, 1996).

The fact that there was little guidance in the literature on Multiple Intelligences theory in mathematics education contexts for an appropriate time-scale for Multiple Intelligences interventions to have an effect on low mathematics achievers is viewed as a methodological outcome of this thesis and will be re-visited in discussion in chapter eight.

Qualitative data on student engagement will be obtained using teacher/researcher-based observations made over time, and teacher-rated assessments of student engagement will be determined according to a scale of engagement. This provides further data answerable to statistical analysis. Validity and reliability of data will be discussed in the Methodology chapter six.

Class students will also keep a record of their reactions to their mathematics class-work as part of the curriculum delivery. These qualitative data are incidentally acquired, but has significance for the study. For many mathematics classes it is as much a component of day-to-day student routine as is working on mathematics tasks, and may be a source of guidance to the class teacher. In this study, the data will be analysed on the basis of students' positive, negative or neutral comments to provide further evidence of affective outcomes.

1.11 Scope and delimitations of the thesis

The following section describes the boundary of the research problem as covered by this thesis, and describes the research conditions briefly.

The thesis describes a mathematics program based on Multiple Intelligences theory. The teaching program draws from the mathematics curriculum as described in the Western Australian Curriculum Framework (Curriculum Council, 1998). The specific classroom tasks relate to the educational outcomes as described in the Western Australian Student Outcome Statements: Mathematics (Education Department of Western Australia, 1998).

The research findings are for Year eight students in a co-educational public senior secondary school in rural Western Australia. The school is the only public senior secondary school in the district, and draws upon a general rural and urban population of about five thousand people.

The school consists of five age-based year groups from year eight to year twelve. Only the year-groups eight, nine and ten operate under the Curriculum Framework model of educational delivery. The curriculum courses are differentiated across learning areas and stratified within each learning area, although the Student Outcomes focus means that overlap in levels may occur for students in years eight, nine and ten. Students attend mathematics classes as part of a compulsory curriculum framed by the eight learning areas (including mathematics) described in the Curriculum Framework (1998).

The Year eight mathematics classes are heterogeneous with respect to gender and mathematics ability. The research problem of how to assist students of low mathematics ability is delimited in the thesis learning program by sub-grouping students on mathematics ability through a pre-test with a standardised assessment instrument. Chapter six describes this ability grouping procedure.

Instruction in mathematics is scheduled for four periods of sixty-five minutes instruction per week. The thesis author is responsible for teaching the mathematics classes involved in this thesis. The remaining two mathematics classes are taught by the Year eight Coordinator.

Factors of reliability and validity in terms of the population samples used in the thesis are described in detail in the Methodology contained in Chapter six. The evident constraints that existed before the initiation of the learning program are related to the school's policy on organisation such as class sizes, student allocation to classes, length of class contact time, and time scheduling of classes.

Delimitations were identified prior to the study with respect to the classroom context and include such variables as physical resources, requirements for school assessments and behaviour management.

Approval to conduct the program for one nine-week term was obtained through the School Principal. The nature of the mathematics data obtained for the thesis is typical of that collected within the school in order to deliver best practice programs in education. A condition of approval was that the program would be regularly supervised and monitored by the mathematics learning area Head of Department and the Year eight learning group Coordinator to ascertain that the school's curriculum was being delivered and assessed in an approved manner.

Assumptions about the data that have relevance for the analysis of information are detailed in the Methodology Chapter six. Limitations on outcomes and their effects are described in Chapter eight.

1.12 Outline of the thesis

Chapter two reviews the problem of low achievement in mathematics, analyses the characteristics of low achievement, examines the broad reforms in mathematics education and demonstrates that the persistence of low achievement may be accounted for in part by the prevailing pedagogy which continues to be dominated by Piagetian logical-mathematical views of intelligence. Chapter three details the limitations on school learning resulting from current educational practices based on culturally conventional ideas of intelligence. The characteristics of the alternative Multiple Intelligences model are described and this leads to discussion of the cognitive and affective advantages associated with a reconceptualized model of intelligence.

Chapter four examines the importance of the emotional and cognitive resources that students bring to their mathematics classes and focuses on the affective component of self-efficacy in promoting more positive outcomes. The theory of Self-Efficacy is reviewed together with an analysis of the personal, social and organisational attributes that impact on mathematical self-efficacy and its potential contribution to mathematical achievement. Its role as an important self-concept in activating student engagement in mathematics, and as an important predictor of achievement in mathematics is noted.

Chapter five presents an original exposition of the productive relationship that emerges from the synthesis of Multiple Intelligences and Self-Efficacy theories. It constructs a new perspective using convergence of Multiple Intelligences Theory and Self-Efficacy Theory and offers a distinctive new basis for a learning program that can improve the mathematics outcomes of low achievers. It describes how teaching and learning mathematics under a Multiple Intelligences model can assist students to participate in resonant learning experiences that improve mathematics achievement and increase student confidence to re-engage in mathematics. Chapter six outlines the research design and methods employed to implement the study, including the curriculum design and delivery. Chapter seven describes the results and presents both quantitative and qualitative analyses of the outcomes. In Chapter eight, the outcomes are discussed followed by a description of the implications of the findings for engaging students in mathematics classrooms. It includes recommendations for similar research, and makes conclusions on the contribution of the thesis to mathematics education.

1.13 Glossary of terms

Multiple Intelligences (MI) — the concept that individuals possess an array of mental facilities genetically endowed and which can be modified by environmental influences. The differentiating proposal is that intelligence is not perceived as a single dimension of ability. According to Gardner (1983), other dimensions of intelligence exist apart from linguistic and logical abilities. However, cultural prejudices are argued to selectively value only certain facilities, modifying the environments accordingly to limit individual opportunities for growth that exist through these other facets of human character.

Multiple Intelligences Learning — a school environment in which the available ways of gaining knowledge in a subject area are pluralised in presentation and task, and personalised in that individual proclivities are made central to how knowledge is gained and assessed (Gardner, 1991).

Self-Efficacy (SE) — the concept where a personal assessment is made about one's capability to bring about some outcome or attainment (Bandura, 1986).

Low Achiever — the term is taken in this thesis to encompass those students who do not demonstrate certain performance levels in mathematics assessment using standardised instruments. It may include under-achieving students and students who have learning difficulties in mathematics since these differentials of identification are not carried out in the thesis

CHAPTER TWO

LOW ACHIEVEMENT IN MATHEMATICS

The purpose of chapter two is to analyse the research literature associated with low achievement in mathematics and to assess the curriculum and pedagogical changes that have been implemented over the past decade associated with low mathematics achievement. Their degree of success in overcoming low achievement in mathematics is reviewed critically.

To foreshadow the conclusions of chapter two, it is argued that:

1. Needs of mathematical low achievers have often not fully been addressed by reforms that have taken place in mathematics education.
2. The persistence of low achievement is attributable in part to a lack of equitable practices in mathematics classrooms for students with other than natural logical-mathematical ability.
3. Alternative forms of research are required to fulfil the goals of mathematical reform, particularly with respect to the problem of low mathematics achievement.
4. The theories of Multiple Intelligences and Self-Efficacy may play a substantial role in fulfilling the goals of mathematical reforms. This role is highlighted in chapter two.

The chapter concludes by proposing the current study to begin to address the continuing inequities of mathematics education.

The thesis focuses on low mathematics achievement in a Western Australian middle school context. The US and Australia have major cultural similarities and have similar curriculum programs in mathematics education (Schmidt, McKnight, & Raizen, 1997). Much of the research in the field of mathematics education over the last decade has taken place within and about the US education systems, and the US has produced a number of reports expressing concern at the level of low mathematics achievement (Stedman, 1997). The US has initiated education reforms in advance of similar changes to Australian education systems. As a result of the similarities of the reforms in mathematics undertaken by these countries, the majority of research literature reviewed in this thesis has described the US and Australian fields of low mathematics achievement. A synthesis of meta-analyses of educational research has indicated that results in Australia are rarely at variance with the American studies (Hattie, 1992) which is taken here as offering validity for using US research in an Australian schools context.

2.1 The problem of low achievement in school mathematics

A range of sources will be reviewed that fuel the view that school mathematics failure is a problem. Many nations have participated in international surveys of student achievement. Most countries also have their own monitoring of educational progress and measure the achievement of their students through comparative studies at regular intervals. Schools collect achievement data and teachers assess in order to inform on individual student progress.

Policy statements from the governments of the US (Goals 2000, 1994; No Child Left Behind, 2001) and Australia (National Literacy and Numeracy Plan, 1998; National Report on Schooling in Australia, 1996, 1999; The Adelaide Declaration on National Goals for Schooling in the Twenty-First Century, 1999; The Hobart Declaration, 1989) show that governments in both the US and Australia have ranked numeracy as a major priority. A number of factors such as teacher training, parental involvement, and professional development have received or are to receive increased attention through research and funding on the basis that numeracy outcomes are less than satisfactory (Goals 2000; National Report on Schooling in Australia, 1996, 1999; The Condition of Education, 1998, 2002; US Department of Education, 1998).

In the US there is evidence that many students have low mathematics achievement and fail to demonstrate an ability to perform even basic mathematical operations (NCES, 1997a). In Australia there are significant achievement differences between the bottom "tail" and other levels, and between minority groups and the general student population over time at school (Lokan, Ford & Greenwood, 1996). Issues about the adequacy of student numeracy have frequently been reported in the media

(Bagnall, 2002; Hewitt, 2002; Manzo, 2001; NCTM, 2001; Robelen, 2002). As well as published sources of evidence on low mathematics performance there is considerable anecdotal evidence of low student performance in mathematics from within the schools, from parents and from employers.

There have been several international studies of mathematics achievement over the past three decades that have contributed to the view of poor mathematical competence in student populations. Perhaps the most influential have been conducted by the International Association for the Evaluation of Educational Achievement (IEA). At the time of writing, recent measures are the Third International Maths and Science Study (TIMSS) conducted between 1994-1995, the Third International Maths and Science Study-Repeat study (TIMSS-R) conducted in 1999 that assessed eighth grade students, and the Program for International Student Assessment (PISA) conducted in 2000 that assessed the knowledge and skills of students nearing the end of compulsory education. As a research tool the TIMSS has been used to indicate relative mathematics achievement between countries, and has had longitudinal value as a measure of the efficacy of internal programs applied under mathematics reforms on the basis of variables such as good school practices, meeting benchmark standards, gender equity, and minority access (Jakwerth et al., 1997).

International comparisons of mathematics achievement have been obtained through cross-national studies that have ranked countries on the basis of averaged scores of student achievement in standardised tests. The purpose of this international effort has included the identification of curriculum and instructional variables related to differences in student achievement in mathematics. The implications of the results have therefore been taken seriously by many countries and have been cause for mathematics reforms (McNab, 2000).

2.1.1 Evidence of low mathematics achievement in the United States

The US has a number of organisations, both public and private that have taken on the role of monitoring that country's educational progress. These include the National Assessment of Educational Progress (NAEP), National Centre for Education Statistics (NCES), National Science Foundation (NSF), and National Council of

Teachers of Mathematics (NCTM). The NAEP has analysed trends in US education over several decades to evaluate and report on mathematical achievement at grades 4, 8 and 12. These reports have been used to indicate the effectiveness of mathematics reforms in terms of raising achievement overall in the US. There has been considerable US concern that too high a proportion of the population performs inadequately in mathematics relative to other countries and that too many children fail to achieve satisfactory functioning in basic mathematics. There has been disquiet that US mathematics achievement has negatively affected student preparation to participate and function competently in society (Carnine, Dixon & Jones, 1994).

Substantiated evidence of low mathematics achievement from the Third International Mathematics and Science Study has been cited as reason to continue this concern (Schmidt & McKnight, 1998). The US has been considered as the world's leading economy in which mathematics qualifications act as a gatekeeper, however the associated benefits of that wealth do not appear to have provided access to large numbers of citizens as reflected in students' mathematics performances. The US eighth grade mathematics students performed below the international average of the 41 countries participating in the TIMSS. The US was the only country whose relative position moved from above the international mathematics average in grade four to below the average in grade eight. It then fell further at grade 12. No other country scored below the US in particular assessments of advanced mathematics work at grade 12 (NCES, 1998). Referring to the US (1992) National Assessment of Educational Progress reports, Stedman (1993) has said that it is troubling that so few students reach the upper levels when the problems are not particularly difficult. Even the advanced levels of US mathematics achievement appear to be troublesome after almost a decade of pedagogical introspection and reform when 32% of Japanese students would be in the top 10% of TIMSS mathematics students, compared to 5% of US students (American Federation of Teachers, 1996), and most countries outperformed top US calculus students (Callahan, Tomlinson, Reis & Kaplan, 2000).

Statistically, US mathematics achievement has shown overall improvement (Campbell, Hombo & Mazzeo, 2000; NCES, 1996; NCES, 1997a; US Department of Education, 1999). However, statistics blur the reality of the numbers of children who year after year have failed in mathematics and conceal the negative impact that mathematics failure has on many children. There remains an academic achievement gap that continues to concern education authorities (Lewis, 2002).

Analyses of TIMSS results have reflected an ongoing correlation between factors such as poverty and minority status with poor school performance. Significant low achievement in mathematics has continued to exist for particular sub-groups of the student population. For example, the performance levels of minority students in the US continued to be below averaged white population scores, and in 1996, 64% of grade 4 black students failed to meet the Basic standard compared to 32% of white students. One US state had only 36% of eighth grade students performing above Basic proficiency (Forgione, 1998). These figures represent thousands of children performing poorly in mathematics.

Analysis of longitudinal data has also indicated that the longer students have stayed at public schools in the US, the lower the average achievement on international assessment became (Forgione, 1998). The TIMSS-R has confirmed this for mathematics students assessed in year four and subsequently in year eight (US Department of Education, 2000). These problems of under-achievement and failure are suggested to begin long before students reach the secondary grades (Carnine et al., 1994) because school learning practices have moved many students from predominantly high levels of meaningful learning to predominantly rote-mode learning after grades three or four (Novak, 1996). Downward trends in age-based mathematics achievement exist both within the US and in international comparisons (Paulson, 2001) and have been attributed in part to curriculum deficiencies and teaching practices in that instruction with new, challenging material is reduced for many students after the early grades due to continued concentration on arithmetic skills after the middle primary years (Bracey, 1997). There is also a particular concern that an impact on student achievement is due to a shortage of qualified staff and that the pedagogical and disciplinary knowledge of a significant number of mathematics teachers is poor (Peterson & Barnes, 1996). Analysis by the NSF (1996) has indicated persistent inequities in terms of mathematics achievement by minorities, attributable to the greater likelihood that minority students come from poorer backgrounds with less educated parents and attend schools that have fewer qualified mathematics teachers.

A major concern in the US has been that mathematics skills considered necessary for the changing US society were missing, with students not able to use mathematical tools, not able to communicate mathematics ideas and not acquiring these and other skills such as problem solving and reasoning (NAEP, 1992). The1992 NAEP results revealed that one third of students in grades four and eight performed below a Basic proficiency in mathematics (Ginsberg-Block & Fantuzzo, 1998), and concern has been expressed that too high a proportion of the student population performs inadequately in mathematics and too many children fail to achieve satisfactory mathematical functioning (Jitendra & Xin, 1997).

The NAEP 1996 report of "The Nation's Report Card" (NCES, 1997a) has claimed increased achievement at the lower end of student competence yet it showed that few students (2% to 4%) were achieving beyond Basic and Proficient levels in mathematics in the US. The US National Assessment Governing Panel has an aim that all students should be performing at or above the Proficient level (Phillips, 2001) but the most recent report of NAEP (2000) mathematics figures showed that only a quarter of the US fourth and eighth graders were performing at or above the Proficient level in mathematics, resulting in a call for much improvement (Paige, 2000). NAEP (2000) figures also showed a continued decline in average mathematics scores for grade twelve between 1996 and 2000, reflecting TIMSS data. Any public expectation that even if the lower end of student achievement has not been performing, the upper end could still be depended upon is negated by US TIMSS results showing that mathematics education has failed to support even the performance of the best students (Callahan et al., 2000).

Perhaps because of the poor light in which the US and other countries have been cast, international ranking using the TIMSS has been questioned (Berliner & Biddle, 1995, 1996). Concerns about variables such as curriculum differences, item content validity, student differences in opportunity to learn, and textbook variance have been expressed, along with strong reservations about the TIMSS outcomes (Bracey, 1998).

Despite these questions of validity TIMSS results have been accepted and referred to by policy-makers, parents and education bodies. Although most educators have stated that schools provide a broad range of skills other than academic success, the results of comparative measures of school academic achievement have been the serious focus of many.

2.1.2 Evidence of low mathematics achievement in Australia

Australia was also a participating country in the TIMMS undertaken by the International Association for the Evaluation of Educational Achievement (IEA). Australian national data compared to other countries on international measures has indicated that Australian students have performed well relative to many other countries including the US (Marks, McMillan & Ainley, 2001; National Report on Schooling In Australia, 1996). Australian education systems are more centralised than US schools and have a relatively common curriculum between state systems, which may have contributed to the higher levels of TIMSS achievement.

However, similar longitudinal comparative achievement data to that which gave conclusions about US achievement trends show that the mathematics achievement level of Australian students at the lower secondary school level has declined over the last three decades (Afrassa & Keeves, 1997). These researchers have called for investigating conditions of learning in Australian schools, focussing on student variables of aptitude, ability and perseverance, and on school level variables of quality of instruction and time for learning. At the same time, simplistic attributions of achievement to populist factors such as school hours and teaching time are cautioned against (Stedman, 1997) because the TIMSS gave no clear indication that these caused the differences between countries. Stedman (1997) advises to consider all of demographics, family circumstances and school factors.

Data on comparative school mathematics achievement between Australian states has been limited apart from the TIMSS. Individual Australian states have monitored their own student levels of achievement performance in mathematics although particular instruments, student samples and definitions of achievement have precluded comparisons (National Report on Schooling In Australia, 1996). Numeracy benchmarking has only recently been instigated in Australia as part of a program for raising mathematics performance in Australian students (Department of Education, Training and Youth Affairs, 2000). At the time of writing, comparative data on different states was not evident. Data from the PISA 2000 survey has shown that indigenous students continue to be over-represented in low-achieving mathematics groupings (Lokan, Greenwood & Cresswell, 2001).

The site of this study is the Western Australian education system. There has been evidence of poor mathematics performance in a significant proportion of Western Australian schoolchildren that may be extrapolated across the nation's states in this relatively homogeneous country. Substantial mathematical failure has been indicated in the recent Western Australian Child Health Survey (Zubrick, Silburn, Gurrin, Teoh, Shepherd, Carlton & Lawrence, 1997). Over nine thousand Western Australian students (3.4 % of the student population) were reported as "far below age level" in overall mathematics competence, and approximately forty four thousand students (16.1 % of the student population) were described as "somewhat below age level" in overall mathematics competence (Zubrick et al., 1997, p. 20). It is evident that low achievement in mathematics creates negative consequences of disproportionate impact for various student sectors, with the particular performance of indigenous children identified as low or in decline for some age-groups (Doig, 2001; Zubrick et al., 1997). Indigenous groups have demonstrated consistently lower results in school literacy and numeracy compared to the non-indigenous population. Only 19% of indigenous children reached graduation level in Western Australia and more than 70% of indigenous students were below basic numeracy standards (Miller, 1999). Recent Western Australian mathematics data have shown that indigenous children were well below the mathematics performance of all other sub-groups, across all mathematics content areas, and across all three year group measures (Department of Education, 2002).

For the general student population in the Western Australian education system, there is evidence of pervasive mathematics failure for a significant number of schoolchildren. Student data on mathematics performance levels have been monitored for a number of years and reported through the Education Department of Western Australia (EDWA) documents of "Student Achievement in Mathematics in Western Australian Government Schools" (Van Wyke, 1996) and "Student Achievement in Mathematics: Western Australian Government Schools 2000"

(Department of Education, 2002). Statistically, student achievement in mathematics in WA schools has improved over the four-year period between assessments from 1992 to 1996 and recent Western Australian Monitoring Standards in Education (MSE) data show improvement between 1996 and 1998 (Doig, 2001).

However while statistical evidence represents improvements in overall student populations, the data exposes the persistent mathematics failure of many students to achieve or progress. Improvements have not been consistent over time, with mathematics performance showing a significant decline between 1998 and 2000 for years seven and ten students (Department of Education, 2002) and a fall in primary school numeracy in 2001 (Hewitt, 2002). A more detailed analysis of the 1996 EDWA document (Van Wyke, 1996) provides particular reason for concern as the overlap in achievement between significantly different age-grouped populations has shown that the top 10% of year three students performed at a higher level than at least 20% of year seven and 5% of year ten students. The top 10% of year seven students performed at a higher level than 50% of year ten students. National benchmark testing undertaken in 2001 indicated that about 78% of year seven Western Australian students reached numeracy benchmarks, compared to 89% in year three (Hewitt, 2002). The EDWA and benchmark figures indicate that a large number of children have shown very little achievement in mathematics beyond basic skills acquired early in their schooling, despite their years at school. These Western Australian data correlate with descriptions that some students effectively have shown no progress in mathematics beyond the basics of early education, despite a further decade at school (Bowman, 1994; Magne, 1991). Western Australian data support US evidence that for a large number of students, attendance at school has had little effect on their success in gaining mathematics knowledge and skills congruent with their developmental abilities.

The Western Australian findings do not sit well with the community expectations expressed in the West Australian Child Health Survey that children will do well in school (Zubrick et al., 1997). As an assessment of the concept of “doing well”, teachers were asked to compare and rate individual children with their age-equivalent peers in a survey of overall academic competence. Results indicated approximately 19% of students (or one in five) were below age level expectations of performance with 75% of that sub-group of low achievers being below age level in mathematics. This equates to about one child in seven in Western Australian schools achieving below expectation in mathematics.

The teaching community has clearly recognised that many children possess inadequate mathematical skills. These children appear to have not been benefiting from their attendance at school or from their time spent in mathematics classrooms after the early years.

2.2 Causes of student failure in mathematics

There have been a number of reasons for mathematics failure, concentrating on school factors, social causes, and family circumstances (Stedman, 1997). Outside of neuro-pathological causes, the main influences on low mathematics achievement have been described as patterns of individual behaviour such as passivity, withdrawal, limited initiative, low attention span, and school maladjustment (Magne, 1991). An extensive study of “at-risk” year eight US secondary school students who were likely to fail in mathematical or reading competence reported similar characteristics, but included minority representation as an added factor (Kaufman, Bradby, & Owings, 1992; NAEP, 2000). Beliefs collated from practicing primary and secondary teachers why children are failing to achieve in mathematics included lack of student ability, parents who show little interest in what their children do at school, parents who do not instil self-discipline in their children, students who do not value school work, and students from unhappy homes who had psychological problems (Archer, 1999).

While many causes of low mathematics achievement tend to place the student at fault for not achieving at school the significant role of the school in influencing low mathematics achievement is suggested in that the degree of low achievement exhibited by some children has been described as increasing with attendance at school, with the greater proportion of mathematics achievement appearing to occur in these students’ primary school years and falling in secondary school (Bowman, 1994; Magne, 1991). The practices of conventional or traditional mathematics instruction have been implicated in this low achievement in that they can fail to incorporate innovations, do not connect classroom experiences to everyday experiences, and persist with curriculum content that concentrates on basic skills beyond developmental stages (Silver, Smith, & Nelson, 1995; AFT, 1996).

The importance of connecting classroom experiences to everyday experiences takes on heightened significance in the light of psychological understandings of how children learn mathematics. The classical work in this area, by Skemp (1987), outlines the constructivist nature of mathematics knowledge, and the importance of relational understanding developed from appropriate mental models. The building of understanding through interactions with the environment is contained in the Piagetian constructivist theory of personal growth of schema, and Vygotsky's social constructivism of understanding within a social context using scaffolded instruction (McInerny & McInerny, 1998). Constructivism has influenced reform recommendations in mathematics education (NCTM, 2000) with understanding "making sense" through students reflecting on their experiences and actions, and through shared, interactive task engagement. This reform movement suggests that successfully acquiring mathematics understanding is unlikely in behaviourist environments of overt control, isolated contexts, and passive reproduction or rote learning.

The Piagetian "stage" nature of cognitive growth, progressing from concrete manipulation through to abstract thinking, and the Vygotskyan theory of learning in zones of proximal development, have also been significant for mathematics learning. Understanding new and more complex information is believed likely to be more successful when students can build on their established skills and knowledge, (Reys, Lindquist, Lambdin, Smith, & Suydam, 2004).

There are also educational factors argued to contribute to difficulties in mathematics learning. Research literature has described a number of mathematics reform programs focussing on curriculum, pedagogy, teacher enhancement, classroom practices and the redress of socio-economic impacts (Edwards, 1994; Futrell et al., 1997). From TIMSS data the office of US Educational Research and Improvement (OERI) has particularly identified the mathematics curriculum, student enrolment in challenging mathematics courses, and the adequacy of teacher preparation as major factors for the relatively high failure of US students in mathematics (Forgione, 1998). The next section considers these factors associated with mathematics teaching as causes for mathematics failure.

2.2.1 Equitable access to curriculum content

The US had been developing curriculum and professional standards as recommendations for education practice since the 1980's as a result of national reports on educational achievement such as "A Nation at Risk" (NCEE, 1983). The NCTM (1989) noted that traditional ideas about basic mathematical skills had been overtaken by ever-higher expectations of people's competences and knowledge, and by new methods of production. Technological and information-based changes made repetitive and rote-learning practices in mathematics education redundant, with the practices of rote-learning, "drill and practice" and "assembly-line schooling" viewed as limiting student understanding of mathematics concepts outside of the learning context (Stedman, 1997). Evidence from the TIMSS indicated many students were not prepared with adequate mathematics tools and skills needed in a changing economic climate with the Middle School curriculum in particular regarded as problematic because year eight students are learning work considered developmentally appropriate for year seven students in other countries (Schmidt et al., 1997). Other curriculum content concerns have been too much concentration on basic arithmetic and insufficient challenging work, particularly within classes of low achieving and underachieving mathematics students (Silver et al., 1995). The consequences of this curriculum for low achievers not only precluded opportunities for these students to engage in problem-solving, but placed them at a distinct disadvantage for becoming proficient (Montague and Bos, 1990).

Because of concerns about low levels of mathematical attainment, new recommendations for classroom practices have emerged over the last decade that have aimed at allowing students to understand mathematics concepts, rather than memorise facts. This focus on the learner's role in mathematics understanding began the development of reforms in mathematics instruction programs that attempted to incorporate new skills of thinking and working in mathematics. The changed requirements for numeracy meant that students needed to be motivated to think about and use mathematics much more than in the past. Both curriculum and methodology in mathematics classrooms moved from a behaviourist approach using rote learning and practice examples towards an interactive problem-solving approach in specific contexts (Knuth & Jones, 1991; Nickson, 1992).

Classroom practices and the curriculum are closely linked (Silver et al., 1995) and the reviews and reforms of mathematics education have been most evident through the US National Council of Teachers of Mathematics publications of Curriculum and Evaluation Standards for School Mathematics (NCTM, 1989), Professional Standards for Teaching Mathematics (NCTM, 1991), Assessment Standards for School Mathematics (NCTM, 1995), and Principles and Standards for School Mathematics (NCTM, 2000). In part these Standards attempted to provide all students with access to equitable learning opportunities in a country that has no uniform curriculum. On the basis of international assessments and standardised measures, US mathematics students were being blamed for lacking the kinds of mathematical understanding needed in society, but were not being given equitable opportunities to acquire these requisite skills in the schools (Forman & Steen, 1999). This low correlation between what teachers cover in class and what external assessments measure has been shown to continue (Keenan et al., 2000).

Reform-based mathematics education has been designed to improve understanding of mathematics, to increase intrinsic interest and appreciation of mathematics in daily life, and to improve confidence in students such that they become independent and willing to accept challenging tasks in mathematics (Stipek, Givven, Salmon, MacGyvers, & Calanne, 1998). Reforms aimed to shift from traditional rote practices towards communication of mathematics concepts, collecting information and solving problems, from competitive learning to cooperation, from isolated concepts towards situated or connected learning and application (Frye, 1991; Wheelock, 1996). Examples can be found in the National Science Foundation funded *Mathematics in Context* reflecting the NCTM Standards (1989, 1991), the *Quantitative Reasoning Project* using instruction emphasising cognition, and the *Maneuvers with Mathematics* project that supplements curriculum material with manipulatives and hands-on discovery (Edwards, 1994).

Curriculum reform in mathematics has also been a major policy in Australia. As a result of IEA studies, Australian curriculum programs have been analysed and shown as generally uniform across states (Keeves, 1995). However, even small differences such as school age entry were assessed as a contributing factor to low mathematical achievement in the increasing requirement for a mobile workforce, and have given momentum to the development of national curriculum statements and profiles in Australia (Keeves, 1995). Australian mathematics education policy has paralleled the US recommendations for changes to mathematics education with the issue of "A National Statement on Mathematics for Australian Schools" (AEC, 1990) and the publication of national goals (The Adelaide Declaration on National Goals for Schooling in the Twenty-First Century, 1999).

Mathematics education reform has led to Australian states developing curriculum guidelines or *frameworks*, linked to performance measures or student outcomes in a similar fashion to the NCTM Statements. These performance measures have been instituted under National Literacy and Numeracy Benchmarks against which Australian states could measure the performance of their students, and the effectiveness of their curriculum programs (Commonwealth Department of Education, Science, and Training, 2002). The reform leading to the present Western Australian school education model, the Curriculum Framework (Curriculum Council, 1998) under which this study has been conducted began with an Australian national aim for a common curriculum.

Much work has therefore been done in the establishment of common core curricula combined with an examination of crucial elements of instructional quality, learning environment, and student needs in order to fairly and equitably enable more students to achieve in mathematics.

Despite the efforts of changes and reforms, a high percentage of students still show low achievement in mathematics. For example, over 9000 students or 3.4% of the student population have been described as performing far below age level in mathematics competence in Western Australia (Zubrick et al., 1997) and the NCES (2000) report on US mathematics achievement indicated little more than one-quarter of year four and year eight students were reaching proficient levels of mathematics performance.

2.2.2 Equity and mathematics failure

A disproportionate percentage of mathematically low-achieving children has been shown to be associated with groups based on socio-economic factors, ethnicity, family structure, or race (Forgione, 1998; Jones & Bouie 2000; Okpala et al., 2001; Roscigno, 1998; Secada, 1992; Stanic, 1989). There are a number of identifiable factors that appear to directly correlate with mathematics achievement such as parental education level, parental mathematical achievement, and books in the home (Lokan et al., 1996); social background (Young & Smith, 1997); and differing cultural, economic and ethnic backgrounds (Carnine et al., 1994). Each factor introduces a diversity of student learning needs.

In providing for that diversity, new kinds of meaningful tasks aimed at engaging students have had to be developed. The implementation of tasks that consider equity and excellence has required an increased student discourse, recognition of varied linguistic and cultural needs, incorporation of a variety of culturally relevant connections to mathematics, and encouragement of links between schools and their communities (NCREL, 2001). This has introduced classroom management problems of selection and development of worthwhile activities and the allocation of suitable amounts of instructional time in order to assist with the diversity of students' needs. The feasibility of these practices to engage students consistently and successfully in cognitively high-level classroom tasks "doing mathematics" has been questioned (Henningsen & Stein, 1997) because in reality the maintenance of engagement with cognitive activities for a diverse suite of student needs in standard mathematics instruction is difficult (Briars, 1999), particularly as new forms and goals of mathematics are incompatible with traditional methods (Smith, 2000b).

These difficulties of balancing the competing aims of providing common outcomes and experiences while catering to diverse student needs have been recognised (Gamoran & Weinstein, 1998). Earlier reforms dealing with concerns of equitable access to learning have aimed at improving the learning opportunities for low achievers through diverse curriculum programs, through streaming classes, through improved resources, through targeting students' environmental backgrounds, and through the professional training of teachers in implementation of new curricula (Ascher, 1983). The classroom circumstances of low achievers have been identified and targeted from the point of view of cognitive support with more structuring of their learning, more active instruction, more feedback, higher success rates and smaller steps in cognitive demand, and more practice, support and encouragement (Meadows, 1992).

Recent reforms have used a variety of targeted programs mainly based on NCTM recommendations about equitable learning such as the Standards-based Core-Plus Mathematics Project (Schoen, Fey, Hirsch, & Coxford, 1999); contextual mathematics programs such as the Connected Maths Project (Hoover, Zawojewski, & Ridgway, 1997), and the University Chicago School Maths Project (Carroll, 1998; Wisconsin Center for Education Research, 1996); projects designed to deliver mathematics to urban and low-achieving populations such as the QUASAR Project (Silver et al., 1995); gender intervention programs as with the Cognitively Guided Instruction system (Carey, Fennema, Carpenter, & Franke, 1995); projects to cater for technological applications like Computer Assisted Instruction (Kaput, 1992), and projects targeting minority populations such as Equity 2000 (NCREL, 2000), The Algebra Project (NCREL, 1991), and SEED (Leonard, Glee, & Baker, 2001). The variety of targets and methods of these reforms have reflected the complexity of pedagogical problems and the diversity of student characteristics.

Gender differences have also been proposed to cause lowered achievement for females (Tartre & Fennema, 1995). The lowered status of women in society has been a recognisable cause of differentiated achievement levels (Keeves, 1995) along with lessened opportunities for exposure to mathematics courses and mathematics careers information (NCREL, 2001). There has been evidence that the deliberate intervention of policies and programs aimed at encouraging participation and performance of girls in mathematics has had some success. In the US, the gap in mathematics performance between males and females has closed, if slowly (NAEP, 2000). Although unmistakable gender differences in achievement had been indicated in past international measures, Australian equity-based projects have also been initiated over the past decade and in terms of improving mathematics performance for girls have largely achieved their objectives (Lokan et al., 1996).

However, while much instructional analysis has been placed on learning facts and problem-solving skills, on classroom organisation such as grouping, and on training teachers in order to improve performance in mathematics, these did not always reach the students who needed improvement the most (Joshi, 1995). There has been clear evidence that not all equity reforms have worked in accordance with their goals, and a major objection to the value of these mathematics reforms in raising student achievement has been that the inequities have remained with respect to those continuing to fail to achieve in mathematics, the minority groups and the economically disadvantaged (Fashola & Slavin 1997; Forgione, 1998).

After a decade of reforms in mathematics education, improvement in mathematics education is still consistently demanded (Darling-Hammond, 2000). The conclusion has been that low achievers in mathematics have continued to experience failure in the face of reforms.

2.2.3 Equity and teacher quality

The Glenn Report (National Commission on Mathematics and Science Teaching for the 21st Century, 2000) concluded that the most consistent predictors of high achievement in mathematics were qualified teachers or those with major knowledge in their fields. Of all policy-controllable inputs, the quality of teachers in the classroom have been identified as more efficacious in degree for students at risk than factors such as class size or capital resources (Darling-Hammond, 2000), with a clear link between highly-qualified teachers and students' mathematical achievement (Okpala, Smith, Jones, & Ellis, 2000).

Yet there is considerable evidence that many students have teachers lacking mathematics as a major field, that low-achieving mathematics students have a higher association with these teachers, and that this has a negative effect on students' opportunities to learn mathematics (Braswell et al., 2001; NCES, 1996; NSF, 1996). The peak position on mathematics reform driven by measures indicating unsatisfactory levels of mathematical achievement in the US has urged the development of rigorous programs involving teacher preparation in both subject expertise and pedagogical mastery, and an immediate focus of concerted effort on improving performance in middle-school mathematics (US Department of Education, 1998). For most reforms, teachers have been described as the best agents to develop high quality mathematics education for all students, with pedagogically aware teachers being more likely to implement best practices to increase mathematical achievement in line with reform goals, and more likely to be confident in teaching mathematics, moving away from the safety of traditional practices to encourage students to explore mathematics knowledge under guidance (National Research Council, 1997).

Teachers' beliefs about the nature and purposes of mathematics and how students learn have a powerful effect on the practice of teaching (Ernest, 1989). So important has the teacher been seen in mediating between the goals of education systems and the outcomes in terms of student capabilities and understanding that the term "teacher enhancement" has been synonymously used with "school reform" (Frechtling, Sharp, Carey, & Vaden-Kiernan, 1995). Teacher enhancement has been made part of mathematics reform policy to increase factors such as student motivation, engagement, and to develop and maintain interest, enthusiasm and competence in students' mathematics. Pedagogically aware teachers have been argued to use challenging experiences in traditionally taught areas that usually do not have such methods, to encourage minority participation in mathematics, and to empower others through transferring their experiences to other staff. A conclusion is that only when the greater proportion of mathematics teachers have been appropriately and adequately trained will low achieving students have an equitable access to the level of expertise provided to other students. Examples of teacher enhancement programs with the underlying goal of raising students' mathematical achievement have been the National Science Foundation's *Middle Grades Mathematics Project* (NCREL, 1995a), and the Ford Foundation's *Urban Mathematics Collective* (Frechtling et al., 1995)

Yet the broad success of these reforms in US mathematics education has been questioned. For example, in the National Science Foundation (1995) report on teacher enhancement it was stated that evaluations rarely produced credible evidence of positive student outcomes (Frechtling et al., 1995). Although it has been reported that most teachers in enhancement programs had increased confidence, developed new curriculum materials, spent more time on teaching and got more positive reactions, the impact of programs on educational outcomes has not been reliably demonstrated. The evaluation of impacts from teacher enhancement projects has been described as poor with unreliable methodologies being used (Frechtling et al., 1995).

The Australian federal government has recently funded programs aimed at improving teacher qualifications and pedagogical knowledge under a "Quality Teacher Program" (EDWA, 2000; EDWA, 2001). The impact of this on improving mathematical achievement is yet to be assessed, although little data is available as to how any benefits will be determined, over an unspecified timeframe.

2.2.4 Contextual causes of failure

What students learn is connected with how they learn, and their opportunities to learn mathematics are related to the setting, tasks and discussions they take part in (NCTM, 1991). The level to which students know about, think about, and use mathematics depends on their engagement and experiences in classroom activities (Schoenfeld, 1992).

The next sections describe major classroom factors that research has shown to influence mathematical failure for students. The NCTM's Statements and Standards (1991, 1995, 2000) have given a focus for this thesis to draw attention to the significant role that traditional pedagogical assumptions and practices are argued to play in that failure.

2.2.4.1 Content delivery rate

Most mathematics departments in schools have a goal of covering as much material as possible in the lessons available yet this does not allow all students to complete the assigned course with understanding (Scott, 2001). The traditional classroom environment in mathematics has been strongly oriented towards a syllabus-based delivery, using teacher control, textbook resources and pencil-and-paper assessments in decontextualised tasks (Silver et al., 1995), with mathematical knowledge frequently portrayed as disconnected and abstract (Nickson, 1992). Most mathematics curricula in schools have commonly operated on a spiral model, where text-based content is covered in one year to certain depths and encountered again in subsequent years (Isaacs, Carroll, & Bell, 2001) with the demand to understand increasing complexity assumed met through students' developmental growth. Yet a common comment by students in mathematics classrooms has been that "the teacher goes too fast" (Cornell, 1999; Weast, Williams, & Gross, 2000). Low achieving students have not been able to spend sufficient time on earlier levels to allow conceptual comprehension. The acquisition of prior knowledge, a major determinant of capability, willingness and ease in classroom learning (Yates & Chandler, 1996) can then become inadequate while topic coverage in the form of rapidly sequenced instruction and topic changes has proven to be too much for proper understanding for many students. As a consequence, providing the same learning content to all students in uniform ways has caused some students to be left behind because of the complexity, or has caused others to be provided with repetitive non-challenging tasks. In both cases the likely outcome has been boredom, frustration, and failure to achieve.

Recognition has been given to these difficulties of implementing curricula. Teachers are expected to cover many topics, but most of the topics take a lot of time to teach thoroughly (Carnine et al., 1994). The pace of syllabus coverage has been a prime consideration of traditional mathematics instruction in many cases (Stodolsky & Grossman, 1995) resulting in diminished opportunities for some students' achievement because of negative effects on the learning factors of prior knowledge and time to learn. These are significant for achievement in mathematics (Reynolds & Walberg, 1992) and problems of syllabus-driven coverage have been addressed under learning *Outcomes* identifying what students should achieve, shifting the focus from what is taught to an emphasis on differentiated learning rates (Curriculum Council, 1998).

However, coverage has not been the only problem for many students.

2.2.4.2 The classroom composition

The separation of students on the basis of academic achievement, course-taking or ability is a controversial but accepted practice (Boaler, 1997). In mathematics particularly streaming occurs earlier than other learning areas (Zevenbergen, 2002), usually on the basis of prior achievement (Archer 1999; Davenport, 1993) and has some inequitable consequences. From their educational placement it may be difficult or impossible for low-achieving students to gain the knowledge that would enable them to move into other classes that provide access to strong mathematics programs, to better models of learning, and to well-qualified mathematics teachers (Davenport, 1993; Haury & Milbourne, 1999). Using low ability as a placement basis also appears to have a negative influence on students' achievement, emotions and attitudes (Butler & Marinov-Glassman, 1994), tending to confirm self-concepts of low mathematics learning ability. When predicting how they will achieve in mathematics there is a student belief that ability plays a strong part (Stevens, 2000). Observations show many low achievers tend to attribute their lack of success to perceptions of a lack of ability in mathematics and these self-doubters often withdraw from or avoid good classroom practices that would otherwise assist their achievement (Bandura, 1986).

Yet providing academic challenge across a range of student abilities in non-streamed classes is also difficult. Heterogeneous classes with co-operative groupings have not necessarily acted to improve the achievement outcomes of low achievers, and small group instruction in mathematics does not always bring about improvements in the mathematical learning (Mulryan, 1992). Some research has noted that while high mathematics achievers maintained progress or benefited from such strategies, low achievers revealed continued passive academic engagement (Secada, 1992), although it has also been shown that mathematics achievement of average and less able students is improved relative to peers in same-ability classes (Linchevski & Kutscher, 1998).

Balancing the competing aims of providing common educational experiences with meeting individual needs is a cause of tension for effective learning (Gamoran & Weinstein, 1998), and whether the practice should occur does not seem to have a ready answer, with a variety of descriptions published on its benefits and problems (Boaler, William & Brown, 2000; Ireson, Hallam, & Plewis, 2001; Gamoran & Weinstein, 1998; Loveless, 1999; Vandenberghe, 2002) and on the different meanings behind classroom composition (Fiedler, Lange, & Winebrenner, 2002). Given this dichotomy of evidence, and considering that high-achiever learning is not necessarily compromised in heterogeneous classes, equitable access to the same education is argued to have an overriding value (Haury & Milbourne, 1999). This existence of a diverse suite of student abilities within the same learning environment suggests the value of knowing and using students' multiple intelligences to provide cognitive challenge and to meet affective needs (Snyder, 1999).

2.2.4.3 Pedagogical inequities resulting from identification

There has been a growing agreement in research that differences in mathematical ability need description using cognitive, affective, and motivational factors (Seegers & Boekaerts, 1993) yet there is a lack of consensual conceptualisation about low achievement and its identification has differed geographically and has been confounded with other problems of learning cognition (Keogh, 1988). The nature, characteristics and reasons for low achievement are not always clear with low-achievement associated with both learning differences and underachievement (Jitendra & Xin, 1997). Although any lack of distinction is disputed (Kavale, Fuchs, & Scruggs, 1994) literature reviewed for this thesis has confirmed a lack of uniformity and acceptance in the definition of low achievement generally in education (Keogh, 1988) and in mathematics education in particular (Ma & Kishor, 1997). An outcome is that mathematics classrooms can often have children with diverse cognitive needs receiving the same curriculum (Carnine, Jitendra, & Silbert, 1997).

Although descriptions differ widely, all seem to include evidence of poor academic achievement (Butler & Marinov-Glassman, 1994) possibly creating inaccurate and inadequate differentiation between learning needs and contributing to some students' persistent low mathematics achievement. Underachieving students have been differentiated by characteristics of not working to ability, not concentrating, work avoidance, blame, and disengagement (Rimm in Shaughnessy, 1999). Low achievers have been characterised on cognitive criteria such as functioning at a lower grade level in literacy or numeracy (Kastner et al., 1995), or on the basis of test performance (Baker et al., 2002). Students with learning differences have been identified with difficulties in the acquisition of skills in literacy, numeracy, and reasoning, as well as with self-regulation and social interaction that are not tied to instruction or socio-economic environments (National Joint Committee on Learning Disabilities, 1997).

Regardless of the accuracy of labels, the mathematics curriculum and the instructional methods provided for students identified as low-achieving is often not the equal of that provided for students identified as high achievers (Grouws &

Cebulla, 2000; Lumpkins, Parker, & Hall, 1991). Low-achieving students may receive fewer opportunities from their learning environments because of altered classroom practices due to cultural preconceptions about achievement ability (NSF, 1998). These include being seated differently, receiving less attention on academic tasks, being asked questions less frequently, less likely to receive feedback, given less complex feedback, and being less engaged in class-work (Kastner et al., 1995). Many low achievers in mathematics have found it hard to get attention, felt ignored and even avoided the teacher because they were confused about their knowledge, or were shy and embarrassed at revealing a lack of understanding (Bishop, Brew, Leder, & Pearn, 1995).

Both instructional grouping and instructional methods in mathematics have been shown to favour high rather than low achievers (Woolfolk, 1998) although low achievers who are not separated on ability can show relative gains in mathematics, suggesting every effort should be made by educators and parents to gain an equitable education for low-achieving students (Lumpkins et al., 1991). These consequences of low achievement inhibit learning (Seegers & Boekaerts, 1993). Academic engagement of low-achievers is significantly and characteristically lower than either high achievers or children with learning difficulties, both of whom by engagement received higher responsiveness from the teacher. By displaying little interest, low achievers are more ignored. This passivity of low achieving students and lack of engagement has been shown to be counterproductive to learning in that it produces a vicious cycle of disengagement and poor performance (Kastner et al., 1995).

Because many of these attributed causes have begun in students' primary school years, the negative academic and emotional effects from experiences of failure are likely to have been entrenched by the time low achieving children reach secondary school. Student learning environments have been shown to be an important influence on self-efficacy (Moriarty, 1991) and research has suggested that self-beliefs affect effort and persistence applied by students (Schunk & Schwartz, 1993), and even students with skills may not achieve (Bandura, 1997) because performances are dependent on the strengths of perceived self-efficacy for tasks.

Two responses to these influences on low achievement are suggested. The first is to alter beliefs that ability is linked to achievement in mathematics, and the second is to engage low achieving mathematics students in order to create successful experiences and more positive attitudes and self-beliefs. By diversifying the representation of mathematics through the incorporation of multiple tasks within heterogeneous classrooms there could also be a valid challenge to the notion of who are the "mathematically elite" (Diezmann, 1995) that may assist in altering students' beliefs and behaviours towards mathematics.

The next section examines impacts of assessment on achievement, and some consequences of failure on students' thinking, attitudes, and behaviours.

2.2.5 Equitable assessment and mathematics failure

Assessment in school has usually been implemented and measured using limited forms of tasks generally referred to as "pencil and paper testing" emphasising logical processes of calculation, deduction, and organisational skills. Some mathematics tests have exhibited the characteristics of components of common psychometric tools used in the tests of intelligence, such as the WISC-III (Hearne & Stone, 1995). Unless carefully crafted, tests of mathematics (particularly in primary and middle schools) have risked assessing factors independent of classroom mathematics learning, measuring personal student abilities instead of their performance in mathematics.

Developmental dissociations suggest school mathematics assessment experiences are contributing to low mathematics achievement. Over time a divergence occurs between success and failure of high achievers compared to low achievers (Gray, Pitta, Pinto, & Tall, 1999), and is evident through an increasing student anxiety and concern about achievement compared to a static enjoyment of mathematics tasks (Gierl & Bisanz, 1995). The increasing divergence over time between low and high achievers with respect to affective and behavioural factors such as persistence, strategy use and positive self views has a correlation with a similar divergence in the academic achievement of these groups: by middle school, a gradual differentiation in self-perceptions is created between successful and unsuccessful learners with students who were low achieving seeing assessment as a confirmation of their inadequacies, inhibiting their efforts (Paris, Lawton, Turner, & Roth, 1991). Much of the lack of achievement progress for low achievers can be linked to traditional methods and beliefs about mathematics progressively introducing new material in abstract and decontextualised forms on the basis of assisting generalisation (Cordova & Lepper, 1996) even though procedural methods and limited representations within an increasingly sophisticated and complex symbolism inhibit progress for some students who eventually revert to rote-learned definitions regardless of accuracy or meaningfulness (Gray et al., 1999).

Self-beliefs of capability also have a considerable detrimental effect on behaviours and are commonly drawn from difficulties encountered as classroom experiences (Schoenfeld, 1991). For a number of students, these difficulties begin early under traditional mathematics assessments and the optimistic self-views about their abilities become replaced by external indicators of self-competence based on test scores and educational placement (Paris et al., 1991). Whereas success has a powerful influence on motivation to achieve (Middleton & Spanias, 1999), failure can cause a student's sense of efficacy or confidence for achievement to diminish. When people do not do well, those with self-doubts will give up but those who have a strong belief in their capabilities try harder (Bandura, 1989). A low sense of mathematical efficacy can be accompanied by high mathematics anxiety (Bandura, 1997) and both are associated with assessments that confirm a future of low mathematics performance. The emotional impact of assessment generates negative thoughts and anxieties when tests are presented and tends to drive from mind material that may be well known but is lost under the pressure of high-stakes testing (Mantzicopoulos, 1997) which carries significant consequences for students (Paris et al., 1991).

Both in the US and Australia, changes for classroom assessment have been promoted. In the US the NCTM's Curriculum and Evaluation Standards for School Mathematics (NCTM, 1989) recommended that computational algorithms, rote-learned regurgitation, and pencil-and-paper reproductions should not dominate school mathematics assessment. The National Statement on Mathematics for Australian Schools (AEC, 1990) recommended that assessment needed to take into account different ways that students learned, and the different abilities each child brought to learning. The Western Australian Curriculum Framework has expressed the requirement that assessment should be inclusive and considerate of diversity (Curriculum Council, 1998).

A powerful implication from these reforms is that alternative forms of assessment validate the use of different cognitive strengths to demonstrate understanding. Some children form visual images better, some are strong in logic, others sense the meaning of a problem better in its written form, whilst others may require discussion and reflection for understanding. The value of alternative assessments to mathematics learning is liberating in that they provide teachers with the authority to make ongoing and situated judgements about achievement resulting from their teaching (Perso, 1999). The result can be more than cognitive improvements. Creating informative and motivating assessment experiences in mathematics using personally interesting tasks carries a number of opportunities for reducing perceptions of failure. The establishment of communications between achievement groups using non-traditional task structures meant that those with a lesser knowledge could gain an entrance into a normally competitive environment for support which could increase successful experiences in mathematics tasks (Vale, 1999).

However, in the absence of these opportunities a narrow conceptualisation of abilities has a significant impact on equitable opportunities to learn mathematics and demonstrate that learning. The mathematics teaching culture is resistant to change and these altered forms of assessment have been slow to be implemented (Senk, Beckmann, & Thompson, 1997). This is argued to perpetuate achievement gaps because traditional testing in mathematics does not adequately allow opportunities for connections and experiences to be drawn on by a diversity of students (Stanley & Spafford, 2002). Moreover, introducing new assessments is unlikely to be sufficient without eliminating such practices as streamed classes and differentiated curricula (Kitchen et al., 2002) although the policy to remove streaming is resisted more in mathematics than in other subjects (Gamoran & Weinstein, 1998).

2.3. Mathematics reform and its effectiveness

A wide variety of research has examined low achievement in mathematics (Reynolds & Walberg, 1992). The literature review has shown that low achievers in mathematics are a group that has been limited in developing mathematical understanding by a traditional mathematics delivery, leading to reforms that focused on helping students construct personally meaningful conceptions of mathematics topics (Fraivillig, Murphy, & Fuson, 1999).

The NCTM Principles and Standards (NCTM, 1989, 2000) and Australia's National Statements of Standards (AEC, 1990) have represented the major thrust of recent mathematics reforms in these educationally similar countries. The reforms have been characterised by a change to mathematics pedagogy and curricula, evident through three major shifts in educational delivery:

- The implementation of *Standards* frameworks
- A shift from a syllabus focus to student *Outcomes*
- A move from teacher-directed classrooms to student-centred learning

Standards in mathematics education have been described as statements about priorities and goals, formulated from social value judgements of what students should know and be able to do (Hiebert, 1999). Standards-based curricula have been closely aligned with the NCTM recommendations (Bay, Reys, & Reys, 1999) aiming for increased student achievement in mathematics through benchmark goals for performance. These benchmarks of achievement have aimed to increase school effectiveness, and to ensure that all students have the opportunity to attain higher levels (Futrell et al., 1997).

In an effort to overcome the problems of differentiated needs, the use of *Outcomes-based* education has been proposed as offering an education based on quality of achievement and equity (Willis & Kissane, 1995). An argument for reform in education was that because some students do not appear to exhibit talent in mathematics, their exposure to an education equivalent to that experienced by higher performers was not being provided. Outcomes have been offered as indications of what schools are expected to provide to all students in terms of mathematical knowledge and skills. The goal of their use is that by defining what is regarded as valuable and worthwhile, students will be receiving facilitative learning congruent with their particular cultural, social and personal needs. This process of stating that the outcomes are learning capabilities achievable for all students has put accountability on schools to devise means by which the outcomes are achieved regardless of any disabling characteristics associated with diversity in class, gender, ethnicity, infirmity or proclivity.

The third major shift was from a transmission model of learning towards an education perspective emphasising understanding of mathematical principles. Recent mathematics education reform has adopted the theoretical approach of *Constructivism* (Clements 1997; Treagust, Duit, & Fraser, 1996). The Constructivist approach has its roots in the work of Piaget (Arthurs, 1999; Battista, 1999; Lerman 1996; Snowman & Biehler, 2000). Students "construct" their own knowledge by testing ideas and approaches based on their prior knowledge and experiences. From this state of conscious understanding, the student has "operative knowledge", referring to knowing what to do to construct solutions instead of following some algorithm (Pasztor et al., 1999). The goal is for the student to be stimulated and cognitively encouraged into critical thinking, and thus into learning (Applefield, Huber, & Moallem, 2000; Von Glasersfeld, 1991). Students interpret meaning from the teacher and adjust that meaning within their personal schemata (Nickson, 1992) and learning takes place within and through social interactions involving verbalised thinking, clarification, and reconceptualisation (Koehler & Grouws, 1992).

New curricula have been created to assist in these goals of providing a richer, more engaging mathematics curriculum that increases mathematical skills and understanding (Silver et al., 1995). A basis of reform has been the NCTM Standards documents (1989, 1991, 1995, 2000) that have called for significant change to mathematics pedagogy and content (Bay et al., 1999; Crawford & Snider 2000; Harris, Markus, McLaren, & Fey, 2001; Reys, 2001; Riordan & Noyce, 2001; Reys et al., 1999; Schoen et al., 1999; Trafton et al., 2001). A number of reforms were developed based on these standards, with particular programs being initiated through the National Science Foundation (NSF). The new curricula emphasised reasoning and problem-solving, utilised interesting and challenging contexts, gave opportunities for all students to learn, incorporated technology, used various assessments, and led to further mathematical options at school. The NSF funded, piloted, assessed and refined these Standards-based curricula projects providing evidence in target groups of the value of reforms to mathematics achievement (Battista, 1999; Harris et al., 2001; Reys et al., 1999). The Longitudinal Evaluation of School Change and Performance (Planning and Evaluation Service, 2001) has also provided evidence that mathematics achievement is being positively influenced by the targeted implementation of Standards-based reform practices in high-poverty students gaining from exploration in mathematics, from teachers' professional development, from challenging work, and from parental communication. Recent US data assessing mathematics skills of students who have completed a school cycle under reform principles showed significantly better mathematics scores, both generally and as equity gains for minorities (Schoenfeld, 2002).

Yet the development of specific targeted and funded programs incorporating the components of education reform does not necessarily reflect a broad adherence to Standards recommendations or an implementation across the tens of thousands of schools in many socially, economically and geographically disparate circumstances. Students' mathematics opportunities with respect to curriculum, texts, teachers and pedagogy will vary from school to school (Cogan, Schmidt, & Wiley, 2001). In terms of the overall effect of reforms the National Research Council has noted that although specific interventions were improving student achievement in mathematics, the large-scale Standards-based reforms were not seen to be making substantial progress (National Research Council, 1997). This may be because the effects of reforms will take time to show up in subsequent assessments at higher grades as indicated in the TIMSS-R, because the demonstrated beneficial effects of particular reform programs such as the three-year curriculum of the Connected Mathematics Project (CMP) require demonstration over the full implementation period (Cain, 2002), or because it takes time for educational organisations to collect data. For example the 1996 NAEP teacher-reports indicated a continued concentration on traditional content with modest, localised standards-based instruction by informed advocates (Kilpatrick, Swafford, & Findell, 2001) but recent data evaluating systematic mathematics reforms within particular state and district-wide programs have shown considerable improvement in mathematics outcomes although it has been tied to the necessity that schools have the resources (such as reform-oriented mathematics textbooks) and implement programs with a high fidelity to curriculum, standards, and assessment principles (Briars, 1999; Schoenfeld, 2002).

This fidelity is not guaranteed under circumstances where education authorities within and across states are free to choose their own standards (Bandlow, 2001). An examination of research literature and reviews of reforms in mathematics has shown that teaching practices in the US continue to reflect the traditional model than the standards-based models (Riordan & Noyce, 2001), changes have not been successful in gaining broad improvements in mathematics performances (Allexascht-Snider & Hart, 2001), and many teachers remain unaffected by Standards or innovative instructional materials and continue to teach in traditional ways (Enderson, 2001). The summation is that although the reforms have been well-intentioned, little appears to have changed for many students who have experienced persistent poor performance in mathematics. This has resulted in considerable debate in the face of good teaching as to the value of Standards-based changes and of the move away from traditional teaching of mathematics (Colvin, 1999; Reys, 2001; Schoen et al., 1999). While particular, resourced applications of Standards-based instruction have been described as improving achievement (Carroll, 1998), non-traditional curriculum programs have also been described to have inconclusive differentiated effects on mathematics achievement although achieving goals of promoting interest in, and an appreciation of mathematics (Boaler et al., 2002; Planning and Evaluation Service, 2001).

The effectiveness and degree of implementation of Standards-based reforms is currently of close interest and concern (Ferrini-Mundy, 2001). Assessing the fidelity of new curricula to the goals of a rigorous, constructivist environment in mathematics requires caution (Goldsmith & Mark, 1999) in that the degree that conditions and practices within research classrooms truly reflect mathematics classrooms that assert the use of reform practices is uncertain. The types of curricular changes required by reforms are significant in terms of new content, tasks, strategies and assessments (Bey, Reys, & Reys, 1999) yet reforms based on Standards and Outcomes do not prescribe either content or method of instruction, making change difficult (Draper, 2002). Evolving data mean that an exact picture is not possible but it is apparent that in spite of the current reforms, the average mathematics classroom shows little change (Hiebert, 1999), with the same methods of teaching persisting even in the face of pressures to change. It has been suggested that this has been because mathematical reform has added more information to pedagogical practice but educators have taken away little from their practices (Schmidt et al., 1997). Part of the lack of impact of mathematics reform can be attributed to the influences of teachers' personal beliefs, mathematical knowledge, and pedagogical knowledge (Manouchehri & Goodman, 1998) and given that reform practices have been found unrelated to achievement if used with traditional course structures (McGaffrey et al., 2001), it suggests new curricula and practices may need their own alignments, creating further need for professional development for teachers.

Yet it is difficult to change the way in which teachers teach because in part it requires providing teachers with new opportunities to learn, and most teachers have relatively few opportunities to learn new methods of teaching (Hiebert, 1999). For example, some US middle school mathematics teachers were reported to receive an average of six to fifteen hours per year on methods of teaching mathematics (Keenan et al., 2000), and it is doubtful that the principles of teaching to reform standards could be adequately developed in this timeframe. In Australia there has been an observable lack of enthusiasm to accept and adopt responsibilities to assess under the Curriculum Framework reforms in mathematics (Perso, 1999) and many teachers have expressed concern and uncertainty in response to the implementation of new curriculum changes, particularly over the paradigmatic shift in assessment and reporting (McNamee & McNamee, 1996).

There are concerns associated with the development of new curricula and their implementation, with teachers' professional knowledge and professional development, and with professional and public acceptance of new forms of assessment. It is clear that the task of encouraging the use of a Standards-based mathematics delivery measured against Outcomes has made substantial progress, and student learning does significantly improve with professional development and appropriate curriculum materials (Schoenfeld, 2002), but many students are still not receiving opportunities through their diversity to reach outcome criteria within curriculum and assessment reform.

Whereas the reform components of curriculum, professional development, and assessment deal with the whole class context, the shift to student-centred learning uses Constructivist principles of interactive learning focussing on the individual (Nickson, 1992). The next section examines effects of this aspect of reform, particularly on low achievers in mathematics.

2.4 The problematic outcomes of mathematics reform

The continued failure of many average and low-ability students in the mathematics classroom suggests teaching for understanding to those who do not naturally grasp the concepts is not broadly mastered (Waggener, 1996). The underlying tenet of this thesis is that these are the students who do not have a strong logical-mathematical ability, and that they are low-achieving because of a continued verbal-linguistic and logical-mathematical emphasis in curriculum materials, assessment tools, and the structure of lessons. Furthermore it is suggested that these students are not being well-served by mathematics education because there may be alternative ways for low achievers to understand mathematics that are not being used in classrooms.

A number of cognitively-oriented programs have aimed to remedy low achievement in mathematics and a great deal of attention has been paid to pedagogical reform and design on the basis of constructivist principles, cognitive theory, and the role of prior knowledge with respect to new learning (Ng & Bahr, 1999).

Constructivism is an instructional model suited to the recommendations of increased problem-solving in mathematics (NCTM, 1989) as it centres around exploration and formalisation of ideas (Thompson, 1992). The Constructivist approach to mathematics learning is argued to lead to greater understanding of mathematics when applied to the physical, social and cultural experiences and developmental contexts of the learner (Secada & Berman, 1999) whereas traditional mathematics' use of highly structured worksheets, step-wise rules, practice examples, and formulaic solutions to word-problems has been criticised for its poor survival of understanding and application beyond the classroom (Perkins, 1993). Typical constructivist problems are intended to contrast the traditional efficiencies of symbolic expressions and word problems against students interpreting verbal statements with clarity, logic, and thoroughness, and undertaking explorations to solve problems both in groups and individually (Star, Herbel-Eisenmann, & Smith, 2000). Conditions of classrooms that foster a Constructivist approach involve the use of realistic problems and conditions and the use of multiple perspectives (Snowman & Biehler, 2000), active engagement, group participation, frequent interaction and feedback, contexts that connect learning to a real world, and integration of assessment into instruction (Goldsmith & Mark, 1999; Manouchehri & Goodman, 1998).

However, there are many circumstances where curricula have claimed a reformed status but do not implement the principles with fidelity (Battista, 1999), and despite the availability of innovative materials school practices do not appear to have greatly changed over time (Manouchehri, 1998). Moreover, there is confusion about what is "traditional" and what is "reform" in terms of altered mathematics practices, with roles overlapping significantly in setting class tasks, organisation of tasks, making explanations clear, and monitoring work (Staples, 2001).

Therefore there are a number of key questions to be asked in moving students towards the Standards using Constructivist principles: to what extent are problem-solving and reasoning skills being learned, and students being shown how to apply skills? Are Standards being incorporated and promoted? What methods of assessment are being used? Is technology used to replace procedural calculations and rote learning? Has the curriculum de-emphasised verbal-linguistic and logical-mathematical skills, has there been a broadening of representations of mathematics concepts, and are low achievers in particular catered for in Constructivist practices?

While the effectiveness of particular standards-based curriculum implementation programs have been reviewed such as the *Connected Mathematics Projec*t in middle school (Bay, Beem, Reys, Papick, & Barnes, 1999; Cain, 2002; Riordan & Noyce, 2001), and the *Connecting Math Concepts* and *Everyday Mathematics* curriculum in primary school (Crawford & Snider, 2000; Fraivillig, Murphy, & Fuson, 1999), broad-based curriculum analysis of reform mathematics is sparse in reviewed literature although there is sufficient concern about the effectiveness of new curriculum materials for research to have generated a number of evaluation guides (Kulm, 1999; NCREL, 2002).

A significant, longitudinal and recent analysis of mathematics education taught in classrooms is the Survey of Enacted Curriculum Project (Blank, Porter, & Smithson, 2001; Keenan et al., 2000). This study collected data in mathematics and science from schools across eleven US states, aiming to compare the reported implementation of content standards and reform-recommended practices of "initiative" or implementation schools against "comparison" or traditional schools.

2.4.1 A sample analysis of the middle school mathematics curriculum

Reported Findings on comparisons between Initiative Schools and Comparison Schools:

Problem-solving: Of time allocated as "problem-solving", 30% of middle-school time is spent on the interpretation of problem-solving as computational exercises from texts and worksheets. More than 25% of middle-school mathematics time is spent on word problems from texts and worksheets or procedural work. Time spent on "reform" initiatives of solving novel mathematical problems, writing explanations to problems, and making estimates and predictions was longer.

Multiple assessment formats: At the middle-school level there were no significant differences in the use of the most common assessment strategy of short-answer questions (eg a calculation or procedure), nor in the use of extended responses for which students must explain or justify an answer.

Content: the mathematics taught at middle school level was reportedly not significantly different between schools on any of the subject areas of Number, Measurement, Data Analysis, Algebraic Concepts, and Geometry. Most time was spent on Number Sense (25%) and Algebraic Concepts (30%). Number Sense concentrated on fractions, decimals, percent, and ratio and proportion. Within group variations were large indicating differences in implementation of recommended practices. Expectations as outcomes of learning focussed most on Understanding Concepts (representing a concept, applying it and explaining it), and on Perform Procedures (using numbers for counting or ordering, computations, and solving equations).

Use of technology: While calculators were commonly used in middle school mathematics, the average class rarely used graphing calculators, whether operating under reform principles or not, and one-third of middle school classes were reported not to have this technology.

Curriculum influences on teachers: the most consistent influences reported in both sets of schools were state-based standards (as opposed to national standards such as those of the NCTM), and textbooks.

Alignment of teaching content with standardised assessment content: grade 4 mathematics showed a correlation of 0.37, indicating less than half the expected taught content topics intersected with assessment items found on state tests or on assessments conducted by the NAEP.

Teaching strategies: At the middle school mathematics level no significant differences were reported with respect to teachers being prepared for cooperative learning groups in mathematics, for the integration of mathematics with other subjects, and for teaching mathematics using manipulatives. Most reports were that teachers were well-prepared, but within-school variation showed a significant number of teachers were not well-prepared for these representative innovative strategies whilst others were very well-prepared.

This analysis suggests that some problematic practices of traditional mathematics instruction continue and that the implementation of reform initiatives is variable, supporting literature describing mathematics education to be relatively unaltered within national reform movements (eg Enderson, 2001; Riordan & Noyce, 2001).
The analysis of curriculum, in the absence of widespread reform curricula comparisons, suggests traditional mathematics instruction continues to be found in classrooms, and particularly in middle and secondary schools (Weast et al., 2000).

Most mathematics continues to be presented as a collection of facts and rules used to manipulate symbols, coverage of curriculum through textbook lessons is still a priority and external representations continue in the majority to be diagrams, tables, graphs, and word-problems (Scott, 2001). Mathematics instruction continues to be constructed, in the minds of teachers, as a task that draws principally on the linguistic and logical skills expected to be present in students. This assumption of an age-dependent cognitive development draws on the Piagetian model. Data is drawn from textbooks, reality is represented in drawings, symbolism is emphasised, examples are drawn from the majority culture, and skill acquisition is emphasised by rote learning. These summarised components of a persistent appeal to logical and verbal-linguistic strengths will be described further in Section 2.4.

2.4.2 The persistence of traditional media and methods

While acceptance of alternative representations has been evident for at least a decade of reform (Hiebert & Carpenter, 1992), there continues to be a low use of varied representations in secondary school mathematics (Howard, Perry, & Lindsay, 1996; Manouchehri & Goodman, 1998). Even with reform changes, traditional curricula remain the overwhelming majority of programs in use and traditional media such as textbooks remain with few significant changes made to texts in alignment with Standards (Reys, 2001). Textbooks have been the major curriculum resource in traditional mathematics and have come under criticism in that for economic reasons of production they continue to cover many topics, limiting attempts to increase understanding through a depth of treatment (Schmidt et al., 1997). Because much of classroom organisation is based on texts, mathematics reforms appear to have aimed at improving texts instead of abandoning their role (Crawford & Snider, 2000), but many reform attempts basically consist of traditional curricula with superficial changes (Battista, 1999). The TIMSS-R study showed that the majority of year eight mathematics students continue to work independently from textbooks or worksheets (NCES, 2000a), suggesting a curriculum that persists with representing mathematics as symbolic knowledge, conducts mathematics as problems on paper in classroom contexts, and does not fully apply constructivist principles of collaborative and shared verbalised thinking. There are specific mathematics textbook series developed and tested to reflect NCTM's principles and standards (Martin, Hunt, Lannin, &

Leonard, 2001) but the autonomy of education authorities leaves the degree of their implementation unknown, and the introduction of new materials aiming to shift the nature of mathematics teaching has not historically been shown to have changed school practices much (Manouchehri, 1998).

2.4.3 Constructivism and low mathematical achievers

While research in mathematics on the effects of reform-based pedagogy and curricula on low achievers in mathematics is not prominent (Baxter, Woodward, & Olson, 2001) some of the components of a constructivist classroom have been researched. Reform-mathematics recommends multiple concepts within integrated topics, as applied in many NSF curriculum materials (Martin et al., 2001), yet this structure can create problems for low-achievers who may lack pre-requisite knowledge, who need additional time, who lack appropriate social and behavioural skills necessary for engagement, who process information differently from average and high achievers, are less apt at prediction and selection of strategies for problem solving, and are less likely to complete activities (Montague & Bos, 1990). Constructivist recommendations calling for contextual mathematics tasks may cause recontextualising difficulties for children from minority cultures and for economically disadvantaged students because of the differences between their school and other-context mathematics, possibly resulting in failure and confusion for these students (Zevenbergen, Sullivan, & Mousely, 2002). A Constructivist curriculum recommends students engage in reading, discussing and explaining their mathematics (Draper, 2002), yet low-achievers have been described as contributing minimally to lesson discussion, often appearing distracted when receiving other students' explanations, and when engaged in group-work the role of low-achievers is in non-mathematical tasks leaving the higher achievers to make mathematical decisions (Baxter et al., 2001). It is also possible that the level of cognitive load and mental demands of the reform-curriculum may be beyond low-achievers to cope because the reform curriculum can remain highly structured, retaining the spiral model to build conceptual understanding over time by successively adding depth, with the practical impact of such a structure being rapid and superficial coverage of many topics (Engelmann, Carnine, & Steely, 1991). There is sparse evidence in literature of broad practice of Constructivist principles in secondary mathematics utilising multiple materials or representations that particularly are focussed on the needs of low achievers in mathematics.

2.4.4 Limitations of representation

Understanding of a mathematics concept is suggested to exist if it is part of a network of representations of the concept, and further understanding occurs as representations get increasingly connected into structured and cohesive networks such that more and stronger connections lead to greater understanding (Hiebert & Carpenter, 1992). Under the Piagetian conceptualisation, strength of understanding is viewed as building cognitive bridges between old knowledge and new experiences. Representative information is met and arranged by mental structures or schemata that act to structure language and thoughts through the act of a logical-mathematical intelligence. Images, relationships, and language are brought to mind by the power of this intelligence in its operation, with logical thinking mirroring the cognitive act of thought (Phillips, 1969).

For individual students this ordered structuring may be supported or hampered in dealing with new information in that it is the *form* of this met, external information that makes a difference to them in the way that information is internally represented (Hiebert & Carpenter, 1992). External activities and representations influence internal mental activities (Diezmann, 1995) and assist in long-term memory drawing on experiences, memories and related concepts to construct new thoughts and ideas. Understanding is suggested in this thesis to be helped by resonant connections provided through the social language and experiential information that exercise the operative intelligence. The Piagetian model offers intelligence as a logical-mathematical form, suggesting that the best exercise is in the form of abstracting knowledge from tasks and arranging it to make sense (Piaget & Inhelder, 1966). Under this narrow representation of intelligence, making sense is suggested to be assisted by greater degrees of abstraction, or decontextualised tasks, and the use of symbolic logic to organise it.

These increasingly abstract representations are a model of students' developmental experiences within traditional mathematics education. The realities of the secondary mathematics curriculum have been indicated in the Survey on Enacted Curriculum

(Keenan et al., 2000) showing many of the components of traditional mathematics remain in mathematics classrooms and secondary mathematics continue with limited representations. Despite pockets of reform at the secondary level the normative experience is one of seatwork, note-taking, and reproduction in assessment, and even innovative practices may be of little value without changes in professional knowledge of new methods (Thompson & Thornton, 2002). Current mathematics reforms aim for student explanations in the forms of writing, symbols, pictures, and words as part of a broadened instruction and assessment (Baxter, Woodward, Olsen, & Robyns, 2002) yet these are still restricted to the verbal-linguistic, logical-mathematical and visual competencies.

2.4.5 Constructivism and teacher effects in mathematics education

There are few long-term studies that describe the relationships between implementation of curriculum changes and teachers' interactions with innovative practices (Manouchehri & Goodman, 1998), and a lack of empirical research on curriculum integration (Hurley, 2001). However there is evidence of a difference between the Constructivist intentions of mathematics teachers and their actual classroom practices, with many instructional practices reverting to traditional pencil-and-paper seatwork, assessment in the same medium, and solutions developed from individual efforts (Manouchehri, 1998). Teachers continue to give priority to curriculum content coverage, place an emphasis on mathematical procedures, and use teacher-based instructional deliveries (Haimes, 1996). The 1996 NAEP teacher-reports indicated many mathematics classrooms do not regularly use group work in accordance with the principles from which such practices were derived, few student projects were undertaken more frequently than weekly, and even where teachers reported implementations of reform practices there were discrepancies between these and observations made in classrooms (Kilpatrick et al., 2001). The TIMSS-R indicated most eighth-grade mathematics students said their teachers almost always showed them how to do problems (NCES, 2000a). Patterns of pressure on the differences between intentions and implementation include traditionalist teacher backgrounds in mathematics, the demands of time available designing and planning for innovation, and the challenge of balancing teaching for understanding against skill acquisition (Geist, 2001). This last point is significant under accountability of schools through large-scale state and national assessments, where teachers' perceptions of the content of such assessments will affect how they teach mathematics in order to maximise their results (McGehee & Griffith, 2001). A further significant factor in the continuation of traditional practices is that the pedagogical or professional knowledge of teachers does not necessarily match that required for particular reform implementation (Acquarelli & Mumme, 1996), although where teachers have received professional development, teaching is consistent with the principles of reform-based mathematics (Smith, 2000b; Stipek et al., 1998).

An analysis of the US mathematics curriculum has also identified a number of contrasting factors between the mathematics reform-based recommendations and schools' implemented curricula. Although a Constructivist approach and language requires students to discover, develop meanings, attempt different solutions, integrate topics within a real context, and use fewer topics in order to deepen mathematical understanding (Snowman & Biehler, 2000), the US mathematics curriculum possesses many separate topics which increase in number from primary into middle school; the language of the US curriculum frequently emphasises traditional instructional practices to introduce, emphasise, reinforce, and master content; basic skills topics are carried beyond developmentally appropriate grades; and those challenging tasks that allow for stimulating and critical thinking in a range of contexts occur up to a year later than many other countries (NCREL, 2002; Schmidt et al., 1997).

There is clear support for Constructivist approaches in mathematics, and research into the value of Constructivist methods mathematics teaching has revealed that within specific programs, outcomes exceed traditional methods (Schoenfeld, 2002; Thompson & Senk, 2001). The same impact is observed in classrooms with mathematics teachers who are familiar with, or philosophically in agreement with constructivist or Standards techniques (Manouchehri & Goodman, 1998; Schmoker & Marzano, 1999). The successes of Constructivism depend very much upon the expertise of teachers in their field, in order to use their knowledge to scaffold strategies so that students can begin to construct their own meanings (Chrenka, 2001). However, this pedagogical expertise is not always present, and teachers' knowledge of mathematics has been described as less than good at the middle school level and particularly at the elementary school level (Fennema & Franke, 1992). TIMSS data indicated that on average, only 41% of US students at 8th grade were taught by teachers with mathematics as a major area of study (ISC, 1999) although knowing how to teach mathematics well to students having difficulties may be more important than mathematics qualifications (Baker et al., 2002). Yet even if this is accepted, secondary teaching qualifications have been described as absent in up to 50% of middle school mathematics teachers (Weast et al., 2000).

Therefore, in the general arena of the many mathematics classrooms operating within an evolving implementation of reforms there is sufficient evidence to assert that regardless of the Constructivist theme and an intended curriculum, mathematics often continues to be taught in traditional ways. There is not a consistent use of collaborative work, assessment practices commonly are with pencil and paper, traditional texts forms are the resource for problem-solving, and teacher-directed algorithmic tasks often predominate in class-time. The continued emphasis on verbal and logical modes of representation of mathematics concepts within the Constructivist-based mathematics reforms is argued to contribute to the continued poor performance of many students of mathematics who do not possess a high level of linguistic or logical-mathematical intellectual competence. While the Constructivist model underpins reforms to mathematics learning, it is contended that advantage continues to be given to students who possess strong natural or intellectual abilities in linguistic, logical and spatial operations. Most mathematics classrooms haven't taken advantage of potential resonances with differentiated or multiple intelligences (Gardner, 1983), although a rich diversity of multiple representations can lead to a more robust and flexible understanding, with visual, contextual and multiple representations successfully used in the modelling of mathematical functions that are normally taught with a strong symbolic emphasis (Confrey & Doerr, 1996).

One of the goals of education is that students realise mathematics is personally relevant (AEC, 1991), yet many students see mathematics as a solitary activity at which one is good or not, see "doing mathematics" as using formulas and exercises with single answers that are right or wrong, or see mathematics as memorising facts and procedures (Southwell & Khamis, 1994). Ignoring the variety of mental structures that students use outside of formal schooling to develop ideas about mathematics concepts could be negating opportunities inside classrooms to develop the long-term school objective of understanding and facility with symbolic manipulation, abstract conceptualisation and formal rules (Battista, 1999), because their beliefs about what it takes to be a successful mathematics learner cause them to abandon efforts in circumstances where persistence would have given success (Schoenfeld, 2002).

The next section examines these consequences of a narrowed representation of mathematics learning.

2.5 Teaching through limited competencies

Children's early introduction to schooling has been characterised by a variety of stimuli and a choice of environmental experiences (Butterworth & Cicero, 2001). Their natural interests have been incorporated into educational programs and a divergent, holistic and non-restrictive world has existed. Young children's enthusiasm and curiosity is reflected in their enjoyment of mathematics (AEC, 1990) as they engage in mathematics within a pedagogy that introduces concepts through concrete materials (Fullarton, 1994).

For some children this experience does not last (Cordova & Lepper, 1996). While elementary mathematics classrooms emphasise the representation of concepts in the form of manipulatives or concrete materials (Fennema & Franke, 1992) that assist in motivating and making mathematics meaningful (Vale, 1999), this use decreases with movement through primary grades and has little application in secondary mathematics (Boren & Hartshorn, 1990; Howard et al., 1996). Teacher-reports in the 1996 NAEP showed that while 27% of grade 4 children used manipulatives of some form weekly in mathematics, 8% of grade 8 students did so (Kilpatrick et al., 2001). There is a developmental pre-occupation with verbal-linguistic and logical-mathematical abilities in schools (Hearne & Stone, 1995) with the transition period between primary and secondary school assumed to match children's progress from the concrete operational stage towards a capability of thinking abstractly (Piaget &

Inhelder, 1969). While mathematics comprises strongly related abstractions that require particular representational forms that allow students to relate concepts to what they already know, teachers need to know how to translate this abstraction into understandable representations (Fennema & Franke, 1992). Teachers of mathematics have traditionally aimed to connect the conceptual move from concrete to abstract representations with diagrams, pictures, texts, drawings and imagery (Fullarton, 1994), and have attempted to deal with the increasing linguistic and symbolic complexity with algorithms, and with repetition and practice (Gray et al., 1999).

For Western culture, the peak of mature thought is represented through the ability to reason in a logical-mathematical manner (Lynch, 1990). Piaget (1972) has expressed the view that mathematics is logic, with understanding dependent upon a free and full development of the intellect. However, differences between students inevitably mean that some will be more adept than others in their capabilities to deal with this increasing complexity and abstraction of mathematics concept representation. Formal operational ability is proposed to develop about the age of twelve years yet this ability to think in abstractions and in logical ways may not occur until later or even not at all, with some research showing that a little over 20% of eighth graders were at the formal operational stage (White & Sivitanides, 2002), and almost 60% of students in eighth and ninth grades function at the concrete operational stage of cognitive development (Valanides, 1996). Dealing with the abstract forms met in traditional mathematics requires logical reasoning ability of the highest order of Piagetian cognitive development (Snowman & Biehler, 2000), represented by logical-mathematical intelligence. The processes of comprehending mathematics problems through Piagetian accommodation and assimilation are argued to be quicker and stronger for students with a greater degree of logical-mathematical intelligence given that these logical-mathematical structures are the internal, neurological system with which and into which students incorporate the components of problems (Flavell, 1963). Students with strongest logical-mathematical and verbal-linguistic abilities are likely to be advantaged cognitively and emotionally if mathematics delivery converges on these particular intellectual strengths with increasing grades.

It is argued in this thesis that this convergence has been the nature of traditional mathematics delivery and continues to be. Reform mathematics has moderated the focus on mathematics as pencil-and-paper calculations, emphasising reasoning, explanation, problem-solving and a variety of applicable content such as statistics and technology as tools of mathematical analysis (Battista, 1999). Students are assumed to acquire the intellectual maturity to comply with these cognitive requirements of systematic and logical thought, construction and use of hypotheses, developing trains of thought leading to prediction, and reasoning through analogy and metaphor as a natural developmental consequence (Piaget & Inhelder, 1958). The expectation of all students to equally develop such skills is reflected in the national goals of mathematics education that students explore mathematical situations, use tools, gather data, make connections with other disciplines, and explain results (NCTM, 1989, 1991, 1995).

There is a tacit assumption that students can equally draw on resources in developing these skills yet the goals of reform do not appear to have specifically included considerations about the developmental differences of low achievers (Baxter et al., 2001). Mathematics delivery is still embedded and undertaken in text form, and the medium of mathematics instruction continues to be mainly based on textbooks (Crawford & Snider, 2000). For these students at risk of mathematical failure the difficulties associated with word-problem solving diminish their ability to function well (Jitendra & Xin, 1997) and may limit the ability of students to use their informal knowledge (Carey et al., 1995).

The decontextualised use of books and graphs may not be an optimal way for low achievers to understand mathematical concepts because the still-common medium of mathematics – pen and paper – represents a virtual reality that proves too great for these students when it comes to making mathematical connections (Noss, Healy, & Hoyles, 1997). Symbolism is a language form that is compact, abstract, and needs rich and meaningful connections (Rubenstein & Thompson, 2001) and if low achievers do not know how to read for mathematics they lose the link between the concepts and the mathematical symbols. There are growing examples where specific programs initiated into schools are successful in providing for these links through connected tasks (Thomas & Santiago, 2002), writing in mathematics (Baxter et al., 2002; Goldsby & Cozza, 2002; Liebars, 1997; Pugalee, 2001; Reed, 1995), technology (Heid & Edwards, 2001), problem-based teaching (Harris et al., 2001), group work with tools (Riordan & Noyce, 2001), aligned textbooks (Crawford & Snider, 2000), altered assessments (Kitchen et al., 2002), and professional development (Frykholm, 1999; Lloyd & Frykholm, 2000) but while mathematics reforms have moved curricula away from teacher-led tasks and single texts as the resource for lessons, the traditional presentations and activities of mathematics have remained (Lokan et al., 1996). These factors contribute to a continuation of traditional mathematics teaching with its emphasis of appeal to verbal-linguistic and logical-mathematical intelligences, resulting in mathematics education serving those easiest to serve (Pisapia & Gross, 1991). Although other different capacities of students are recognisable as exceptional personal qualities, they have not usually been included in mathematics classrooms as relevant aids to learning. Fluency with conventional mathematical symbolism is a necessary aim of mathematics education (Carroll & Porter, 1998), but if students are to become fluent they need to be introduced to the variety of ways mathematical ideas can be symbolised, particularly because students do not generally record the word meanings of symbols and can lose a sense of their role (Rubenstein & Thompson, 2001).

As well as maintaining a narrow entrance into cognitive representations of mathematics concepts, this focus on verbal-linguistic and logical-mathematical intellectual abilities has also produced the potential for inequitable differences in how children are taught (Lumpkins et al, 1991). Teacher-beliefs about what constitutes mathematics have an impact on teaching practices (Ernest, 1988; Koehler & Grouws, 1992) and many mathematics teachers (particularly those in secondary mathematics) frequently suggest that certain abilities are considered necessary to learn mathematics, and regard streaming as essential in mathematics because of its structured logical nature (Archer, 1999; Zevenbergen, 2002). Mathematically exceptional students have been shown to have particular cognitive profiles involving non-verbal reasoning, spatial ability and memory (Benbow & Minor, 1990; Gray, Pitta, Pinto, & Tall, 1999). A logical-mathematical emphasis in the forms of algorithms and abstracted contexts may resonate more with these students who have exceptional inductive and deductive capabilities, particularly as "mathematical thought" is considered as the deductive ability to transcend reality (Flavell, 1963).

These abilities are valued in the culture of school (Robinson, Abbott, Berninger, & Buss, 1996), and students are offered special academic courses such as the Talented and Gifted Students programs that give advantage to their innate capacities (Elmore & Zenus, 1994). Students' self-concepts may be positively influenced by participation in these gifted programs, being related to the realisation of intellectual potentials or talents (Feldhusen & Hoover, 1986). To a large degree students derive their ideas of what constitutes mathematics and construct their self-concepts from their mathematics classroom experiences (Schoenfeld, 1991).

By contrast children who do not demonstrate high logical-mathematical ability may suffer poor self-conceptions in their ability to learn mathematics as a result of obvious differences between their own abilities and those valued by the school. While young children do not have fixed views on intelligence as a predictor of mathematics achievement, when they are nearing or entering adolescence their increased association with the nature of mathematics causes some students to consolidate their beliefs that intelligence is represented by logical-mathematical ability, and that success in mathematics is related to possession of that ability (Elmore & Zenus, 1994; Stipek & Gralinski, 1996). Such beliefs can cause students to withhold effort, reduce efforts, or withdraw from enrolling in mathematics. Given these consequences, these beliefs need altering and Multiple Intelligences learning offers to do this for diverse students.

All children have been proposed to have potential sets of abilities and need opportunities to display that individual potential (Gardner, 1991). This has been recognised in national goals in a call for equitable learning experiences to build on student strengths and for teachers to avoid interpretations of 'ability' or 'intelligence' based on culturally narrow interpretations of important knowledge (AEC, 1990). The next section shows how biased opportunities to learn mathematics occur if learning is mainly limited to the culturally valued abilities of verbal-linguistic and logical-mathematical intelligences.

2.6. Traditional mathematics instruction, cultural dissonance and failure

From a contemporary Constructivist perspective of mathematics education, personal experiences and previously learned knowledge and skills are encouraged as components for understanding (Snowman & Biehler, 2000). Observations, hypotheses and conclusions are made, tested and drawn within a social environment that allows sense to be made. Unreasonable or meaningless mathematical solutions (such as an answer where a car has seven wheels) would be mediated by cultural knowledge, and skills acquired in class could be used in real contexts. Increased understanding should result from mathematical tasks being linked to personal student experiences, and from the incorporation of the linguistic and culturally relevant components of students' lives, such as the shop in traditional contexts, or the Social Security agency.

Despite these intentions of an accessible mathematics education with broad appeal, a number of children continue to have difficulty with mathematics concepts at school, with low socio-economic background, inner urban backgrounds, and cultural minority groups disproportionately represented among them (Catsambis & Beverage 2001; Kim & Hocevar 1998; NCES, 2001; NSF, 1996; Okpala et al., 2001). It is suggested in this thesis that a consideration of intellectual structures beyond verbal-linguistic and logical-mathematical skills will offer assistance to these and other low-achieving students.

Traditional task representations used in mathematics have frequently been made in the linguistic and experiential modes drawn from the dominant culture (Stedman, 1997). Mathematics has its own specific forms of discourse and students who are fluent within their own cultural contexts may not possess the same fluency in the school cultural context of middle-class white society (Kouba, Champagne, Roy-Campbell, Cezikturk, Benschoten, Sherwood & Ho, 2000). Some of that difference in fluency may derive from different opportunities that children have to engage in particular forms of mathematical activities (Guberman, 1999). It is less that students differ in capabilities for mathematics but that some cultural practices may emphasise, engage with, and practice mathematics that supports the academic forms that are commonly used in school. Children from non-traditional homes may not have the connecting experiences used in the schools' culturally dominant mathematical task descriptions where links between tasks and personal experiences are made (Khisty,

1995) whereas students with strong personal socio-cultural mathematical and linguistic experiences benefit if these match schools' verbal-linguistic and logical-mathematical delivery.

As long as schools continue to emphasise these competencies, they continue to support the culturally dominant group and may marginalise those students who receive less social and cultural practise in these abilities (Zevenbergen, 1997). This can be magnified in its impact when students have had dissonant cultural experiences compared to the school's cultural emphases in task representation (Gordon & Yowell, 1994), and when students have demonstrated differences in language experiences necessary for the construction of metaphors and mental models in mathematics (Khisty, 1995). The problem of schools' twin emphases on language and logic has further significance in that that for some children the inability to extract logical meaning from contextual detail may be interpreted as an inability of the student to respond to teaching (Kouba et al., 2000; Morgan & Watson, 2002). Any lack of success in mathematics by students from outside the mainstream culture is frequently viewed from a psychological perspective of a personal inadequacy, such as lack of mathematical ability, or of intelligence (Allexascht-Snider & Hart, 2001; Zevenbergen, 1997).

Under Multiple Intelligences theory (Gardner, 1983), if children with the same intelligences have differing cultural or experiential lives, then an advantage may be given to the child whose background resonates most with how the school teaches mathematics, and whose family values resonate with the reasons why the school teaches mathematics. The knowledge that students bring to school has a powerful influence on how students interpret and learn school mathematics (Guberman, 1999). Classroom values may fail to recognise the relevance of others' contextual knowledge, thus draw these children less into class discourse and offer them fewer learning opportunities, with a consequence of a persistent achievement gap. Zevenbergen (1998) suggests that because of a certain linguistic background and discursive knowledge, and a middle-class acceptance of the hierarchical, algorithmic nature of mathematics pedagogy, some students gain access to mathematics content and processes more readily than others. Gardner (1991) also sees a dominant set of pedagogical practices inhibiting equitable access to mathematics, but broadens the inequity to the apparent invisibility of intelligences other than verbal-linguistic and

logical mathematical. Multiple Intelligences learning can assist in negating the verbal-linguistic and mathematical inequities that a cultural mainstream can introduce which resonates with particular backgrounds within emphasised skills.
The persistence of traditional mathematics delivery in secondary schools is tied to the continued structure in terms of timetables, emphasis on subject-area delivery of curriculum, relative ease of teaching with texts and worksheets, and an implicit belief that mathematics requires an ordered classroom. There may be an administrative reluctance as well as an absence of pedagogical knowledge to incorporate new and possibly threatening modes of mathematics education using knowledge on the value of multiple entry points into mathematical concepts.

However, strong links have been found between educational restructuring that assisted reforms and improved student learning in schools (Lee, Smith & Croninger, 1996). The next section examines learning frameworks beyond the traditional delivery in order to identify the attributes of successful programs.

2.7 Attributes of successful programs

The umbrella classification of "*authentic learning*" has represented a group of educational reform programs that have been theoretically and practically able to reflect recent neurological and psychological theories in ways that can ameliorate the impacts of traditional school learning on low achievers. The role of culturally valued activities as sites of context has relevance for developing these strong cognitive processes in children (Serpell & Wade-Boykin, 1994) and a number of alternative frameworks for building on connections between mathematics concepts and their contexts exist in educational theory. Authentic learning is offered in a number of forms including Situated Learning (Lave 1988; Lave & Wenger, 1991), Multiple Intelligences learning (Gardner, 1991, 1993), Experiential education (Boren & Hartshorn, 1990) and Constructivist learning (Vygotsky, 1978). These have encapsulated the need for authenticity of contexts with learning, offered a wider concept of competence, and attempted to meet emotional needs.

A review of literature outside of traditional Western models under the collective term of "*experiential education*" has noted the role this plays in encouraging engagement and the conversion of difficulties into incentives for action, promoting personal agency and leading to self-awareness in terms of personal competencies (Carver, 1995).

The process of "*constructivist learning*" (Wilson, Teslow, & Taylor, 1993) has also emphasised the active role of the learner. Two important characteristics of constructivist learning are the use of complex, real life learning environments and social interaction. Other elements are cooperative working, authentic tasks, multiple representations of content, cognitive apprenticeships, student-centred instruction and thematic projects. These factors are frequently found in contexts outside of classrooms, and the role of outdoor education has been shown to improve student engagement and achievement (Broda, 2002).

"*Situated Learning*" has incorporated the values and attitudes of the community, supporting the reform notions that learning should be connected to real life (Wilson et al., 1993). The development of skills can then be facilitated in their application across areas of competence. Important differences between learning in and out of school include cognition in school being usually individual whereas effective functioning outside of school requires the engagement with others; more tools are used outside of school to assist cognition in complex activities whereas school depends particularly on thought processes; and school activities are mainly decontextualised while outside activities are connected to real events (Resnick in Boulton-Lewis & Catherwood, 1994). An awareness of contexts in which low-achieving students do have mathematical competence has been described as important because it offers the opportunity for a personalised pathway to learning and fair assessment (Telese & Kulm, 1995). Real-life connections with situated activities and appropriate contexts have been demonstrated to evoke mathematical knowledge that can be carried beyond specific classroom procedures and utilised in non-school settings (Boaler, 1998).

Recent attention has also been given to the importance of mental representations and their connections through knowledge structures such as analogy, metaphor, and imagery, and the use of visual, auditory and kinaesthetic sensory components to represent abstract mathematics concepts in order to reach all students through multiple approaches (Pasztor et al., 1999).

It is evident that authenticity and meaningful connections are gained in each of these approaches by the incorporation of experiential material, genuine learner activities, real-life values and broad-based interests to engage the learner. The NCTM (1989) emphasised activities that allowed students to see the relevance of mathematics in their lives and these alternative modes of education offer ways to construct experiences that support and promote mathematics education goals while maintaining cognitive demands of tasks, which has been a major dilemma to reformers (Smith, 2000b). However, the value of merely providing contextual learning as interesting tasks related to the real world does not necessarily enhance the outcomes for some students whether abstract or contextual tasks are used. This may be because students' cognitive engagement and understanding is still lacking, that they do not have a "feel" for the situation. Because of this, a knowledge of the students' personalised learning needs should precede decisions made about the nature, contexts, and choices of tasks (Boaler, 1993), effectively mediating between what the teacher intends as outcomes of learning and the understanding developed by the student.

A recent summary of knowledge by the National Research Council on assisting students in mathematics education has advocated that teachers play an increased role in engaging students, and that multiple representations of problems forms a part of this (Kilpatrick et al., 2001). Work in authentic learning that opens opportunities for students to build more meaning into their classroom mathematics is *Multiple Intelligences Theory* (Gardner, 1983). This theory assumes people to have a broad array of abilities available as intelligences, which offers a wider possibility of engaging student comprehension and interest. To offer a fair education with the best chance of learning, Gardner has advocated authentic contexts, knowledge of individual competencies, and the use of assessments that accompany and reinforce learning. In later publications the relevance of concurrent, intelligence fair assessment as an essential component of genuine learning has been addressed (Kornhaber, Krechevsky & Gardner, 1990; Gardner, 1991; Gardner, 1993; Kornhaber & Gardner, 1993; Gardner, 1995).

In particular, the educational advantages offered in Gardner's theory have appeared to match the gaps that have been made evident in previous mathematics reforms. Multiple Intelligences learning offers a view of mathematical understanding as capable of being mediated by other mental strengths than logical thought, and that the characterising qualities of these other strengths allow their equal conceptualisation as *intelligences.* Multiple Intelligences theory offers resonant learning opportunities, it offers to engage students in diverse tasks, to increase student confidence and to allow mathematics understanding to be achieved by all students.

The positive impacts of Multiple Intelligences theory are proposed to work in education environments in theory. The next section examines the outcomes of programs that have applied Multiple Intelligences theory to educational contexts.

2.8 Multiple Intelligences applications to address low achievement

Part of the perplexity about low achievement is that it has persisted within a framework of intensive research and expenditure. In mathematics the focus of interventions has been on the cognitive domain (involved with actively acquiring and using knowledge), on metacognitive functioning and on affective reactions focussing on attitudes and feelings (Naglieri & Gottling, 1997; Wong, Butler, Ficzere, & Kuperis, 1996). Attention has also focussed on the nature of mathematical tasks, attempting to engage students in thinking and reasoning at a high level (Henningsen & Stein, 1997). Recent research has encouraged the application of varied psychological theories of intelligence to the attainment of desirable educational outcomes (McGrew, Keith, Flanagan, & Vanderwood, 1997). Multiple Intelligences theory belongs to this class and has allowed for the consideration of a range of cognitive abilities to be factored into learning, opposing the limited dimensionality historically given to human intelligence (Gardner, 1983; Gardner, 1991; Gardner, 1993).

The Theory of Multiple Intelligences has been argued to have a sound theoretical and empirical base (Gardner, 1994) although it has generated academic conflict (Allix, 2000; Bawden, 2002; Delisle, 2002; Gardner & Connell, 2000; Sternberg, 1994). The premise that intelligence is not limited to linguistic and logical ability has encouraged many teachers to include a variety of their students' intellectual strengths in acquiring understanding. To be fluent in the symbols of mathematics, students need to be introduced to the different ways that an idea can be symbolised (Rubenstein & Thompson, 2001) and mathematics concepts may be expressed metaphorically in ways intellectually comprehensible by different students, and taught through media in which students are better able to construct conceptual meaning. Teachers frequently struggle with how to approach differentiated classes in terms of what needs to be covered, where the emphasis should lie, and what assessments should be used. A Multiple Intelligences approach uses individualised instruction that can create meaningful experiences, covers conceptual understanding rather than factual knowledge, and allows a demonstration of understanding that is informative and motivational (Gray & Waggoner, 2002). The opportunity to vary formats allows open-ended tasks that carry less emphasis on single, correct answers. Self-concepts of ability such as self-efficacy are likely to be enhanced in learning environments that allow individuals to participate without having to be "right" (Randwaha, Beamer & Lundberg, 1993). Mathematical self-efficacy is likely to be raised by altered experiences and in turn may lead to increased engagement with class-work.

In order to construct hypotheses about the effects of applying the principles of Multiple Intelligences theory to teaching mathematics it is necessary to ask what is meant by improved outcomes in mathematics.

Low-achievers in mathematics show lowered understanding of concepts, limited engagement, inappropriate classroom behaviours and lowered time on task. Therefore a successful intervention using Multiple Intelligences principles is proposed to result in a better demonstration of understanding about mathematical concepts in the specified instruction, increased experiences of success, increased engagement, appropriate behaviour and attendance to tasks. Willingness to participate would be interpreted as reflecting increased perceptions of self-efficacy for the tasks.

The following section provides a brief summary of the evidence supporting the roles of Multiple Intelligences instruction in improving educational achievement, engagement and attitudes.

2.8.1. Evidence for proposed effects of Multiple Intelligences instruction

The literature review on Multiple Intelligences applications undertaken in this study has centred on publications associated with the author of Multiple Intelligences theory, Gardner, and articles derived from cross-referenced ERIC, ProQuest, AustRom, Infotrac and PsychInfo searches. At the time of planning the thesis (1996-7) searches revealed only one article in the specific area of Multiple Intelligences learning and low achievement in students (Beuscher, Keuer, & Muehlich, 1997). That study reported outcomes of improved student engagement and improved students' social skills. At the present time of writing, research-based articles have remained sparse in electronic searches. For example, PsychInfo revealed on hundred and sixty eight Multiple Intelligences articles with eight in mathematics, of which one was research-based in middle school. An ERIC review with keywords produced the following articles: Multiple Intelligences (1350), Multiple Intelligences and mathematics (189), and Multiple Intelligences, mathematics and achievement (48). Of the articles located in the electronic ERIC search, eight were directly related to research-based mathematics learning.

Apart from these research studies on the interaction between Multiple Intelligences learning, low achievement and mathematics there are many narrative descriptions of the methods of applying Multiple Intelligences theory in schools (Campbell, 1997; Ezarik, 2001; Simmons, 2001). A variety of applications of Multiple Intelligences theory have been reported as improving motivation, lowering discipline problems and having overall positive effects on affective variables such as attitude to school and valuing work. Specific research studies have reported improvement in behaviours conducive to learning (Chen, 1993; Dare et al., 1997; Janes, Koutsopangis, Mason, & Villaranda, 2000; Layng et al., 1995; Outis, 1994), engagement with work (Beuscher, Keuer, & Muehlich, 1997; Dare et al., 1997; Ellingson, Long, & McCullough, 1997; Layng et al., 1995; Lindvall, 1995) and in connecting school knowledge to real-life situations (Carver et al., 2000).

These gains have been made for low achieving students or at risk students in classrooms ranging from elementary schools (Condis, Parks, & Soldwedel, 2000; Dare et al., 1997; Geimer, Getz, Pochert, & Pullem, 2000; Lindvall, 1995), to secondary schools (Coleman, Peters, & Murray, 1997; Hughes, 1995; Miller, 1995). Campbell and Campbell (in Gray & Waggoner, 2002) noted that Multiple Intelligences in classrooms has significantly raised achievement, and that in specific situations across primary, middle and secondary schools using MI theory for periods of five years, basic skills at all levels had been boosted. Some studies have particularly noted positive effects on "at risk" students rather than general ability students (Miller, 1995; Rubado, 2002), although a broad impact has also been noted (Hughes, 1995).

These altered pedagogical practices and outcomes are components of the NCTM's educational reforms applied to mathematics (NCTM, 1989, 1991, 1995, 2000) demonstrating that Multiple Intelligences theory can provide the framework for adaptive curricula and classroom practices required of school reforms. The large array of variables involved in interventions implies that Multiple Intelligences interventions may need to be tuned to the students and school in order to be effective. For example, the findings of Miller (1995) on the influence of Multiple Intelligences interventions on middle school students included the comment that it probably required a longer time to be effective, and perhaps should be begun in earlier grades. Hughes (1995) reported that work within the high school environment was vulnerable to time constraints, which have been recognised as impediments to the use of non-traditional teaching and learning (Pesci, 2001).

While improvements in attitudes and behaviour have been evident, achievement gains have not been as consistently or as generally reported across the studies reviewed. Cognitive, affective and behavioural gains have occurred at primary school levels, however Multiple Intelligences learning has been described in some studies only as making work more interesting and relevant to students in secondary school (Coleman et al., 1997) and not productive in promoting academic success (Smith, Odhiambo, & El Khateeb, 2000). The strength of effect from Multiple Intelligences theory on learning has also appeared less evident at the secondary school level. Motivational improvements appeared more evident in primary than secondary school (Bartscher, Gould, & Nutter, 1995; Baldes, Cahill, & Moretto, 2000), with increased intrinsic motivation but less significant gains for engagement at the middle school level under Multiple Intelligences learning (Lane, Marquardt, & Meyer, 1997).

A review of studies that specifically looked at the impact of Multiple Intelligences learning on mathematics performance attainment for low-achieving secondary school students has indicated improvements in mathematics communication and vocabulary (Schwarz, 1999), motivation (Klein et al., 1998), mathematics reading comprehension (Kuzniewski et al., 1998), problem-solving skills (Abbott & Warfield, 1999), and improved confidence (Eilers, Fox, Welvaert, & Wood, 1998). While these outcomes are notable goals of the NCTM's Principles and Standards (2000), significant improvements in mathematics achievement performance resulting from Multiple Intelligences interventions were not described in the majority of reviewed articles.

The problem of low achievement in mathematics is evident in the literature. While mathematics reforms have produced definite, sizeable improvements in performance levels generally, students are still failing to achieve in mathematics. One of the purposes of mathematics research is to improve the learning of mathematics (Kilpatrick, 1992) suggesting finding a new approach to representing mathematics could be of value to these low-achievers. Multiple Intelligences theory has indicated it offers this new approach. Multiple Intelligences learning has been shown to provide affective support to students, but few applications have been available in Middle School mathematics contexts that demonstrate cognitive gains.

Interventions that aim to confer cognitive advantage while supporting emotional and behavioural adjustments and adaptations occurring during this period are considered necessary to meet the most recent recommendations in the NCTM's (2000) Principles and Standards, advocating problem-solving, reasoning and proof, connections, communication, and representation (Schoenfeld, 2002). Multiple Intelligences learning appears to offer substantial support in assisting low-achievers to attain these standards, as they provide a framework for utilising the multiple intelligences that children bring to class activities (Adams, 2000).

2.9 Conclusion

In proposing that mathematics reform can be assisted through a reconceptualisation of intelligence, this thesis has taken equitable access to mathematics education further than responses to demographics or pedagogical practices. The identification and description of differentiated cognitive abilities as *multiple intelligences* (Gardner, 1983) is the basis of the mathematics equity program in this thesis. The problem of low achievement is addressed in this thesis by arguing that student perceptions of mathematical concepts and understanding of the meaning of the mathematics content will be raised if concepts are learned through personalised cognitive paths and contexts. In turn, low achieving students may strengthen their *self-efficacy* for mathematics. It is proposed as a result that many children would become more engaged in class leading to further success and confidence. Raised mathematical achievement may translate into a self-fulfilling prophecy.

In order to apply the theory of Multiple Intelligences, it is considered necessary to examine the theory in detail. The theory has not been widely represented in literature in mathematics education and its relevance needs expansion. This is described in chapter three.

CHAPTER THREE

COGNITIVE AND AFFECTIVE ADVANTAGES OF A RECONCEPTUALISED MODEL OF INTELLIGENCE FOR MATHEMATICS EDUCATION

Chapter one has outlined the thesis problem as one of persistent low mathematical achievement and lowered student self-confidence for doing mathematics. Low achievers have shown poor comprehension of mathematics concepts, little engagement in class activities, a low class profile, low self-activation, and poor self-perceptions of ability. Many low achievers in mathematics have different values from the school's learning goals with respect to the significant purpose and functional use of school mathematics in their lives.

A range of mathematics reforms aimed at raising student achievement have been implemented driven by the need to provide all students with mathematical skills to allow them to be adaptable and useful members of society. Many of these reforms have addressed low mathematics achievement from the perspective of providing equitable access to learning opportunities while others have reflected NCTM's standards, or provided specific skills and behaviours (Fashola & Slavin, 1997). Reforms have produced substantial mathematics achievement gains in particular contextual programmes and gains for the general student population, yet many students do not achieve well in mathematics (US Department of Education, 2002).

As an explanation for reforms not meeting the needs of all, chapter two has examined the influence of schools' pedagogical beliefs in creating inequitable educational practices. It was proposed that the standard school representation of intelligence emphasises, practises, and strengthens logical-mathematical and verbal-linguistic competences. In turn, being good at manipulating numbers, memorising formulae, and solving mathematical word "puzzles" is valued and rewarded by the school, community, and many parents. Mathematics learning in the majority of classrooms continues to have a major emphasis on the three segment lesson (Romberg & Kaput, 1999), where lessons review previous work, new work is introduced along with some problem examples, and is followed up by prescribed exercises. The major tools are pencil and paper, and the dependent student skills are a competence in reading, writing and logical deduction. Achievement is measured through class tests in similar problems, resulting in such assessments being deficit-based sources of information for many students.

Chapter three examines how traditional conceptions of intelligence contribute to low achievement in mathematics and to the negative feelings some students develop about mathematics. Gardner's Multiple Intelligences theory (Gardner, 1983) is described as an over-arching model that situates traditional intelligence as a component facility within a spectrum of intelligences.

Multiple Intelligences theory is presented as a way of equitably providing for all students in mathematics learning. It offers implications for mathematics pedagogy that strike at the root causes of many students' cognitive and affective difficulties with mathematics — the lack of personal meaningfulness and a history of failure. Through a contrast between the traditional narrow concept of intelligence, and Gardner's *Multiple Intelligences* concept, the advantages of a school mathematics pedagogy driven by Multiple Intelligences theory are demonstrated.

This is followed by an outline of key learning programs that have used Multiple Intelligences theory, providing evidence for the value of student learning under this theoretical model.

3.1 Low achievement in schools: a cognitive perspective

The majority of mathematics educators have heard comments such as "why do we have to learn this stuff?", "it's too hard", "what's it mean?", "when are we ever going to use it?", and "what's it for?" when introducing topics in class (Trafton et al., 2001). While almost all students begin school with a positive view of mathematics and learn in ways that make sense, many leave uncertain about how to use mathematics for anything but the most basic of tasks (Battista, 1999). One of the major reasons students become frustrated with mathematics is its perceived lack of relevance to their lives (Steen and Forman, 1995 cited in Higgins, 1997) with distinct differences between students' views on the purposes of the mathematics curriculum and that of the educational institution (Frid, 1994). It appears that connections between school mathematics and students' lives are missing for many. Although some students approach their mathematics confidently, many others express confusion, anxiety and rejection when faced with mathematics problems. These students see little relevance for their learning mathematics beyond basic skills because the curriculum does not engage them in an intrinsic commitment, is often irrelevant, lacks imagination and fails to challenge them. While students might generally value education they may not be interested in the day-to-day routines of the school (Heargraves & Earl, 1994).

Many students are not cognitively engaged with mathematics in school, and express the belief that they are not capable of learning the concepts with low mathematical achievers in particular perceiving mathematics as of little use and making little sense (Bishop et al., 1995). Bewildered by abstract material they can not understand, some students become frustrated, anxious and fearful of mathematics, and may come to strongly dislike the subject and have a poor view of themselves as learners (Owens et al., 1998). Yet when students investigate situations that are personally relevant they have no difficulty becoming engaged and asking questions (McNair, 2000).

The difficulties of understanding mathematics may lie more with the school than with students in that an inability to learn appears to emerge mainly inside the formal learning processes. There is a definite distinction between practical mathematical methods and competence in the context of real situations, and the type of student performance in school (Lave, 1988). Students labelled as lacking ability, or lacking engagement in mathematics classes have readily acquired or advanced their knowledge across an array of competencies outside of school. Some can recall the complete lyrics to music or play instruments well, others are computer literate beyond their teachers, or can reduce a carburettor to components and re-assemble it faultlessly. Yet school is difficult.

This situation has not gone unnoticed. Considerable interest has arisen from evidence that unschooled persons solve everyday mathematics problems successfully using ways that are different from those learned in school (Hiebert & Carpenter, 1992). The role of context in developing mathematics understanding and confidence has been shown to be significant in making mathematics meaningful and in overcoming anxiety, using principles of Multiple Intelligences theory (Green, 2001). The value of context in facilitating mathematical understanding is optimised when problems are embedded in a larger array of meaningful practices (Roth, 1996). By comparing school learning to students' informal learning, it is evident that real contexts include social inputs, personal efforts and evaluations, and the values and implicit support of the surrounding cultural environment as well as cognitive ability.

The bewilderment of some children in mathematics classes is argued in this thesis to result from these limited forms in which mathematics concepts are presented. Making meaning, drawing on memory, and building mental frameworks for new knowledge is assisted by providing contexts that allow associations to what students already know (Muir, 2001). Whereas street mathematics is contextualised and everyday mathematics tasks are found in a natural, familiar setting, the tasks in which classroom problems are contained may carry few cognitive supports for a number of students (Hiebert & Carpenter, 1992). The lack of understanding by some students in school may be due to them regarding the school content as foreign and without context (Gardner, 1991). The continued traditional representation of mathematics concepts using formal, written tasks or pictorial representation can have the effect of isolating a number of children from making the best use of their abilities, or of their comprehending issues in the "outside" world. Gardner (2000a) emphasises the gulf between the real-world of meaningful learning opportunities and the classroom environment when he states that a person from the early years of the 20th century would readily recognize and be at home in many of our schools, but would find relating to the outside world of even a ten year-old bewildering. Uninformed, unattracted and unmotivated by mathematics presentation, many students are not connecting the curriculum content to their lives and are failing to learn.

It is this concern of "why are so many kids street smart and yet school dumb?" which has turned the attention of mathematics reform to the value of rich experiences, and the importance of personally constructed meaning. The release of the NCTM's "Principles and Standards for School Mathematics" (NCTM, 2000) emphasised the goal of rich, engaging mathematics learning. In Australia a mathematics curriculum called New Basics has been introduced to provide a "rich pedagogical soup" using the driving tenets of recognition of difference, connectedness, intellectual quality, and social support (Education Queensland, 2001).

A number of mathematics reforms have used connectedness in order to make conceptual understanding more meaningful, such as Cognitively Guided Instruction, and the Connected Mathematics Project (Fashola & Slavin, 1997). Often, these reforms have attempted to make up for aspects of students' lives that have resulted from inequitable circumstances. Chapter three proposes that although schools may not be able to control most of the negative external environmental factors of students' lives, they can know each student's strengths, draw links to their cultural supports and accommodate their differences. Knowing the variety of ways that students may best learn is an imperative of education requiring a change in school climate and pedagogy (Attinasi, 1994) and is a principle of mathematics education advocated by the US professional organisation, the NCTM (2000). The provision of equity-based opportunities has also been called for in the development of Australian *Standards* which recommend that educators should avoid interpretations of "ability" or "intelligence" based on culturally narrow interpretations of important knowledge (AEC, 1991) when devising learning programs.

Statements of Standards represent performance levels that are goals for students (NCTM, 2000). Under an Outcomes philosophy in mathematics reform, all students are expected to aim for and achieve these Standards. However, from an equity perspective there are student differences that challenge the accessibility and meaning of mathematics traditionally taught in school. Traditional mathematics learning appears to view mathematics as a natural ability possessed by only a few and which is tuned to their style of comprehension (Zevenbergen, 2002). Equity programs have made many positive changes to learning opportunities from the perspective of cultural differences and the economically disadvantaged, but notions of intelligence do not appear to have been widely considered as a new opportunity to raise achievement in mathematics.

Talent in mathematical reasoning is highly valued and students who reason well mathematically and verbally are frequently sought out using academic aptitude measures that fundamentally are sub-sets of standard intelligence tests (Robertson et al., 1996). To extend equity requirements in mathematics suggests altering how intelligence is viewed by the mathematics education culture and by students. The central challenge for the design of mathematical learning environments is to make visible that which is normally visible only to the mathematical cognoscenti (Noss et al., 1997). Under the traditional perspective, mathematics is seen as an independent set of facts, accessible to the few who could master it (Scott, 2001). Consequently many children may be failing to understand concepts as well as they might because the essential interplay between their own constructions and the mathematics embedded within the tasks may be absent.

The question remains as to how conceptions of intelligence are linked to traditional mathematics education, and therefore to the problems of low achievement and low self-efficacy for mathematics. Understanding that link will allow the value of Multiple Intelligences theory to be applied to a new mathematics pedagogy. The next section examines how conceptions of intelligence have affected students' achievement in mathematics.

3.2 The influences of different conceptions of intelligence on mathematics education

To understand the impact of different conceptions of intelligence on mathematics education, it is first necessary to review the major approaches to the study of intelligence. A definition of intelligence that contributes to understandings of individual differences in achievement has been proposed by Neisser et al., (1996).

> Individuals differ from one another in their ability to understand complex ideas, to adapt effectively to the environment, to learn from experience, to engage in various forms of reasoning, to overcome obstacles by taking thought. Although these individual differences can be substantial, they are never entirely consistent: A given person's intellectual performance will vary on different occasions, in different domains, as judged by different criteria. Concepts of 'intelligence' are attempts to clarify and organise this complex set of phenomena.

The major approaches to the study of intelligence have focused on the effective use of particular knowledge, the flexibility of thinking, creativity, insight, efficiency of memory, and capacity for logical thought. In particular, intelligence has focussed on successful performances in abstracted fields of learning such as mathematics and language. Assessing intelligence has emphasised defining and quantifying particular skills, linking the performance outcomes of testing to age-based cognitive development. A generalised intelligence has therefore been linked to academic performance.

As well, a number of theories have regarded intelligence as multi-faceted with intelligent behaviour suggesting more than having a good memory or excelling at school. Intellectual functioning is also viewed as successful functioning in the social and physical environment, with a variety of qualities considered in the spectrum of skills used or necessary for that success. Early theorists such as Thurstone and Guilford used models of mental abilities such as reasoning, memory, and judgement. Modern views of intelligence have incorporated abilities to adapt to changing circumstances, and to adaptively learn and plan for future changes. This is found in Sternbergs' Triarchic Model (Sternberg, 1985) and in Gardner's Multiple Intelligences model (Gardner, 1983). As well, the importance of social environments for the cognitive development of individuals is contained in Piagetian and Vygotskian theory (McInerny & McInerny, 1998). This multifaceted view of intelligence suggests a change in mathematics classroom learning from the dependence on single teaching tasks, from the classroom contexts of learning, and from the emphasis on assessment through written tests.

Yet there exists strong empirical validation for how mathematics is traditionally taught. The characteristics of mainstream mathematics classroom teaching and learning have drawn on Piaget's model of students' innate cognitive growth and the nature of intelligence (Case, 1993; Inhelder & Piaget, 1958; Piaget & Inhelder 1966; Pulaski, 1971) implying substantial benefits to learning from this model. Psychological studies on thinking have frequently dealt with the mental abilities thought to be associated with doing mathematics (Kilpatrick, 1992), and verbal-linguistic ability and logical-mathematical thinking have been given a premium status in mathematics education (Pajkos & Klein-Collins, 2001). These abilities operate as tools of the intelligence, viewed in Piagetian terms as logical-mathematical in nature (Inhelder & Piaget, 1958). The logical-mathematical intelligence uses networks of rules and strategies (Romberg, 1992) to shape information cues, develop patterns, fill in missing details, invent solutions, and selectively organise new information into systems that make sense on a personal level (Phillips, 1969). The nature of abstracted reasoning commonly developed in secondary school mathematics parallels this form of thinking equated with intelligence, represented through symbolic logic "as a calculus or an algebra" (Piaget & Inhelder, 1958, p. 269), resulting in a convergence between Piagetian intelligence and traditional mathematics instruction.

Under a Piagetian epistemology, new experiences change conceptual understanding (Von Glasersfeld, 1991) but growth in mathematics comprehension depends on how this new information is structured **(**Hiebert & Carpenter, 1992). Within the framework of the traditional mathematics classroom students with strong logical-mathematical intelligence may more readily assimilate new learning experiences into existing mental structures or schemata because of a resonance between their mental constructions and those mathematics tasks involving memory, formulaic knowledge, algorithmic procedural skills, and a rapidity of working such problems.

Those who are good at these aspects of mathematics are regularly accounted by the school culture to be the most intelligent, and by students as "smart". It is this narrow perspective that is suggested to negatively influence mathematics performance levels for a number of children. The literature review allows that many schools continue to teach mathematics in traditional ways, using tasks and assessments that emphasise logical reasoning and rely on symbolism and metaphor for contexts, implicitly filtering out *who* is most successful in mathematics at school.

However Piaget's theory of intellectual development does not have a necessary congruence with the nature of mathematics education. Although the logically ordered nature of Piagetian tasks typically used in mathematics learning has been offered as useful in mathematics instruction, many children have learnt mathematics concepts and skills yet have failed Piagetian tasks (Weaver, 1985). That is, not possessing high competence in Piaget's logical-mathematical cognitive processing has not precluded learning mathematics concepts. And nor should it. Many approaches to learning mathematics are available, and personal differences suggest that a variety of activities are necessary to help all students, rather than fitting them to the traditional methods (Adams, 2000). Yet merely being familiar with contexts is not sufficient to incorporate the variety of ways that students may interpret and integrate their mathematics (Boaler, 1993). Mathematics understanding needs an appropriate schema into which new information can be assimilated (Skemp, 1987) and the diversity of students' beliefs, personal experiences and novel learning situations means mathematics teachers cannot afford to ignore the perspective of personal relevance (McNair, 2000). The schema by which each student structures knowledge to make sense of it may be very different from the organisation and structure used by the mathematics teacher in presenting concepts (Ernest, 1989). This restriction suggests that an intentional consideration of multiple forms of representations of mathematics is needed to match the intellectual composition of different students.

This multiplicity offers resonant opportunities that can be provided if personalised prior knowledge that has formed in and been taken from the student's own cultural circumstances is structured by the strongest intelligences to form more, potent and robust linkages. Making meaning is dependent upon the experiences in students' social environment of peers and adults as well as the physical environment, suggesting tasks that allow a multiplicity of forms are those that reflect real contexts, use projects and themes extending over time, encourage active and continued communication, incorporate links to memories of prior experiences, and incorporate choice (Goodnough, 2001; Muir, 2001; Trepanier-Street, 2000). Schools can positively improve school-based achievement if the learning environment interacts resonantly with students' ways of thinking, and provides a similar socio-emotional environment that nurtured their cognitive growth outside of school (Gardner, 1991) because knowledge learned under such contexts is richer, and better understood than would be acquired solely as traditional classroom learning tasks. Well-structured and well-understood knowledge is more readily retrieved when faced with new but related learning (Hiebert & Carpenter, 1992), and is more likely to be generative of new understanding. Almost everyone can develop competence in some field with early intervention and consistent training regardless of initial differences if that capability is culturally valued and good affective factors exist (Gardner, 1983).

A narrow view of intelligence doesn't only limit task-based opportunities. When students do not appear to meet the educational expectations of school cultures their achievement performance may be interpreted in terms of intelligence and ability factors (Zevenbergen, 1997), resulting in such practices as placement in homogeneous, lower-level mathematics classes and remediation groups that disadvantage students further. Moreover, the emotional consequences of self-perceptions of intelligence caused through the responses of the school system, and from failure to achieve have a significant effect on motivation and engagement. The next section outlines the emotional implications of failure associated with educational judgements derived from traditional notions of intelligence.

3.3 Affective advantages of a reconceptualised model of intelligence

A number of factors such as attitudes towards mathematics, confidence, causal attributions, anxiety, and motivation have been shown as components of affective influences on students (McLeod, 1992). The importance of students' beliefs about intelligence does not appear widely in mathematics education research yet they are an important and powerful predictor of academic outcomes (Stipek & Gralinski, 1996). Basic psychological constructs of general intelligence and cognitive ability need to be reviewed to include the influence of multi-differentiated cognitive abilities on educational outcomes such as school achievement (McGrew et al., 1997). Low-achievers who believe their ability or intelligence is fixed can be negatively affected by further failure (Dweck & Leggett, 1988) and these students sometimes need to be shown they can succeed and can benefit from diverse teaching strategies in mathematics that influence them cognitively and affectively (Higbee & Thomas, 1999). It may be possible to improve self-perceptions and mathematics performance in low-achievers in mathematics if they can be influenced with respect to negative beliefs about ability, intelligence and mathematics success.

Classrooms comprise a significant environment for students to form perceptions of their own abilities in mathematics. Schools are part of a society that evaluates and defines intellectual ability with tests, and acknowledges and rewards high performance, creating a risk for the self-concepts of many students who may be effortful without success (Ferguson & Dorman, 2002). Intelligence is strongly correlated with a verbal-linguistic and logical-mathematical ability, exemplified by the symbolic reasoning found in items used in measures of intelligence (e.g. Efklides, Papadaki, Papantoniou & Kiosseoglou, 1997). Specialised and enriched programs for the mathematically gifted also appear to entrench the idea that success requires a logical-mathematical "mind" while low achievers are frequently given a diminished and unchallenging mathematics curriculum that fails to encourage its target population, and whose perceived inadequacy in mathematics may be keenly felt. Low-achieving students form quite stable self-perceptions of what it takes to learn mathematics and by the middle grades many students start to see mathematics as a special subject where smart students succeed and other students will have difficulty because mathematics is something to be naturally good at or not, no matter how hard you try (Middleton & Spanias, 1999). Yet this pessimism in low-achievers is changeable under the notion of malleability or "plasticity" of intelligence. While students whose view of intelligence as a fixed capacity in logical-mathematical competence are more likely to think of themselves as being unable to change their chances of doing well in mathematics, those who view success as alterable by effort are less concerned with ability (Stipek & Gralinski, 1996). Shifting logical-mathematical ability from its privileged position to that of a component of a set of abilities through which mathematics can be learned may be useful in overcoming low mathematics achievement.

While mathematics education and Multiple Intelligences theory have been widely described in the research literature as separate fields, there appear to be few research-based descriptions of Multiple Intelligences theory and low mathematics achievement in the secondary school mathematics context. Therefore in order to demonstrate the extent to which Multiple Intelligences theory has reconceptualised intelligence in ways that may prove beneficial to mathematics education, an explanation of the theory and its principles is provided in the next section.

3.4 The theory of Multiple Intelligences

Under psychometric theories Piaget's model of intelligence has been considered as a uni-dimensional construct of relatively unchanging form (Eisner, 1994). Individuals were viewed as possessing degrees of intelligence, as measured by IQ or some test scores, usually made in school contexts, about school performance. Developments in psychological theories have caused the advancement of other conceptions of intelligence. Modern theories of intelligence have allowed for a malleable, dynamic and multi-dimensional view of intellectual possession. Models of intelligence that combine cognitive processing interacting with contexts have allowed for these multiple forms of intelligence. For example, Sternberg (1994) has presented a Triarchic theory of intelligence as that which encompasses attributes of practical problem solving, verbal ability, and social competence. Although the definition has expanded the Piagetian view, it continues to place an emphasis on logical competence and verbal facility.

Gardner's theory removes the cultural bias and offers the potential of other, latent intelligences that students bring to mathematics classrooms to be applied. The Theory of Multiple Intelligences (Gardner, 1983) has proposed the possession of multiple intelligences as a universal human characteristic. This model of human intelligence postulates that people possess a number of biologically based intellectual potentials, separately derived and operating with independent mechanisms. These intelligences are declared as separately derived cognitive capacities, distinct, multi-faceted and discernible. They are differentially manifested as culturally evoked abilities, brought to the fore by societal forces acting to select out desirable, useful or valued traits.

To date, Gardner has referred to the existence of

- linguistic intelligence
- logical-mathematical intelligence
- bodily-kinesthetic intelligence
- musical intelligence
- spatial intelligence
- interpersonal intelligence
- intrapersonal intelligence
- naturalistic intelligence

Conditional criteria on this construction of intelligence are that is to be viewed not as interpreted scores in standardised assessments but as measures of performance in fashioning products or solving problems in ways relevant to context and culture (Gardner, 1983). For example, a *problem* might be to finish a story ending; a *product* could be a musical composition or a scale model of a town. Additional to that, based on biological evidence, an intelligence must also have a core set of operations triggered by information internally or externally provided and be able to be framed in symbolic notation. Eight intelligences have fitted these criteria (Gardner, 1996).

A decade after the primary definition of intelligence, with a view to clarification intelligence was further defined as a biological and psychological potential that is capable of being realisable as a consequence of an individual's experiences, cultural context and motivational factors (Gardner, 1995). Therefore possessing intelligences has meant possessing intellectual potentials that may be manifested under appropriate conditions in different combinations and different strengths (Blythe & Gardner, 1990).

Individuals can demonstrate varied capacity in these intelligences over time and may be more amenable to processing information through a preferred mode at different stages of development than their peers. Under the theory the cultural environment influences the development of intellectual ability. Across cultures and within any evolving culture those capacities (or intelligences) that are most valued have their operational skills honed by appropriate forms of education.

The theory of Multiple Intelligences offers that intelligences can be influenced, strengthened and developed by support and encouragement in schools therefore it is important to examine the social and cultural influences on mathematics education.

3.5 The influence of cultural setting

The emphasis of Piagetian notions about intelligence underpinning school practices raises the question of "whose interests are being served?" Powerful cultural forces appear to be acting through schooling to select valued abilities (Eisner, 1985) in a process of social Darwinism (Howley, Howley, & Pendarvis, 1995).

There is a relationship between the value that a culture places on some academic discipline, the formation of self-concepts with respect to that discipline, and achievement in that discipline (Bempechat & Elliott, 2002; Gordon & Yowell, 1994). Before formal schooling, students' mathematics concepts begin to develop through a variety of channels resulting from diverse social interactions and environmental observations and most children enter school eager to learn mathematics (Kilpatrick et al, 2001). In the stage of early childhood the acquisition of mathematical competence can operate through diverse capacities or intelligences in many forms such as dance, language, drawing, music, play, or games. Students learn to speak, draw, count, and socialise through observation, interaction, and imitation and are encouraged by the freedom to do so (Butterworth & Cicero, 2001). They copy adults and adult practices, and gain skills from contextual learning (Stanley & Spafford, 2002).

In pre-industrialised Western societies this mode of learning may have continued over an extended period of time in forms such as apprenticeships where learners work alongside adults who guide, advise and assess in context (Gardner, 1990; Gardner, Kornhaber, & Wake, 1996; Wisconsin Education Association Council, 1996). However, when these societies became more complex the nature of learning, and of mathematics became more formal, organised and scholarly in order to meet its role in maintaining the economic and social structure of a ruling class (D'Ambrosio, 1985). This complexity in information requirements from pre-industrial to an industrial society has implications for the modern but traditional school. Technological societies advanced more rapidly than their craft or agrarian predecessors and instead of knowledge and skills being acquired and transmitted over generations, information had to be reduced to codified forms and to be transmissible over much shorter time frames because the needs were more immediate. The Capitalist philosophy embedded in the rising Western system promoted a search for efficiency and standardisation (Raju, 1999). The most efficient methods were "schools", where the same information could be presented to a large number of individuals simultaneously. A standard measure of the mental ability of a student to be schooled was developed by Binet in the form of increasingly complex verbal and logical tasks requiring a reasoning or sense of judgement (Kilpatrick, 1992), with the derivative Intelligence Quotient (IQ) continuing to be valued in institutionalised market economies (Sternberg, Grigorenko, & Bundy, 2001). Standardised tests continue to influence the way educators regard intelligence (Vialle, 1994) perhaps because they are good predictors of IQ scores, academic achievement, and school grades. The qualities that suit achievement performance in standardised tests appear culturally linked in Western schools to beliefs about intelligence and the ability to learn mathematics.

As a result, schooling in Western society has decontextualised learning, and has reduced gaining knowledge from real experiences to that of notational representation using linguistic and logical forms (Gardner et al., 1996). The hegemony of the logical-mathematical intelligence in traditional mathematics education has not been isolated from social forces. Talent in the mathematical and science learning areas is frequently determined through the use of standardised measures of cognitive ability and logical reasoning, exemplified by the Johns Hopkins University Talent Search that identifies students as exceptionally talented in mathematics and verbal reasoning through high scores on standardised tests (Center for Talented Youth, 2002). It is clear that beliefs about the ability to learn mathematics continue to be linked to logical-mathematical intelligence. As Zevenbergen (2002) suggests, the dominant ideology in mathematics education offers that mathematics is hierarchical in complexity, with students likely to be positioned within schools on the basis of their ability to deal with that complexity. A mathematics classroom that emphasises learning through logical-mathematical and verbal-linguistic intelligences acts to selectively enhance and resonate with those students who are strong in these intelligences, resulting in inequitable opportunities that mathematics advancement brings such as access to higher-level courses, better teachers, and positive affect.

The opposite side of the coin is also true in that schools that concentrate on representing mathematics through texts and problem-tasks can be teaching many children through their weaknesses (Hearne & Stone, 1995), ignoring the opportunities for mathematical understanding through personally powerful constructions. This is because culture plays a critical role in structuring learning outcomes (Gardner, 1993; Gardner, Krechevsky, Sternberg, & Okagaki, 1994) and a misalignment may exist between mathematics instruction and those students whose prior mathematics acquisitions were linguistically, experientially or socio-culturally different from the practices and expectations of the mathematics classroom (Stanley & Spafford, 2002; Zevenbergen, 1998). These mismatches can reduce learning opportunities for some students. More appropriate and useful tasks than are offered from a uniform curriculum may be generated by accepting that mathematics is a cultural activity (Wiest, 2002). The increasingly multicultural nature of society means that teachers face great difficulties in providing effective learning opportunities (Green, 1999) suggesting a need for adaptive and accommodating learning (Curriculum Council, 1998). This need can be provided through the principles of Multiple Intelligences, where the nature of intelligence is offered to be dynamic, involving individual competence and the values and opportunities afforded by society (Kornhaber et al., 1990). Adopting this view of intelligence legitimises a variety of entries into lessons that have individual purpose and carry tangible relationships with different backgrounds.

The mechanisms of how Multiple Intelligences learning may act to alter the circumstances of cognitive and affective influences on low mathematics achievement are discussed in the next section.

3.6 The contribution of Multiple Intelligences theory to teaching and learning mathematics

How can a reconceptualisation of intelligence help low achievers in mathematics? One significant conclusion from Multiple Intelligences theory is that intelligences are potentials that can be supported and strengthened through experiences and training. Research has shown that intelligence is modifiable in a positive reciprocal relationship with educational achievement, resulting from appropriate educational challenges and successful experiences at school (Sternberg et al., 2001). Using different intelligences as pathways to increased mathematics understanding may strengthen students' logical-mathematical intelligence and improve the frequency of successful outcomes.

3.6.1 Principles of Multiple Intelligences learning

Multiple Intelligences theory is a theory of the psychological and biological characteristics of cognitive development, rather than a theory of education. It has been interpreted on philosophical grounds as valuable in arguing for equitable practices in education, yet apart from adhering to the principles there is no prescriptive way of implementing this form of learning. Whether or not Multiple Intelligences learning will "work" depends on the situation and purpose to which the theory is put. If the purpose is to improve grades, it may not prove to be any more effective than other theories in improving test scores but if the purpose is to broaden understanding for as many students as possible then it offers much in opening up the possibility for genuine understanding (Latham, 1997).

A Multiple Intelligences curriculum can broaden opportunities for successful learning by utilising students' different intellectual strengths, backgrounds and interests (Simmons, 2001). There are numerous approaches to multiple intelligences but the effectiveness of the theory needs the support of appropriate implementation in the form of specific practices linked to educational goals (Gardner, 1997). It may be an instructional process that provides multiple ways to lead into the lesson content, a way to develop different talents early in life, to integrate curriculum, or to develop self-learning skills (Campbell, 1997). Classrooms can use small "apprenticeship" groups being taught a particular subject area by a community expert, individual work, themes and projects. None of these ways is more correct than any other, but can be implemented on the basis of what is most appropriate for students. Whatever methods are used should consider the variety of strengths, experiences and perspectives of individual students (Adams, 2000).

Chapter two has shown that the mathematics student group most in need of support in their learning were the low achievers. These children have possessed such diverse characteristics that unless a suitable variety of engagement practices is developed, programs which have aimed for remediation of difficulties may not reach these target students. Multiple Intelligences learning deliberately seeks to include the strengths of each child in planning.

There are three major ways in which the theory can be applied in schools: through multiple representations of concepts; the incorporation and valuing of student cultural backgrounds; and the personalising of the classroom environment (Gardner, 1995).

First, enacting Multiple Intelligences theory within classrooms essentially means providing for different intelligences through multiple representations in learning. This is done by approaching concepts in different ways, through differing senses and with differing media. There are three desirable outcomes of this pluralistic representation:

- that more children will be reached
- that students gain a perception of themselves as being able to represent knowledge in more than the valued ways of the dominant culture, and
- that assessment opportunities are broadened such that student understanding and misunderstandings can be assessed under emotionally comfortable contexts

Second, the theory requires that social, community or cultural values are employed to reinforce the benefits of those particular skills used to understand mathematical concepts. The lack of alternative cultural representations that evoke a variety of intelligences schemata can account for the fact that many capable students are not succeeding in mathematics. If the internal networks of school mathematics can be connected to non-school mathematics, then a transfer of understanding may occur such that the mathematical skills and knowledge in one setting could be learned by strategies obtained in other settings (Hiebert & Carpenter, 1992). Cultural difference creates a difficulty for students to get a sense of the work and internalise concepts if class discourse ignores socially contextualised instruction (Khisty, 1995). Schools appear to have mostly failed to identify and encourage the use of other intelligences, negating learning opportunities for those minority culture, low-socio-economic and non-mainstream students. Yet to do so offers a way to enhance these students' positive self-concepts and general intellectual abilities (Vialle, 1994). These are frequently the mathematical low-achievers so by encouraging the broad use of skills and capacities that are valued in their communities, specific intelligences that have usually been not considered in the schools may mesh with academic concepts within these roles (Gardner, 1995).

Third, applying Multiple Intelligences theory requires that the classroom environment is personalised. How to best intercede with mathematics learning programs when faced with a diversity in student needs is offered under Multiple Intelligences learning to be through a personalised education, using a curriculum that emphasises personal meaning (Eisner, 1985). This requires that differences among students are taken seriously and utilised in social contexts; that students gradually assume responsibility for their own learning, and that meaningful representation is given in ways that allow each student the maximum opportunity to master those materials and to show others and themselves what they have learned and understood (Gardner, 1995).

3.6.2 Applications of the plurality of intelligences to mathematics

There are many opportunities for Multiple Intelligences theory in schools (Campbell, 1992; Campbell, 1997; Emig, 1997; Leland & Harste, 1994) and the theory can be at work in all mathematics tasks (Fogarty, 1999) and diversities of culture (Butterworth & Cicero, 2001) such that the goals of mathematics Standards (NCTM, 2000) are achievable for all students. For example Trepanier-Street's (2000) primary school Garden Project uses a combination of intelligences in planning the rows (logical-mathematical), in arranging borders (visual-spatial), in estimating time for picking (naturalistic), and in communicating mathematical information (interpersonal intelligence). Primary school students have been introduced to probability and statistics using hoop games associated with travelling carnivals, relating the concept of chance to their experiences through visual, interpersonal and kinesthetic paths (Uslick & Barr, 2001), and ethnic diversity in games has been used to understand mathematics and demonstrate its relevance across cultures (Adeeb & Bosnick, 2000).

While methods using real tasks, concrete materials, and "manipulatives" have not been common in secondary mathematics learning (Howard, Perry, & Tracey, 1997) there are many opportunities in middle and secondary schools to motivate a range of students and connect various mathematics topics in solving problems. Even complex topics such as calculus are rarely explained adequately with a single notation system (Kaput, 1992), and opportunities are available to broaden the representation of such sophisticated branches of mathematics, as shown by Jones and Jackson (2001) who linked the visual-spatial and kinesthetic experiences of football with the logical-mathematical requirements of algebra to solve calculus problems with graphics calculators. In doing so, a step-wise calculation is replaced with a rich experience that offers broader motivation, has meaning for more students, and allows a number of unique approaches to solving the problem.

Multiple Intelligences is a theory and requires its principles to be applied appropriately. The use of Multiple Intelligences in mathematics is strongly tied to contexts but if students do not know much about the particular contexts in which mathematics tasks are set or described, then it is unlikely that their intelligences will be able to construct meaningful representations or linkages across knowledge networks (Hiebert & Carpenter, 1992). Although some intelligences are more readily applicable to strengthening mathematical understanding than others, it is not necessary to include all intelligences in every concept taught (Gardner, 1993; Hoerr, 1996), but it is necessary to provide a multitude of learning opportunities so as to provide choices (Adams, 2000), with choice being one of the key teaching strategies that attract students and meet their different learning needs (Muir, 2001). The NCTM's process Standards of problem-solving, reasoning, communication, connectivity, and representation (NCTM, 2000) allow for much overlap and integration reflecting the fact that mathematics is an interconnected discipline. This allows teachers to significantly vary the contexts of tasks so that those factors of socio-economics, cultural diversity and intellectual emphasis no longer have to restrict the field of representations of concepts. For example, Wilson and Chauvot (2000) have used history to highlight problem-solving, making connections, and to link mathematics to society using music, astronomy, and exotic cultures. This integration allows mathematics to be seen as connected to other subjects in real ways, and the multiple entry points offer opportunities for all student backgrounds.

Specific researched examples aside, mathematics education goals can be incorporated into classroom activities designed with the various intelligences in mind. One of the most significant changes to the perception of mathematics and to mathematics learning is that it is socially constructed and part of culture (Ernest, 2000), as opposed to the competitive and isolated role portrayed in traditional deliveries. Communicating mathematically allows the diversity of conceptualisation to be available to students of differing strengths in mathematics. Students need these opportunities to discuss their representation of concepts, as much as they need the concepts differently presented to them in order to make judgements on the accuracy of their understanding. The need and the value of student discourse for understanding has long been recognised in learning research (eg Piaget, 1958) and its importance has re-emerged in mathematics through communicative processes (NCTM, 1989). The use of group discussions, re-written mathematical descriptions of task purposes and situations, and the encouragement of students to explain their working, their successes and their failures can utilise *verbal-linguistic* strengths coupled with *interpersonal intelligence*.

The use of journals in which students may describe their attitudes, reactions and procedures in mathematics classes encourages reflection on their work and themselves as mathematical thinkers (Pugalee, 2001). Students can ask of themselves "did they check with peers for understanding and new perspectives", "did they practise doing mathematics through their personal strengths", "did they check that all members of their group could explain the tasks", "were they effective and responsible in their participation". This allows a form of metacognition, which can be thought of as part of the *intrapersonal intelligence*. Mathematics reforms that favour communication can develop these metacognitive skills that allow students to self-monitor in the face of problems going wrong (Goos, 1997), potentially reducing the incidence of failure. Group work may strengthen both individual and collaborative metacognitive processes (the intrapersonal intelligence), and through discussion and critical appraisal of other thinking, utilise and strengthen the interpersonal intelligence that may build better behavioural patterns and social acceptance for low-achieving students. Sensitive and appropriate use of journals may form a useful indicator of this growth in personal intelligences, allowing educators to gain insights into the emotions and attitudes of students (Glasgow, 1999).

The incorporation of certain intelligences may necessarily be indirect, particularly at secondary school level. For example, while *musical intelligence* can be utilised directly in some mathematical tasks such as sequences and fractions (reflecting the underlying scales of music) it may also be incorporated as a setting for task descriptions such as dance steps in geometry, or as a motivator — perhaps as a source of frequency data. The uses of other intelligences to model the *processes* of inquiry that are so important to mathematics reform has been applied to an alternative method of learning dance movements through verbal, kinaesthetic, and written representations paralleling mathematical solutions without the need for rote memorisation (Westreich, 2002).

The engagement of students through diversified tasks is likely to be higher than with tasks restricted to language and symbolism. Students are interested in games, in nature, in music, and they love to socialise. These personal and environmental supports offer ways for different intelligences to structure their conceptual understanding. *Naturalistic intelligence* can be incorporated into as many lessons on diverse subjects (such as topology, frequency data, and measurement) as teachers can imaginatively develop. Where aspects of the physical environment cannot be drawn on (perhaps in inner urban schools) or where culturally esteemed components of society are absent or distant (as in some rural environments) technology can enhance opportunities for individual student strengths to be brought into classrooms (Dickinson, 1998). The complexity and tedium of hand-calculations in senior secondary school mathematics has been shown to be overcome with the use of technology (Heid & Edwards, 2001; Murphy, 1996), which – apart from developing and enhancing *logical-mathematical intelligence* – allows low achievers in mathematics to become engaged with class-work using tools such as computers and calculators, causes them to develop persistence and coping skills, and to bring personal dexterities and competencies into the classroom. In particular, positive results from technology are more likely to result when usage reinforces constructivist principles of group-work and real-world contexts (Shedds & Behrman, 2000), adding emphasis to the relevance of Multiple Intelligences learning.

Multiple Intelligences learning offers to open up mathematics to more students, to bring to mind those occasions where mathematics is and could be used. Too often students feel that the mathematics has nothing to do with them (Murphy, 1999). The obscure vocabulary, rote memory work, computational procedures, and isolation of instruction mean that forgetting is likely, and tests become attempts to recollect vague methods and rules (Cornell, 1999). Assessment practices under traditional mathematics education have mainly used written, symbolic tasks in decontextualised circumstances. The following section outlines how Multiple Intelligences theory can contribute to raising student achievement and self-beliefs in mathematics by altering instructional and assessment practices.

3.7 Assessment under Multiple Intelligences theory

Changes within mathematics education are concerned with giving students the skills and knowledge to communicate mathematically, to solve problems in their lives, to use mathematics confidently, and to prepare them for life in a changing work environment (Pandey, 1990). Reforms in mathematics portray it as a human activity that draws on interests, varied capabilities, visual and kinesthetic senses, and uses informal knowledge to make meaning out of experiences (Romberg & Kaput, 1999). Framed by this view of mathematics, traditional assessment's focus on relative performance is not able to adequately inform on the acquisition of these skills. The realisation of new educational outcomes suggests a need to move away from pencil-and-paper testing to examining performances that involve demonstrations of thinking, perseverance, communication and productivity (Brosnan & Hartog, 1993). Through this change assessment can involve more students in real-life situations, in complex and challenging tasks, and can allow different cultural factors to support student reasoning (Sarouphim, 1999). Where traditional methods of assessment isolated many students from the meaning and function behind mathematics problems, new opportunities allow students to learn with guidance, to judge their own abilities, and to experience failure without fear of failure (Schafer & Romberg, 1999).

The National Statement on Mathematics for Australian Schools states

> The fairness of testing only those aspects of mathematics which can readily be assessed in traditional test questions can easily be challenged. The strengths of some students will be favoured by short-answer questions which rely on quickness of mind and speed, the strengths of others by extended-response questions which rely on reflection and persistence. Students may not achieve equally well on all aspects of the mathematics curriculum. Some may do particularly well with reasoning tasks, while others have exceptionally good memories. Some will develop better spatial skills, others a better understanding of number.

> Consequently, inferring achievement in mathematics generally from a non-representative sampling of the curriculum outcomes or through a narrow sampling of methods of assessment may be unfair to many students (AEC, 1990, p. 22).

The consideration of equity and fairness places conditions on assessment. Equitable opportunities lie in programs that recognise and support diversity and not in the commonality of treatments (Green, 1999). Assessment should be comprehensive, based on multiple kinds and sources of evidence, demonstrably fair to all students and not discriminate on grounds that are irrelevant to the achievement of the outcome (Curriculum Council, 1998). Fairness recognises that some students form visual images better, some are logical thinkers, some like manipulatives or physical models, others sense the meaning of a problem more ably in its written form, whilst others may require discussion and reflection for understanding and these differences should not diminish student opportunities to demonstrate understanding. The nature of equitable instruction is implicitly linked to the form of assessment, including the language, the tasks and the contexts. Accordingly, assessment should use the same types of *referents* that were experienced in learning (Hiebert & Carpenter, 1992).

Multiple Intelligences theory offers to meet these equity conditions embedded in mathematics assessment reform. The diversity of the student population means that to be successful in educating all, there needs to be a personalised awareness of students' intelligences (Snyder, 2000). Assessment has been defined as "obtaining of information about the skills and potentials of individuals, with the dual goals of providing useful feedback to the individuals and useful data to the surrounding community" (Gardner, 1993, p. 174). Multiple Intelligences theory offers to inform on student progress towards mathematics outcomes and extends this opportunity to show mathematical power to students with strong intelligences other than verbal-linguistic and logical-mathematical. This is assisted when the mathematics skills being assessed are placed within contexts that are natural backgrounds for the role of such skills. For example, if spatial ability is to be assessed in mathematics, physical education could be a natural background in which to develop and assess the skill at the concrete level with orientation tasks, through to an abstract level of understanding operating with the visual-spatial intelligence needed for mental constructions in geometry (Nilges & Usnick, 2000). For any outcome, it is possible to develop tasks that draw on a variety of intelligences, constructing a richer sense of the mathematics than if restricted to linguistic and symbolic representations. Students may learn about mathematical series by designing a pattern for a belt, building a brickwork pattern, or generating a number sequence on a graphics calculator. In turn, assessment of understanding may consist of variations within the tasks, or of transferred understanding between representations. In each case, learning advantages are created as students work towards the same conceptual outcome, discussing and comparing their models, with each representation adding to the goal of understanding.

Three conditions of assessment are fundamental to Multiple Intelligences theory: assessment should extend beyond the linguistic, logical-mathematical, and spatial abilities; it should be intelligence fair in that a variety of abilities can be utilised by students to show they understand concepts and procedures; and assessments should be based in the context of learning, or at least based on cultural practices and standards (Kornhaber, 1997). Through these practices, Multiple Intelligences assessment overcomes the bias of traditional assessment and supports the recommendations for good educational practice contained in mathematics reform statements (NCTM, 1989, 1998).

The aim of the next section is to show that the theory has had demonstrable success in offering cognitive and affective support to students.

3.8 Evaluation of Multiple Intelligences programs in education

Before proceeding to apply Multiple Intelligences instruction to mathematics education in Australian schools, it is important to consider the evidence of its implementation elsewhere. Four broad programs have adopted a Multiple Intelligences approach (Gardner, 1993) in their curricula:

a) **Project Spectrum** explored assessment which was intelligence-fair in order to see if individual strengths could be exhibited with preschoolers (Gardner, 1991). The children were immersed in diverse environments and exposed to a rich source of engaging materials. Across the available domains, measures were made of skills and techniques, as well as degrees of engagement.

An outcome of this study was that diverse areas of strength in children can be identified and represent significant opportunities for low achieving children to acquire basic skills. If a wide range of learning opportunities is available, children can demonstrate a variety of skills and competences. Another important outcome was that the attitude and behaviour of at-risk children improved if they could work in their areas of strength (Chen, 1993). However, the literature review was unable to determine if findings may be applied to Middle School mathematics students.

b) **Arts PROPEL** looked at middle school and secondary school students' use of portfolios to understand and learn from domain projects, with assessment operating over much greater time periods than standard measures would allow (Gardner, 1991). This project allowed self-reflection (considered significant for genuine understanding), contextual assessment and the explication and judgement of experts as valued sources of culturally relevant knowledge in order to reinforce student understanding during instruction.

Descriptions of the outcomes of this study have been of limited availability through traditional academic channels. Some major sources of findings appear to be offered as commercial instructional packages based on outcomes.

c) **The Key School** (Indianapolis) arose at the instigation of teachers interested in operating a school under the tenets of Multiple Intelligences theory (Gardner, 1991). It operates with the principle that a diverse curriculum appeals to many intelligences, has theme-centred learning, uses apprenticeship-like "pods" of students and has strong ties to the community. Importantly in Gardner's opinion the school uses projects over extended time periods to investigate thematic factors (Blythe & Gardner, 1990; Gardner, 1993). Student projects are valued highly as they allow exploration in depth, reveal individual profiles more accurately than tests, indicate mastery, demonstrate quality work and provide an opportunity for self-reflection.

One facet of the project has been to develop an environment of discovery through non-directed tasks where cognitive skills (eg visualisation, problem-solving and plan formulation), supportive emotional states (eg self-confidence), and appropriate behaviours (engagement and expression) could be improved. It has been reported that opportunities through task diversity to engage in activities of choice can generate emotional and behavioural consequences of concentration, intrinsic motivation, challenge and perceived competence (Whalen & Csikszentmihalyi, 1991). However, the validity of transferring these qualities into the wider school arena, and over a variety of school-aged children was not known at the time of this report. The literature review did not provide traditional sources containing further outcome descriptions of this project.

d) **The Practical Intelligence For Schools (PIFS)** project involves students gaining competence in work skills, resource construction, self-help and social functioning in school and therefore engages a range of intellectual modes of learning (Gardner, 1993; Gardner et al., 1994).

The PIFS Project targeted middle school students (6th and 7th grade in the US, involving 11 and 12 year old students), because these students are experiencing significant physical, psychological, intellectual and social changes in their lives. The PIFS program aimed to cause transfer of knowledge and skills by equating contexts to a central problem, or meta-curriculum (Gardner, 1993). Context, purpose, the incorporation of abilities and interests, integration of scholastic and practical knowledge, focussing on process and product and self monitoring are all principles by which the PIFS program sets out to enable students.

Students who have participated in the PIFS Program have been described as showing relative gains in behavioural characteristics such as study habits, and affective factors such as attitude. However, measures of success in the PIFS program were not necessarily tied to academic achievement (Gardner et al., 1994). This could suggest that traditional curricula may not be providing diverse opportunities for students to understand, despite student gains in appropriate school skills.

Other formal research into the influence of Multiple Intelligences theory within standard schoolroom environments has been undertaken. Much of this has occurred within a social framework (eg Elias & Weisberg, 2000; Gibson & Govendo, 1999) and has utilised action research methods. The conclusions of these studies showed varied impacts on academic performance, with positive impacts on motivation and affect levels of target student groups. Improvements in school factor variables such as behavioural gains were recorded (Beuscher, Keuer & Muehlich, 1997; Chen, 1993; Dare et al., 1997; Ellingson, Long & McCullough, 1997; Hughes, 1995; Layng et al., 1995; Miller, 1995), as well as gains in affective factors (Dare et al., 1997; Lane et al., 1997; Outis, 1994).

The review of US research literature has shown that Multiple Intelligences theory has appeared to be applied more frequently in primary schools than middle or secondary schools. Multiple Intelligences learning has had a strong influence in a wide range of educational settings in Australia with the predominant sites also located in the primary and pre-primary schools (Vialle, 1997). In the U.S. a three-year project with the acronym SUMIT (*S*chools *U*sing *M*ultiple *I*ntelligences *T*heory) has been recording and certifying schools operating under Multiple Intelligences theory and has listed 41 schools meeting the criteria (Project SUMIT, 2000). Of this number, 37 were elementary schools, with only 6 Middle, junior or secondary schools reported.

Of the Multiple Intelligences studies reviewed, few came from middle or secondary schools. Some studies (eg Marks, 2000; Prescott, 2001) have used narrative descriptions of Multiple Intelligences theory in schools, putting practical applications such as creating diverse paths to concepts ahead of quantification and definition. These descriptions of classrooms functioning with Multiple Intelligences theory have noted higher levels of engagement and increased enjoyment of learning, both by staff and students (eg Campbell, 1997; Emig, 1997).

This section has shown that utilising Multiple Intelligences theory has had positive effects upon a variety of factors considered essential for successful achievement at school such as feeling positive, having a sense of confidence, and enjoyment in tasks. The application of Multiple Intelligences theory in schools has been shown to improve opportunities for low achievers to learn by incorporating their individual differences in cognitive processing. It has also demonstrated that personalising tasks, assessments and environments has raised some students' emotional and behavioural dispositions towards school.

The call for more supportive research evidence of the value of Multiple Intelligences learning theory in classrooms is evident in criticisms that education program descriptions only represent before and after pictures and that details in everyday practice are lacking. This lack has been described as "the puzzle of implementation" (Levin, 1994, p. 573), and implies that more work is needed to fill in the gaps in practical experience, particularly as the literature review found no specific applications to mathematics learning in secondary school settings. Multiple Intelligences theory has been popular in education, but this has appeared to peak (Plucker, 2001). This thesis offers the potential to inform on implementation of Multiple Intelligences learning in a specific program and perhaps widen the arena of interest in mathematics learning.

3.9 Conclusion

Chapter three has described how Multiple Intelligences theory ascribes a variety of intellectual potentials as ways to incorporate new learning experiences. These multiple intelligences can be called on to facilitate understanding of mathematical concepts. Yet the cultural representation of mathematics through verbal-linguistic and logical-mathematical structures can cause fewer opportunities to construct strong connections between new knowledge and personal experiences, and can reduce the level of conceptual understanding.

The consequence of reduced performance achievement is proposed to cause students to believe they lack a capability to learn mathematics, that "only clever kids are good at maths". The perceived inevitability of mathematics failure is offered as a reason for lowered efforts over time, lowered self-efficacy and increasing disengagement. Opportunities for more students to become engaged with their learning, and to better understand concepts may be enhanced if the curriculum, delivery and assessment components of school are designed to include the multiple ways students can learn in mathematics.

This thesis proposes that student self-confidence for doing mathematics will be raised as an associated outcome of Multiple Intelligences learning in mathematics education. In order to validate this influence, the role of self-efficacy in mathematics achievement outcomes is described in chapter four.

CHAPTER FOUR

THE ROLE OF SELF-EFFICACY IN DETERMINING STUDENT OUTCOMES IN MATHEMATICS

Success in school involves more than innate or natural talent, with attitudes, aptitudes, prior experiences and personal background playing a major role (Greenwood, 1997). Components of affect are of central importance to influencing students' disposition to learn (Ingleton & O'Regan, 1998). The responsibility for lack of progress for low-achieving students rests as much with affective factors as cognitive or personal environmental factors. However while cognitive factors such as expectations, and classroom behaviours such as effort and persistence have influenced academic achievement in school (Reynolds & Walberg 1992; Seegers & Boekaerts, 1993) affective factors in school have been undervalued in their contribution to achievement (Bishop et al., 1995; Schiefele & Csikszentmihalyi, 1995). There has been a recent increased interest in the key role that affective factors play in learning mathematics.

It is a continuing problem that many students continue to show poor performance in mathematics and leave school with inadequate mathematics skills even under reform agendas. A contributing factor to this low achievement may be that classrooms fail to develop personal characteristics and behaviours that motivate students into taking advantage of learning opportunities (Malloy & Malloy, 1998). Low-achievement does not necessarily mean students do not want to do well in mathematics (Bishop et al., 1995) but some students do actively avoid engagement in class and avoid enrolment in mathematics if they can, with their choices driven by emotions rather than a lack of ability for mathematics (Ingleton & O'Regan, 1998). Educators need to encourage and arrange opportunities for students to become independent and self-regulating mathematical thinkers (Geoghegan, 2002) and this may mean developing changes in their self-confidence.

Student feelings are of particular importance for mathematical success. Although it is often seen as an objective, emotion-free discipline, strong student emotions are found to pervade learning experiences in mathematics. Mathematics is a subject where failure is unambiguous to students who can either succumb to feelings of inadequacy or regard it as a challenging setback (Yates, 1999). Among the students who feel helpless or inadequate and give up in the face of difficulties are those who believe that intelligence is fixed, that task outcomes reflect measures of ability, and poor performance indicates they are not capable of success (Cain & Dweck, 1995). Such students are unaware that ability in mathematics is not solely critical for achievement in mathematics (Lopez, Lent, Brown & Gore, 1997; Pajares & Kranzler, 1995; Randhawa, Beamer, & Lundberg, 1993). Other relevant components of achievement such as effort, motivation, and persistence with difficult work are directly influenced through students' confidence in their capability to do the mathematics tasks they are presented with, and to cope with anticipated difficulties (Pajares, 1996; Tatre & Fennema, 1995). The concept of confidence in a personal capability to cope with particular situations has been placed under the construct of self-efficacy (Bandura 1986, 1997), an attitudinal variable with a strong correlation to mathematics achievement (Lokan et al., 1996).

4.1 The importance of affective factors in mathematics learning

The essential argument of chapter four is that many low achieving students have low mathematics self-efficacy but achievement can be greater for students with higher perceptions of self-efficacy (Schunk, 1985). It suggests low-achieving students in mathematics can benefit from increased mathematics self-efficacy. Multiple Intelligences theory is offered as an educational strategy that can help to make mathematics more understandable and raise student self-efficacy in mathematics. It is proposed that a personalised learning program that seeks and focuses learning through children's intellectual strengths and interests and advocates an appreciation of using differentiated skills in mathematics classrooms will achieve these intervention goals.

Chapter four considers an explanation of

- The theory of self-efficacy
- Personal attributes of students that affect mathematics self-efficacy
- School and organisational factors affecting mathematics self-efficacy

- Mechanisms by which self-efficacy exerts influences on mathematics achievement.

4.2 The theory of self-efficacy

The role of self-referent thought has been outlined under Bandura's Social Cognitive Theory (1986) as a guiding influence on people's behaviour. Self-efficacy confers a sense of control on people such that they feel able to deal with situations. The way people think and feel affects how they behave. If students think poorly of themselves in capability, they may not try, or may exhibit helplessness, invisibility and avoidance of challenges that threaten their self-evaluations further, whereas a strong sense of self-efficacy may cause students to be confident and rise to meet challenges, drawing on their cognitive and emotional resources to do so (Meyer et al., 1997). The value of these personal qualities evoked by the influence of self-efficacy is reflected in the high explanatory and predictive relationship that self-efficacy has for mathematics performance (Bandura, 1989; Pajares & Graham, 1999), with the self-regulation construct demonstrating greater predictive power for performance in mathematics problem-solving than ability in mathematics (Pajares & Miller, 1995).

Self-efficacy is not an innate or fixed quality that individuals either have or do not have, but is an outcome of cognitive processes (Bandura, 1997). Piagetian-influenced principles of learning have been used to describe self-efficacy as a Constructivist activity (McCombs in Young & Ley, 2001) that has both antecedents and consequences (Schunk, 1985). Self-efficacy beliefs are self-persuasions cognitively constructed from four main sources that are personal experiences, modelled behaviours observed and interpreted in others, verbal persuasion, and physiological and affective states (Bandura, 1997). Through these inputs people evolve self-schemata of personal efficacy that organise and deal with their thoughts, assisting with processing new information and retrieving information from memory. Self-efficacy beliefs are cognitive generalizations about the self (Ng, 2000) and may be thought of as both mediators and triggers for other mediating processes (Phillips, 1969) such as attitudes or motivation. The mediating influence of self-efficacy may also act directly on factors affecting outcomes such as natural ability, by controlling the individual's action in utilising that skill, and indirectly by intervening in the influence of other learning factors such as effort and interest (Fouad & Smith, 1996; Lopez et al., 1997). Self-efficacy is proposed to be a reliable predictor of this interest, effort, persistence and achievement displayed by individuals (Bandura, 1997) and as such self-efficacy beliefs are a valuable tool in the instruction of students (Pajares & Kranzler, 1995).

Becoming confident and capable mathematics learners, developing a positive attitude towards its use and becoming autonomous learners are important goals of mathematics education (AEC, 1990; Curriculum Council, 1998; NCTM, 2000). Achieving these goals suggests the need for a strong sense of student efficacy for academic tasks, for social interactions with peers and others, and for personal control to be able to deal with requisite tasks through engagement, effort, and persistence. The next section examines the influencing factors on mathematics self-efficacy within the mathematics classroom.

4.3 Student attributes and experiences affecting personal mathematics self-efficacy

The thesis focuses on the mathematics learning environment of middle school, a time of considerable alienation that appears to come from a mathematics curriculum that ignores the personal and social contexts of young people (Vale, 1999), and a critical period for encouraging students to choose mathematics courses and for access to future mathematics courses (Singh, Granville, & Dika, 2002). While younger students tend to have a greater confidence in their capabilities and tend more to attribute success with effort, these older students see ability as increasingly important for achievement outcomes (Schunk, 1985; Shell, Bruning, & Colvin, 1995) and they may form stable but debilitating beliefs about intelligence, ability and achievement that inhibit their progress in mathematics learning. Yet such attitudes towards themselves as mathematics learners and towards the subject of mathematics are readily alterable in the primary-middle school transition period (Ma & Kishor 1997; Oerlemans & Jenkins, 1998) indicating it is an appropriate time for intervention programs that aim to cause positive changes in students' beliefs about their mathematics capabilities.

Low achievers in mathematics can have low self-perceptions of capability, tend to not complete activities, hold aversive and disaffected attitudes towards mathematics, and are either passive or otherwise disengaged (Kastner et al., 1995; Kaufman et al., 1992; Montague & Bos, 1990). A number of responses to low achievement such as anonymity, helplessness manifested in the automatic comment that they "can not do it", and self-handicapping may occur when these students are faced with tasks even within their capability. Such behaviours of task avoidance are associated with a low sense of self-efficacy and these students may find themselves in a downward spiral of self-doubt, poor commitment, reduced effort and failure (Bandura, 1997). Yet personal states are alterable as a result of changes in the influences on motivation, thoughts, feelings, and attributions. Individuals are capable of self-directed change and of altering their behaviour depending upon the reciprocal influences between their personal abilities, expectations of success, and self-efficacy (Bandura, 1997). From a pedagogical perspective, interventions that aim to alter student beliefs and behaviours should cause students to believe in their ability to do the work, to provide an emotionally appropriate environment, and to create willing engagement leading to the activation and development of appropriate skills and knowledge.

Mathematics learning has traditionally been represented as a fixed and certain body of knowledge where doing mathematics means completing exercises, mathematical knowledge is demonstrated by remembering how to do problems and success in mathematics is essentially linked to solving disconnected problems within a certain time (Schoenfeld, 1992). Mathematics is usually taught in a hierarchical form where new skills are built on learned material, presenting problems for some learners who move through this traditional curriculum presentation without understanding the earlier material (Miller & Mercer, 1997). Students' knowledge structures or schemata and their mental representations of their learning environment components such as tasks and beliefs play a central role in how they think, understand and act in class (Brown & Borko, 1992), and their prior knowledge influences how and what they learn (Hiebert & Carpenter, 1992). Under a standard mathematics education it is possible that students who can not understand the abstract representations, who can not keep up or remember all the steps, and who can not work quickly and accurately in sets of problems have less automaticity and a narrow knowledge base from which to draw on in new situations. The acquisition of knowledge held in long-term memory in the form of schemata, and the automaticity of its access are important components of learning (Chandler, Cooper, Pollock, & Tindall-Ford, 1998). It is likely that schemata would be more rigid under a traditional mathematics learning that emphasises outcomes of procedures and memorised rules, presenting difficulties resulting in increased failure and negative self-evaluative feedback when problem-solving environments differ from the specific learning environments (Randhawa et al., 1993). Instruction that focuses on rules and practice can fix negative views on intelligence through steering students away from strategies that would use and build their skills (Cain & Dweck, 1995). Students may acquire the belief that they are unable to learn mathematics, rejecting expectations of future success with self-limiting explanations such as work being too hard, or the need to be good at mathematics, and they may believe they are of lesser intellectual capacity.

Achievement history plays a significant role in the development and strength of negative self-evaluations. Low achievers tend to have lower self-efficacy, attribute failure externally to factors such as tasks being too hard or not getting help, and have lower expectancies of success than high achievers (Shell et al., 1995). Yet it is not always the poorest academic students who perform least well under specific circumstances, emphasising the important role that self-efficacy can play in raising mathematics performance. A variety of aptitudes, prior experiences, interests, skills, attitudes, and personalities can be found to form the idiosyncratic nature of each learner (Schunk, 1985) and when capable students are not achieving to their potential it suggests the need to examine processes of self-regulation that can help these students best utilise their knowledge and to develop the personal attitudes and beliefs leading to academic success. Low-achieving students in mathematics need to convince themselves that they are capable of learning the mathematics, and that it is worth the effort. The following sections will examine the four principal sources of influence that guide students in generating their mathematics self-efficacy perceptions about mathematics performance: experiences, observation, verbal persuasion, and affective states.

4.3.1. The role of prior experiences

There is a strong positive relationship between past and current achievement in mathematics (Yates, 2000). Prior mathematics performance is the biggest single predictor of future mathematics achievement, and confidence in learning mathematics is the affective variable most related to mathematics achievement (Tatre & Fennema, 1995). The strongest indicator to students of their mathematics capability has been attributed to past performance achievement (Bandura, 1997), verified in mathematics education at the upper primary and secondary school level (Lopez & Lent, 1992; Phan & Walker, 2000).

It is reasonable to conclude that if achievement performances in mathematics can be positively influenced then students' perceptions of self-efficacy for classroom mathematics tasks may be raised. In the simplest account of influence, success raises self-efficacy and failure lowers it. Repeated success generates resilience in the perception of personal efficacy even in the face of occasional failure. On the other hand, repeated failure experienced early in new situations in which mastery is attempted is likely to lower perceived self-efficacy and cause individuals to attribute failure to personal qualities. These self-doubting students tend to give up in the face of difficulty or remove themselves from engagement in order to maintain their self-view (Bandura, 1986).

Efficacy-based interventions can expose students to novel learning opportunities containing step-wise opportunities for success that alter inaccurate self-appraisals built on past performance (Lopez et al., 1997). The most effective way to develop self-efficacy is through mastery experiences that directly supply evidence of a capability (Pajares, 1996; Pintrich & Schunk, 1996). Opportunities for successful mathematics are particularly applicable to low achieving mathematics students who are often more exposed to learning conditions in and out of school that are not effective in generating academic resilience. Low achieving mathematics students are also more frequently located within minority and economically disadvantaged student populations with reduced access to the language and experiences through which mathematics is frequently learned (Khisty, 1995; Zevenbergen, 1998). Building early positive mathematics experiences and resilience with effective achievement oriented school practices and attentive, caring teachers (Howard & Johnson, 2000) can alter inequitable learning conditions, and is associated with increased mathematical efficacy (Borman & Rachuba, 2001). Such efficacious practices are offered through Multiple Intelligences principles applied to learning.

Multiple Intelligences learning may assist mathematics understanding through personally meaningful rich contextual networks or knowledge structures where the mathematics makes sense using a variety of learning tasks evoking domain-specific schemata. Specific schemata contain much more relevant and well-connected information to use in problem-solving (Chandler, Markus, & Tindall, 1994), encouraging students to devote more cognitive resources to the tasks.

4.3.2 The significance of observing others

Modelling occurs when students pattern certain attitudes, beliefs and behaviours on others, acquiring cognitive skills and new patterns of behaviour and allowing a way to raise self-efficacy beliefs (Bandura, 1986; Schunk & Zimmerman, 1997). These vicarious experiences affect self-perceptions of efficacy because students can judge themselves similarly capable of doing the work. Particular value can come from seeing other students who are judged of similar ability being successful, leading to thoughts of "if they can do it, then I can too". There are some cautions, however. While there is value in teachers modelling strategies, peers can be more effective because of perceived similarities in age and competence (Schunk, 1985). As well, self-evaluations made against students showing high conceptual understanding drawn from abstract, logical-mathematical tasks are unlikely to cause low achievers to perceive similar success in the same ways.

Therefore it is necessary to open up opportunities in mathematics classrooms for low-achievers to observe and interact with children of other abilities and interests. This recommendation for diverse models may be better met with heterogeneous classes. Keeping classes heterogeneous as long as possible provides an opportunity for low achievers to observe multiple cognitive processes and strategies related to concept learning and can promote their self-efficacy for success through their own competencies being included and valued in learning. If the only observations available to low achievers are of peers who, when judged as similarly competent, are seen to fail in tasks then their own perceived competence for the same tasks may be lowered. Heterogeneity does carry the problem of differences in peers' academic status, but the creation of "equal-status" learning tasks may be used to overcome perceived stable differences in academic competence and ability. Such tasks should be non-familiar in the sense that prior skills are not required, or tasks can be flexibly structured so as to incorporate the talents of a greater number of students into displaying task competence (Gabriele & Montecinos, 2001) enhancing the opportunity to raise more students' mathematics self-efficacy. This may require changes to mathematics cultural practices where secondary mathematics classes are more frequently streamed than other learning areas and at an earlier stage (Zevenbergen, 2002).

4.3.3 The force of opinion

Students are often encouraged to believe that they possess the capabilities to perform a task. Given that, it is readily acceptable that the use of encouraging words would be a source of self-perceptions about competence for specific tasks, and that realistic praise can boost confidence. A supportive teacher who is both a model and friend can allow mathematics students to be more self-confident and value themselves as learners (Middleton & Spanias, 1999). Increases in student emotional states through affinity-seeking strategies by teachers are positively associated with cognitive and affective learning (Beebe & Butland, 1994) and a personalised, positive classroom is likely to establish a degree of student trust in a teacher's judgements, causing their praise to be accepted as realistic.

However, the effect of verbal persuasion is not the most powerful of influences on student efficacy. Many teachers and parents have coaxed and sat with children attempting the same type of mathematics problem over and over, and have felt the frustration and seen the anxiety in comments such as "I'll never get it. It's too hard." Realistically, encouragement has to be believable and from a credible source. Low achievers are going to take little comfort from teacher-directed lessons that show a procedural task is readily performed (Schunk, 1985). In the search for positive recognition, peer influences in middle-school students are more likely to be very important, suggesting that working cooperatively with other students can demonstrate the value of effort, encouraging a self-efficacy belief about similar self-capabilities in the lower-achieving student.

4.3.4 The role of emotions

Students' sense of competence for mathematics tasks can be drawn from how they feel and react in specific circumstances. For example, those lacking confidence may get sweaty palms or "butterflies in the stomach" when called on to answer a mathematics question, or in test circumstances. This nervousness can reduce their concentration, whereas students with high self-efficacy feel more confident and can look forward to the challenge and outcomes, mentally preparing themselves to draw on their collection of answering strategies and knowledge. Mathematical anxiety forms a major part of students' negative emotions at school with test-anxious children making more errors, concentrating less and having more negative thoughts (Prins & Hanewald, 1997). Mathematics anxiety has been found to inhibit mathematics achievement (Pajares & Miller, 1995), and is directly related to poor performance (Ma, 1999), less positive attitudes to mathematics, and avoidance of the subject (Hembree, 1990).

Low-achieving students have greater anxiety that has been shown to consistently cause poor performance (Miller & Meece, 1997). However, while failure and anxiety significantly diminish student confidence in mathematics coursework (Lopez & Lent, 1992) self-efficacy has a strong negative effect on anxiety (Pajares & Kranzler, 1995) with students of highest self-efficacy being least anxious about their capability to meet challenges in mathematics. Therefore interventions that reduce students' mathematics anxiety may have an effect on students' mathematical self-efficacy. The radiating out of increased success and engagement can be likened to a snowball (Owens et al., 1998) and provides a positive class mood that is infectious (Archer, 1999). Irrespective of initial achievement levels in mathematics, the induction of positive moods in students can be associated with greater self-efficacy for mathematics (Bryan & Bryan, 1991).

The four sources of influence on self-efficacy provide a blend of information to students as to their capability for tasks, and how well they are coping. Research on self-efficacy beliefs suggest a number of ways that schools and teachers can guide education practices using essential principles of the theory. These include helping students maintain accurate and high levels of efficacy, keeping tasks challenging but not overly difficult, encouraging beliefs that competence is changeable and controllable, reducing comparative assessment information on ability, and concentrating on raising efficacy in specific domains (Pintrich & Schunk, 1996). The application of these recommendations is examined in the next section.

4.4 How school influences self-efficacy

Confidence is both a personal and a social construct (Bandura, 1986). Coping well in a complex society requires people to make good decisions and judgements, to have a reasonable idea about consequences, to be able to use opportunities effectively, and to regulate and select their behaviour appropriately (Bandura, 2001). This also applies to the academic and social system of schools, where coping requires students to develop self-regulation processes such as making appropriate efforts, forming strong self-efficacy beliefs, taking pride in work, and being organised (Schunk & Zimmerman, 1997). Efficacy beliefs can play a key role in these personal attributes and are perhaps more important for students entering middle school where there can be an increased call for multiple competencies and an increased expectation on students' capacity for self-regulated behaviour. This section examines the nature of school factors that influence student efficacy.

4.4.1 The effect of competitive and cooperative environments

For lower-ability children, traditional educational experiences in mathematics may create feelings of inefficacy through practices such as competitive assessment, streaming into lower achieving levels, and a "one size fits all" curriculum. An environment where the whole group studies the same material and teachers make frequent comparative evaluations can cause less able students to suffer most in terms of reduced efficacy (Bandura, 1997). The longer students work in competitive, comparative classes the more likelihood there will be reduced time on task, lowered self-efficacy and inhibitions on achievement (Moriarty, 1991). However, cooperative learning environments not only lead to higher self-efficacy and achievement, they lead to more appropriate behaviour (Moriarty, Douglas, Punch, & Hattie, 1995), breaking down interpersonal barriers and allowing an increase in personal efficacy for engagement through group activities. The impact of increased cross-achievement interaction means that strategies such as peer tutoring of low-achieving students by high achievers is likely to positively influence performance (Farivar, 1992) and in turn support efficacy gains.

In a competitive environment, mathematically able students may readily cope with failure, as these students are more likely to believe they have the ability and resources to learn, and occasional failure serves to further activate their engagement and persistence through challenge. However, low achieving students will take no comfort from observing success in more able peers if they have to work on similar tasks. It is more likely that they will perceive themselves incapable of equivalent performance attainment, especially if these are seen to be troublesome for high-performing peers. These lowered self-perceptions of capability for mathematics tasks may be negated if different and diverse tasks that take into account the particular interests of students are used (Bandura, 1997).

4.4.2 The implications of assessment for low achieving student-efficacy

Evaluation contributes to student confidence when results provide information that allows accurate judgements of progress. Therefore it is important that students have clear standards of mastery and excellence in order for them to be able to self-evaluate their progress. Normative appraisal has commonly represented the model of student assessment in school mathematics where discrepancies in performance using these ranking methods are most obvious for lower-ability students, and these appraisals can have significant negative effects upon student self-efficacy.

While mathematics assessment methods such as multiple-choice or open-ended tasks do not appear to differentially affect student mathematical self-efficacy (Pajares & Miller, 1997) self-efficacy theory can be used to predict that reform-based contextual and diverse "authentic" assessment is more related to the conditions in which tasks are learned, can be intrinsically motivating, and provides personal performance goals (Paris et al., 1991). Intrinsically motivating tasks are those presenting challenges that match student capabilities, provide feedback and therefore foster self-efficacy. Tasks that provide motivation and activation are suggested to be ones in which the student has already shown an interest outside of the mathematics classroom. Learning mathematics using "real-world" activities or other school learning area activities where past successes have been experienced offers a context to raise perceived self-efficacy for mathematical knowledge as applied in the task.

4.4.3 Efficacy and school transition periods

The transition between primary and middle-level schools is a difficult time for many students (Eccles, 1999; Elias, 2001; Rudolph, Lambert, Clark & Kulakowsky, 2001). It can be accompanied by deterioration in positive interpersonal relationships and a reduced emphasis on mastery goals and understanding (Midgely & Edelin, 1998). It can have negative impacts on student self-perceptions, liking of specific learning areas, and achievement (Watt, 1997). Students' beliefs in the value of mathematics, their motivation and engagement can fall over the transition from primary into middle school (Pajares & Graham, 1999). Students' like and dislike of mathematics essentially begins at this transition point (Middleton & Spanias, 1999), with enthusiasm for mathematics that many students have on entering grade seven being lost for some students after a few years of secondary school (Fullarton, 1996).

For children with a history of low achievement in mathematics, starting secondary school may be a threatening experience. The combination of past negative experiences, anxieties about the new mathematics classes, poor expectations about academic success and the uncertainty of new environments can be significant inhibitors on student confidence. Yet confidence is needed to engage in new environments, where new circumstances limit judgements about self-capabilities to perform (Bandura, 1997). The NCTM (2000) Principles suggests students' confidence is shaped by the kind of teaching they receive, although there is sparse evidence in literature on mathematics curriculum and numeracy learning that informs teachers of how to address these particular needs in low achieving students (Vale, 1999). A review of literature on nurturing through effective school practices (Green, 1997) places an emphasis on recognising, respecting and including student experiences and differences, and establishing positive and caring teacher-student relationships in contrast to structured learning and conformity. New school environments may influence individual efficacy through the ways each chooses to enculturate and inform, with the degree of authority expressed, the distance kept from the community, and the forms of assessment affecting students' evaluations of coping in the environment (Bandura, 1997).

The implication is for the school to be aware of student strengths and weaknesses and plan for classroom tasks that broaden the application of the mathematics concepts in order to facilitate successful learning. Middle school practices such as inter-related learning programs linking curriculum to real life with varied tasks can raise interest (Vale, 1999), team-teaching approaches are typical of middle schools and can provide a personalised knowledge of students and give emotional support (Kaplan & Owings, 2001), and peer modelling of coping skills may aid student efficacy in transition between primary and secondary school. The sooner mathematical low achieving students experience success in secondary school, the less likely past experiences will inhibit development of mathematical self-efficacy in this new environment. Multon et al. (1991) noted that self-efficacy effects were particular facilitative for low-achieving students' academic achievement, and that these stronger effects from self-efficacy on performance were achieved in secondary students, again indicating that the middle school transition is an important arena for programs that boost students' mathematics self-efficacy.

4.5 The influence of self-efficacy on mathematics achievement

Self-efficacy beliefs have consequent effects on how students think about their abilities in mathematics, how hard they try and for how long. It influences their attitudes and emotions towards mathematics work, affects how they behave in mathematics classes (Schunk, 1985; Multon et al., 1991), and influences future opportunity in that students mainly using past mathematics performance to judge their capability for future mathematical courses, and enrol or do not enrol on the basis of their histories (Lopez & Lent, 1992).

Efficacy beliefs operate through four main ways to influence how students think, are motivated, feel and act. The first effect is on student thoughts. It is common to hear children who are performing poorly in mathematics to make self-doubting comments, such as they "are not clever enough", or predict that they "will never get the right answer". This is often followed by an abandonment of tasks, as their efforts are perceived as futile. For students who view ability as alterable, poor performance is a stimulant for activating behaviours and thoughts that become self-fulfilling in the sense that they raise performance. However, low-achieving children may conceive of their cognitive ability as innate or stable and regard themselves as lacking capabilities (Cain & Dweck, 1995; Stipek & Gralinski, 1996). Negative experiences from failure can generate that which blind students' ability to evaluate other options to shape situations towards success (Mantzicopoulos, 1997). These students may withdraw from enhancing activities, do not promote themselves because it could attract attention to their perceived lack of intellectual ability, negatively compare themselves with others, and debase the worth of their achievements.

Yet raised self-efficacy can have a positive effect on task-particular perceptions of mathematics competence. Raising self-efficacy can negate concerns about what others think, and about perceived personal lack of capacity for mathematics (Seegers & Boekaerts, 1993). By demonstrating to students that the pathway to learning mathematics in classrooms is not bounded by their past experiences, and that modes of learning can include activities not normally applied as mathematical tasks, low achieving students may view the concept of intelligence as variable and malleable.

A second effect of self-efficacy beliefs is on student motivation. Most motivation is cognitively generated (Bandura, 1997) and student beliefs are highly relevant to mathematics achievement. Students who feel confident in their capabilities for mathematics tasks usually see the subject material as relevant to their lives, creating a motivational force and students engage in behaviour that assists their strategic repertoire, whereas low-efficacy students are less convinced as to why mathematics is necessary and can be much less motivated (De Corte & Op 't Eynde, 2002). Students with low efficacy can attribute performance to factors beyond their control, such as work being beyond their ability, and therefore have little motivation to change behaviour. Past experiences with traditional mathematics tasks and processes may convince mathematical low achievers that there is little value in extra effort, and students who have both a low self-efficacy and low outcome expectations show lessened efforts, are resigned to failure and are unwilling to try (Pintrich & Schunk, 1996). On the other hand, raised self-efficacy is associated with appropriate actions such as persistence and effort in the face of difficulties, and the selection of and commitment to challenging tasks that lead to the development of more knowledge and skill (Bandura, 1989).

The third path of influence of efficacy on performance is through student emotions. A sense of efficacy to deal with anxiety and stress can influence how students feel and behave in class. Students' help-seeking behaviours in mathematics are influenced by their sense of autonomy and competence, and by a class atmosphere of collaboration and social supportiveness (Greenberg, 1998). When a positive social climate is maintained it supports individual diversity and differences, and encourages participation through that social support (Shapiro, 1993). How students think and feel precipitates their involvement, and classroom mood is influential on those feelings. Being in a positive mood has been shown to raise both self-efficacy and performance for students at risk of school failure (Bryan & Bryan, 1991). Low achievers in mathematics classes may have little reason to enjoy their class-time, being unable to conceive of the purposes of tasks, or unable to complete tasks that serve to reinforce the lack of relevance of much of mathematics to their lives. In order to remove the impacts of negative emotions and engage students, it is possible in schools to indulge in engrossing matters of personal interest which students have associated with enjoyment and fun (Holton, Ahmed, Williams, & Hill, 2001; Kubinova, Novotna & Littler, 1998; Rea, 2001; Uslick & Barr, 2001) and still achieve educational objectives. Authentic tasks in which students are exposed to multiple ways in which mathematics is at work in society can engage students without having an outcome of "right or wrong" that initiates anxieties (Pugalee, Douville, Lock, & Wallace, 2002). Multiple tasks and tools can supplant those contributors to lowered efficacy such as anxiety, a sense of failure and trepidation at perceived inability to cope with unknown requirements.

The fourth factor influenced by self-efficacy is student behaviour. In particular, student willingness to engage with tasks, take part in discussions, and use appropriate behaviour is influenced by perceptions of self-efficacy for these acts. Efficacious students accept challenge (Meyer et al., 1997), choose to participate and are more resilient in the face of difficulties. They are more successful because of the use of a variety of strategies that may be tested and discarded, and see success as a result of efforts.

4.6 Conclusion

Chapter four has described how mathematics self-efficacy can be developed, and how it influences academic performance in mathematics. Low achieving mathematics students can be assisted as a result of improved self-efficacy for mathematics. Raising mathematical self-efficacy can transform a reclusive, self-doubting, wayward and at-risk student through the encouragement of self-regulation, fostering the acquisition of new skills, and applying prior knowledge and skills first to familiar contexts and then generalising to new problems.

The aim of this thesis is to investigate the role of Multiple Intelligences learning on mathematics achievement. Chapter five will describe how Multiple Intelligences theory and Self-Efficacy theory can converge in a learning program to activate mathematically low achieving students in class and diminish the characteristic aversive behaviours and emotions that diminish learning opportunities in mathematics classes.

CHAPTER FIVE

THE CONVERGENCE OF MULTIPLE INTELLIGENCES THEORY AND SELF-EFFICACY THEORY TO ASSIST LOW ACHIEVEMENT IN MATHEMATICS

The problematic factors of relevance to this study are

- An inequitable provision of opportunities for low-achieving students to understand mathematics concepts
- A history of failure leading to students' lowered self-belief of an ability to be successful in mathematics
- A polarisation between school values and the communities from which low-achieving students derive their mathematics knowledge and mathematical experiences
- The lack of a perceived empathetic and supportive environment for low achievers in mathematics classrooms.

This pool of circumstances surrounding mathematical low achievers has raised the question of how to optimally intercede with positive educational programs aimed at mathematics achievement performance and raising student confidence to do mathematics. Multiple Intelligences learning has been shown to be effective in improving enthusiasm for mathematics with a culturally sympathetic curriculum (Pajkos & Klein-Collins, 2001), for creating positive attitudes towards mathematics processes (Abbott & Warfield, 1999), and in increasing motivation in mathematics through an increased sense of ownership and responsibility for tasks (Klein et al, 1998). This chapter builds a proposal that Multiple Intelligences learning will also act on the self-efficacy component of the affective domain, adding to positive influences on students' mathematics learning.

5.1 Theoretical support for the confluence of Multiple Intelligences with self-efficacy

While home or family-related variables are outside the control of schools, factors such as classroom environments, teaching approaches and practices can significantly influence students' success (Schunk, 1985; Smith & Bourke, 1996, 1997). There is evidence that the best settings that allow students to develop a sense of what it means to "do mathematics" from their actual experiences with mathematics are situated in engagement with classroom activities (Henningson & Stein, 1997). Although out-of-school environments contribute to these experiences, opportunities for the kind of rich understanding about mathematics that is necessary to function in modern society are usually created in school (Fennema, Sowder & Carpenter, 1999) and the fact that some children actively seek out mathematical problems and enjoy mathematics in school suggests that this enjoyment can be extended to more students if educators look to individual differences as a focus of delivery (Middleton, 1995).

Multiple Intelligences learning offers to provide a number of ways that will cause students to picture themselves as successful learners, that will help them to feel confident in mathematically challenging circumstances, drive them to achieve in class, and encourage appropriate decisions related to learning. Multiple Intelligences theory maintains that there are differentiated cognitive structures or intelligences that can, for different people, better organise their learning experiences with mathematics concepts into more meaningful patterns than the logical-mathematical intelligence's schemata. According to Prenzel (1992), schemata can be both cognitive and affective, and mathematics self-efficacy is considered a self-view of capability constructed from cues that are also organised by cognitive guides, or self-schemata (Bandura, 1997).

It is proposed in this thesis that these affective cognitive guides may be causing the same limitations on the breadth and strength of mathematics self-efficacy that Piaget's logical-mathematical cognitive structures have been argued in this thesis to create for learning mathematics. Students who form self-schemas as poor logical problem-solvers construct negative views of themselves in failure circumstances (Cross & Markus in Meyer et al., 1997). This present study's research in self-efficacy suggests the environment under which mathematical self-efficacy usually develops is one that emphasises traditional methods, appealing to the schemata of the logical-mathematical minds. Romberg (1992) describes schemata as organised sets of similar experiences held in long-term memory, which for many low achieving mathematics students represents a consistent history of mathematics failure likely to have created stable and strong negative self-beliefs in their capability for learning.

This offers an explanation why the highest perceptions of mathematics self-efficacy are strongly linked in reciprocal causation with high mathematics achievement (Pajares & Kranzler, 1995), itself linked to strong logical-mathematical ability (Center for Talented Youth, 2002). While recognising that differences in achievement outcomes are necessarily due in part to aptitude, it is suggested that a pedagogical bias for Piagetian conceptions of intelligence implicitly operating in traditional mathematics classes has suppressed or denied the achievement performance of many students, acting negatively on the most powerful of influences on mathematics self-efficacy, past achievement.

It is the role of chapter five to describe how the synthesis of Multiple Intelligences theory with SE theory may provide productive and beneficial influences on students' mathematics achievement.

5.2 The interaction of Multiple Intelligences learning dimensions with self-efficacy mediating processes

Three main components characterise Multiple Intelligences learning. The first is the provision of a differentiated and re-represented form for each concept in mathematics. The second is that students' cultural capital and resources should underpin their learning contexts, reflecting the theoretical principle that intelligences can be nurtured and nourished by a supportive cultural matrix of connected meanings (Gardner, 1991). The third characterising component of a Multiple Intelligences classroom is that a personalised, empathetic environment should surround each student. This requires a personal knowledge of students' cognitive strengths, their values and attitudes, and recognises that learning is best done within a caring atmosphere. The fidelity of implementation of Multiple Intelligences theory is demonstrated in that if classrooms are personalised, then the essence of Multiple Intelligences theory is at work (Gardner, 1995).

Central to this thesis is that these dimensions of Multiple Intelligences learning may *directly* act upon cognitive ability to create a resonance with individual students' intelligence structures, and may also act *indirectly* on mathematics achievement through raising the mathematics self-efficacy of more students. Self-efficacy beliefs affect outcomes by influencing how individuals think, are motivated, feel and behave. The three components of Multiple Intelligences learning are proposed to interact with these four mediation processes of student mathematics self-efficacy to have an impact on students' affective characteristics and academic outcomes.

Table 5.1: Interaction of Multiple Intelligences and self-efficacy factors

		MULTIPLE INTELLIGENCES COMPONENTS		
		VARIED CONCEPT REPRESENTATION	USE OF CULTURAL SKILLS	PERSONALISED INSTRUCTION
SELF-EFFICACY EFFECTS	COGNITION	Familiar tasks lead to richer and more positive cognitive schemata	Allows new information to be supported and scaffolded into a network of understanding	Caters equitably for individualised sense of understanding concepts in varied contexts
	MOTIVATION	A broader range of tasks motivates more students more often	Particular intelligences are more valued in different cultures, and activities that are structured through these may motivate culturally diverse students	Personally valued tasks carry interest, and motivate through the challenge to advance in the skill area.
	FEELINGS	Selection of tasks that do not threaten self-appraisals, and reduce possible public embarrassment. Assessment carries less expectation of failure.	Positive emotions from familiar contexts encourage cooperation and commitment.	Allows thoughts of positive outcomes through familiar contexts.
	BEHAVIOUR	Choices drive engagement and persistence.	Culturally familiar tasks encourage willingness for engagement and participation in class.	Allows a sense of control through choice over tasks that creates persistence and confidence.

The next sections indicate how Multiple Intelligences learning may interact with mathematics self-efficacy to improve mathematics achievement.

5.3 Variety of representations of mathematics concepts and self-efficacy

5.3.1 Variety of representations and cognition

A fundamental difficulty with learning mathematics is that the meaning of the concepts is derived from the connections that learners can make with them, but the construction of that meaning is frequently unsupported by classroom tasks, settings or media (Noss et al, 1997). A significant feature about the differentiated ability of people to use and understand mathematics concepts in informal, "outside-of-school" contexts is that they are not required to be fluent in symbolic language as a representation of these concepts (Hiebert & Carpenter, 1992). Multiple Intelligences theory allows that this is because there are other organising structures or intelligences that create their own networks to give stronger linkages and more internal representations of the mathematics involved without recourse to a logical-mathematical intelligence to organise and integrate the experiences into their understanding.

Linking current mathematics curricula and delivery to more and varied everyday tasks can reduce unfamiliarity and raise mathematics self-efficacy if students' knowledge base is rich and appropriate instruction is used (Randhawa et al., 1993). This instruction may be enhanced if the representations of mathematics concepts are embedded in tasks that are familiar to students, and in which they already have some confidence. The multiple alternative representations of mathematics concepts are argued to promote cognitive schema that are richly detailed, supported in assimilation by relevant personal experiences. The notion of "rich tasks" means that they are integrated, allow creativity, are purposeful, authentic, use multiple tools and contribute to sense-making in mathematics through active student roles (Flewelling, 2002). This increased meaningfulness from resonances between individual intelligences acting on a range of representations carries a probability that each student may develop an internalised understanding to a higher level than if the concepts were introduced as logical-mathematical representations. With increased understanding, students can change their self-schema, bringing a new sense of capability into future mathematics engagement.

5.3.2 Variety of representations and motivation

When students are restricted to attempting to work through tasks requiring logical-mathematical intelligence, many may be hampered by their cognitive weakness that can slow them down in class (Naglieri & Gottling, 1997). However, using tasks resonating with their cognitive strengths could facilitate planning, improve task completion rates and create higher self-perceptions of efficacy to meet time demands. Increasing students' automaticity by learning through diversified but familiar task settings may free up thinking and allow more tasks to be successfully completed in class (Bandura, 1997).

In turn, students may more readily conceive of future successes. Numerous studies have been cited by Bandura (1989, 1997) to show that when people imagine themselves doing something well it helps them act such that those thoughts are realised. These kinds of positive anticipations can motivate, or act as incentives to try hard and set goals for mathematics. However, the nature of many classroom mathematics tasks consists of written problems, requiring symbolic language. A number of students persistently have trouble with these, view success from their efforts as unlikely, and eventually disengage.

Multiple Intelligences learning offers pedagogical support for a diversity of tasks that may motivate students into involvement. Students mainly tend to get involved when they need to know, and benefit from activities, questions, and situations where they see and feel this need (Yager, 1989). For many students this is the 'here and now'. Offering short-term mastery goals in areas of personal significance can provide an alternative sense of enablement (Bandura, 1997) giving direction for classroom practices aimed at raising achievement levels. Giving students greater personal ownership of learning through a choice of tasks related to personal interests can lead to increased student motivation (Bartscher et al., 1995). Success can lead to further success and if tasks are used that support students in believing that they have a personal ability to be successful then their self-efficacy is likely to be raised. Multiple Intelligences learning tasks have been effective as sources of intrinsic motivation, where student choice has been shown to cause them to seek out and engage in class work on the basis of interest and enjoyment (Ellingson, 1997).

5.3.3 Variety of representations and affect

Efficacy beliefs affect the nature and intensity of emotional experiences through negative thoughts, actions and feelings. Many students dislike even the thought of going to mathematics classes. They say it's their worst subject. They get nervous before class tests and may put in little effort, brought on by a low perception of capability to do the class work even though they may have an adequate understanding. In many classes all students do the same problems, some get them right, and others struggle. As a result a number of children can have low self-efficacy on returning to their mathematics classrooms.

Self-efficacy theory suggests that by gaining mastery over perceived threats, students can reassert to themselves their capability to do the required mathematics. Since the threats emerge from mathematics being represented mostly in logical-mathematical forms, a Multiple Intelligences approach using tasks appealing to a variety of intelligences can remove the threat of failure and embarrassment, and promote self-efficacy for success. If there are opportunities for a variety of activities, they may be sufficiently engrossing to regulate and block out intrusive "bad" thoughts. Coming to mathematics classes may become an attractive thought if there is the expectation of interesting and appealing tasks.

5.3.4 Variety of representations and selection processes

Under self-efficacy theory students make choices on the basis of how capable they feel in certain circumstances and on what threats may emerge, avoiding activities and environments they believe are outside of their abilities but readily engaging in tasks and social situations they feel they can handle. Engagement is an important and separate part of self-efficacy mediation processes. Active engagement is necessary for cognitive changes to occur (Bakken, Thompson, Clark, Johnson & Dwyer, 2001) and it is only after people choose to become involved that they draw on their resources, make plans, and develop an emotional involvement with their work (Bandura, 1997).

One way to keep students occupied at a high level, and actively pursuing mathematics may be through a diverse choice of tasks. If mathematics concepts are embedded in tasks that resonate intellectually and that allow prior knowledge to be brought into play, then students may choose to engage rather than be coerced. Utilising self-efficacy for performance may be a better path to learning mathematics concepts than using unfamiliar tasks because learning efficacy beliefs are less congruent with new work. Self-efficacy theory allows that choices are influenced by beliefs about capability, and when students are familiar with the requirements of tasks they are more readily able to draw on efficacy beliefs developed in earlier similar circumstances (Pajares & Schunk, 2001).

5.4 Incorporation of cultural skills and self-efficacy

Mathematics is recognised as a social construct (Benn & Burton, 1996) providing valuable knowledge that acts to enable individuals within their larger social structure (Kerka, 1995). However societies may be individualistically or collectively oriented (Bandura, 2002), and while self-efficacy beliefs assist the attainment of outcomes in all cultures, differences affect how those beliefs are developed (Bandura, 1997), inequitably affecting the influences on self-efficacy.

This can happen in a number of ways. Deterministic cultural beliefs can create educational environments based on ability that affect achievement outcomes (Stevens, 2000) with the mathematics education culture in particular appearing to associate innate ability with learning mathematics (Zevenbergen, 1997). Another way is that the school culture may support the development of particular intelligences (Gardner, Krechevsky & Kornhaber, 1990). Traditional western mathematics education frequently emphasises logical-mathematical and verbal-linguistic intelligences, and offers mathematics as an individualised capacity. Within a particular system, students from minority groups that differ in discourse, task contexts and social structure can be isolated cognitively and emotionally from the flow of classroom activities because the opportunity to be competent in the verbal-linguistic and representational forms of mathematics is diminished, resulting in higher anxiety, less interest in mathematics, and less self-confidence for doing mathematics than members of the dominant culture (Wiest, 2002).

The impact of cultural factors on self-efficacy is examined in the next section.

5.4.1 Cultural incorporation and cognition

Learning is more meaningful and more likely to be retained when students make clear connections between mathematical ideas, activities, and prior knowledge (Henningson & Stein, 1997) not only through listening and writing but also by acting out, by constructing, and by emotionally and physically connecting with the material (Novick, 1996). Each of these connecting mechanisms may be more relevant in different cultures suggesting the need for differentiated tasks to enable more students to make these connections. When teachers link new information to the student's prior knowledge, they activate the student's interest and curiosity, and infuse instruction with a sense of purpose (North Central Regional Educational Laboratory, 2001). However students can be disadvantaged by narrow representations found in the traditional mathematics education texts, verbal descriptions, contexts, and tools of learning, requiring these to incorporate diversity (Wiest, 2002). Meaningful representations that contain cultural relevance can increase successful experiences, and these are the strongest influence on self-efficacy.

5.4.2 Incorporation of cultural factors and motivation processes

Individual competencies need to be encouraged within a social framework that provides a motivation beyond that sourced from personal needs (Kornhaber et al., 1990). Individualistic cultures are most efficacious when they can manage things themselves, and collectivists are most efficacious and productive when they manage things together (Bandura, 1997). Japan is a collectivist culture with widely shared social and family values, placing an emphasis upon effort, persistence and high expectations. At an international level of comparative assessments (eg TIMSS), much has been made of the differences in mathematics achievement between particular Asian countries such as Japan, and Western countries such as the US. As well as valuing mathematics, the Japanese education system places a high value on effort leading to success in mathematics, and a low focus on the influence of ability in mathematics, allowing individuals to perceive positive outcomes as rewards of this effort. This is contained within a collective social and family efficacy that is confident about the consequences of diligence to study. As a result, overall levels of mathematics achievement are high in Japan as students are strongly motivated to learn, but the individualistic and competitive nature of the western society lacks the "social glue" that unites education systems into effective schools (Kornhaber et al., 1990). The effectiveness of Multiple Intelligences programs is built on its incorporation beyond classrooms and individual schools. Its success – and therefore the success of students – is related to the involvement of school districts, and the acceptance of its principles by an extensive community that reacts positively to new ways of teaching and of assessing (Kornhaber, 1997). Multiple Intelligences learning needs to build school efficacy, and is dependent upon motivating communities to have high standards based on a collective efficacy for change.

At the classroom level, self-efficacy effects may also be differentially developed depending on whether a cultural emphasis is placed on individualistic and competitive learning as opposed to cooperative and shared knowledge. Social and economic forces require students to have skills in both individual and cooperative learning (Curriculum Council, 1998), such that their personal grasp of concepts is relayed to others, challenged, clarified, and interpreted. The mathematics reform movement has called for new goals that put an emphasis on skills of small group work, and increased communication of ideas (Goos, 1997). Students are encouraged to learn not just from school and peers, but also from their community through using mathematics as a tool to study such cultural phenomena as health, poverty, politics, environment, and gender-based wage issues (Wiest, 2002). Such a broadened cultural setting for mathematics may structure mathematics concepts better through the interpersonal intelligence for example, increasing self-confidence for engagement and creating a motivational force from students learning mathematics through valued community settings. Using tasks derived from culturally valued domains may allow a resonance with students' natural abilities, drawing them into the activities as they become motivated by personal challenge, by pursuit of personal goals arising from the tasks, or from the expectations of personal satisfaction.

5.4.3 Incorporation of cultural skills and affective processes

Self-efficacy effects may flow when school cultures become more congruent with the culture of the community. A commonality of purpose sets the stage for reducing anxieties and promotes achievement and success (Shapiro, 1993). Supportive schools that provide cooperative and welcoming environments have a positive effect on students' social and psychological well-being and can lead to greater academic achievement (Kornhaber et al., 1990). Partnerships between the school, families and communities have been associated with similar effects on student achievement and attitudes (Rutherford, Anderson & Billig, 1995). The inclusion of parental involvement in schools offers the opportunity to raise parental efficacy for influencing school outcomes for their children, and for effecting changes in their children's futures. In turn, the children may conceive of themselves as capable because of that encouragement, thus viewing more successful outcomes and aspirations as possible.

The introduction of diverse cultural activities as tasks allows for other affective benefits providing richness to personal schemata. Raising students' self-efficacy for social learning and behavioural selection means they are likely to be more receptive to interaction with others and to respect their cultures and identities (Gay, 1994). As well, raised self-efficacy can raise interest in mathematics, creating academic choices that contribute to more minority enrolment in mathematics (Gainor & Lent, 1998). Multiple Intelligences learning advocates culturally responsive assessment that reflects practices of the broader community and places learners as participants in the process (Reiff, 1997), which can diminish anxiety and raise opportunities for success.

5.4.4 Culture and selection processes

Recent mathematics reforms have placed a strong emphasis on the selection of content that is of interest to students and on creating a culturally relevant curriculum (Davison & Miller, 1998). When teachers use instruction through tasks that foster intrinsic motivation, student involvement in class is high, and those students tend to show higher affect (Bandura, 1997; Turner et al., 1998). Tasks that students are eager to work on and which hold personal relevance are directly related to how hard students will decide to apply themselves and are a source of intrinsic motivation leading to engagement (Herndon, 1987; Seegers & Boekaerts, 1993). The use of culturally desirable and valued skills can contribute to students developing self-regulation for self-directed learning, involving testing their knowledge, experimenting with different approaches, correcting themselves and weighing methods for usefulness (Bandura, Barbaranelli, Caprara & Pastorelli, 1996). This activation works towards the achievement of desirable teaching outcomes (NCTM, 2000) that provide a challenging and supportive environment.

5.5 Personalised instruction and self-efficacy

Essential characteristics of personalised learning include recognition of distinct and individual academic and non-academic characteristics. These include emotional states, learning rates, intelligence profiles, developmental stages, and interests. This prior knowledge allows the presentation of learning opportunities that include choice, that are diverse, and are considered meaningful to the student.

5.5.1 Personalised instruction and cognitive processes

An aim of a personalised education is to facilitate each student's confidence to make the most of their resources. Under Multiple Intelligences theory, concepts in mathematics may be interpreted and internalised more readily against the life-long background of students' experiences and language. Personalised classrooms have been proposed to produce greater levels of perceived capability, with less dependence on the need for approval from significant others such as teachers when making choices, taking risks and proceeding down exploratory paths that involve the risk of a dead end, which otherwise causes students of low self-efficacy to quickly abandon efforts (Bandura, 1997).

A current view of mathematics is that it is a plural noun, that it is integrative, using a wide range of activities, interests, linguistic capabilities, kinesthetic sense, and informal student knowledge (Romberg & Kaput, 1999), catering to a range of cognitive strengths. This diversity can recognise both the cultural need for a fluency in symbolic notation (Gardner, 1993) and allows new concepts to be internalised and transposed into culturally valued but less dominant intelligences through multiple representations (Munro, 1994). Reconstructing meanings in problems can allow misunderstandings about concepts to be clarified, and carries the benefit of testing personal assumptions about what it takes to learn mathematics (Robertson & Taplin, 1994).

5.5.2 Personalised instruction and motivational processes

The major reasons why low achieving students fail to maintain engagement in mathematics appear to be related to their lack of interest in class activities. Without engagement, the student is unable to devote sufficient time to gain success in the set tasks, fails frequently and experiences a reducing sense of self-efficacy in mathematics. Predicting what motivates students has been a persistent problem for mathematics teachers, particularly because the realities of dealing with many students limits a personal knowledge of each, such that many teachers have little idea how their students are motivated intrinsically (Middleton, 1995).

A willingness to engage with mathematics tasks at a high cognitive level, and over sufficient time draws heavily upon the perception of the student to be able to carry tasks through. People tend to prefer activities for which they have some innate capabilities and the stronger their capabilities the more likely they are to find the activities interesting, and interest is a powerful force linked to intrinsic motivation (Deci, 1992). Multiple Intelligences learning creates a personalised learning environment that may assist low achieving mathematics students who have had few opportunities to have their own talents utilised in their mathematics classes.

Under a personalised instruction, differentiated intelligences can be accommodated through a variety of tasks, allowing for a range of personal goals to act as motivators. Using other talent contexts can provide the opportunity for learning goals that raise self-efficacy of low achievers. Goals motivate by personal evaluation against one’s own standards (Bandura 1989). Self-regulated learning is assisted when students monitor their own progress, with positive evaluations leading to higher motivation (Schunk, 1997; Zimmerman, 2002). If students are able to use tasks in which they have set personally high self-standards, it may encourage sufficient persistence to allow improvements in understanding embedded mathematics concepts, or alter other negative classroom characteristics such as alienation, lateness to class, disruptive behaviour, and poor self-views of learning capability. A personalised learning environment which considers and includes questions to which answers are relevant to students is a motivating circumstance, and particularly so for low-achieving students (Vale, 1999). Allowing low achieving mathematics students to experience concepts through personally relevant pursuits set in familiar contexts may motivate and promote a sense of efficacy for engagement.

5.5.3 Personalised instruction and affective processes

The level to which people become stressed and anxious by conditions is limited by their perceived self-efficacy to control both the circumstances and their reactions (Bandura, 1989). Lowered efficacy affects even those who may know the answers, or are quite competent at mathematics but lack self-confidence. Under this accounting, the classroom climate has consequences for academic success. A willingness to understand through investigating and manipulating classwork can be promoted through learning environments that students perceive to be safe, supportive, and have good relationships (Dart et al., 2000). An authoritarian classroom climate can make many children uneasy and unsure of how to respond (Tomlinson & Kalbfleisch, 1998). Teacher-directed classrooms functioning under academic constraints may not allow the benefits associated with practices such as peer-group learning (De Lisi, 2002) because low-achieving children may be reluctant to draw attention or to take risks with challenging work because they lack self-confidence to deal with the imagined possibilities of embarrassment and social insecurity.

However, students who feel emotionally comfortable and confident of being able to deal with the cognitive and social realities that occur in school classes do so through raised student self-efficacy (Bryan & Bryan, 1991). Positive affect resulting from self-satisfied reflections about personal performances can create a confidence that encourages students towards self-regulation and personal control (Zimmerman, 2002). A positive classroom climate can be important in eliminating anxieties and promoting achievement, and is attainable through satisfying a wide variety of student interests and differences (Shapiro, 1993). Multiple Intelligences learning offers a learning program that is deliberately made more empathetic, matching tasks to learners' profiles through knowledge of students. Personalised mathematics learning includes choices from diverse tasks ranging over areas of interest, ability, and developmental competence. It uses a variety of tools that students may be more comfortable with, including calculators, computers, and the internet. De-emphasising single outcome answers and encouraging students to take risks in the form of trying different methods can raise more students' self-efficacy (Randhawa et al., 1993).

5.5.4 Personalised instruction and selection processes

Traditional mathematics frequently offers few choices in terms of task variety, conceptual representation, and social settings yet selections are important because unless appropriate choices occur and students actually engage, they will never feel motivated by the tasks or find out how much fun mathematics can be, or conclude that they can be successful after all (Bandura, 1997). It has been shown that the more that teacher direction is found necessary and the more that teacher-based structuring of learning occurs in mathematics, student achievement is lowered (Smith & Bourke, 1996). Instruction within classrooms needs to attract and arouse natural curiosity and interests of students, and should include appropriate levels of challenge (Tomlinson & Kalbfleisch, 1998).

Successful achievement requires students to work at tasks so they have opportunities to practise and implement appropriate learning advice, to gain experience, to raise self-efficacy and to show themselves they are capable of the work. Task-involved students tend to hold incremental views on ability, concentrate on improving their level of competence, develop new skills, and aim to improve against personal standards (Dweck, 2000). A choice of activities and reduced emphasis on teacher-control over tasks can assist in the realisation of students that they are capable of attaining similar outcomes to peers, building confidence in turn to try different strategies. Choices are essential in acknowledging the substantial role catering for individual differences has for teaching self-regulated learning to students, which itself is dependent upon student self-efficacy (Zimmerman, 2002).

The previous sections have demonstrated how Multiple Intelligences learning provides contexts through which students' raised self-efficacy may help them understand the mathematics concepts better, be more motivated to do the work, select appropriate behaviours, and have better attitudes towards mathematics and themselves as capable learners. The next section qualifies the nature of tasks that allow Multiple Intelligences learning to be synthesised with self-efficacy effects. This is necessary in that the role of the tasks underpins the outcomes of this thesis, and there is sparse research data elsewhere to guide the selection of suitable tasks.

5.6 Operationalising Multiple Intelligences in the classroom

The selection and allocation of tasks to individual students carries a high responsibility in determining the outcomes of this thesis. The tasks used in this thesis are required to adhere to Multiple Intelligences principles in that they should allow mathematics concepts to be approached in a number of ways, resonate with students' strongest natural abilities, incorporate and support community values and skills, take into account student differences and personal educational needs, and support the construction of personal self-schemata of mathematics efficacy.

In order to develop a synergetic relationship between Multiple Intelligences learning and students' mathematics self-efficacy, a medium that allows the interaction is necessary. The classroom curriculum can allow this interaction to occur through its tasks. A school curriculum should support the development of every student's thinking, provide opportunities to use and strengthen the variety of their intellectual faculties, and should be personally relevant, otherwise it can appear a meaningless routine (Eisner, 1985). When dealing with problems in abstract terms there are many students who are passive, indifferent and resigned to failure who have a different attitude and are inventive when the same problems are placed in contexts of interest (Piaget, 1972). Therefore it is a reasonable proposal that learning should be guided by personal histories of aptitude and interest (Carpenter & Lehrer, 1999) particularly as there appears to be enduring interest in those activities where people feel efficacious and get pleasure (Bandura, 1997).

Personalised mathematics tasks set in meaningful and appealing contexts involving choices have been shown to increase student engagement, motivation and perceived competence (Cordova & Lepper, 1996). When students engage in tasks in which they are intrinsically motivated they tend to show desirable behaviours such as increased time on task, persistence in the face of failure, risk-taking, creativity, and they tend towards selecting challenging tasks (Middleton & Spanias, 1999). A choice in tasks also allows students to experience a sense of self-determination resulting in higher attendance, the completion of more tasks, and more substantial work (Kohn, 1993). By contrast overt control on students' learning by teachers can quickly generate a state of helplessness in some students. Yates (1997) has described learned helplessness as a loss of motivation, negative changes in cognition and emotion, and a reduction in personal agency tending to passivity. Recognisably, these are some of the characteristics that initially eager mathematics students gradually acquire within traditional mathematics classrooms.

5.6.1 Multiple Intelligences tasks

A review of Multiple Intelligences literature at the present time of writing indicates there continues to be little research that provides mathematics task models useful for this study. As a consequence, task selection criteria have been derived from Multiple Intelligences principles and from the general recommendations for efficacious school practices contained in the reviewed literature.

The role of mathematics tasks is significant in the development of conceptual understanding and for the faithful implementation of Multiple Intelligences theory in mathematics learning programs. Tasks support the concepts that make up mathematics and provide students with opportunities to develop mathematical goals of problem-solving, reflection, and articulation (Fennema et al., 1999). However the selection of mathematics tasks is not an easy thing because although many interesting tasks exist or can be created they need to have a role through children's eyes (Romberg & Kaput, 1999).

This aspect may be met by using tasks in which students express an interest or show ability, attracting and encouraging students because of their intrinsic motivational value. An individual's interests are dispositions that have developed over time, are stable, associated with increased knowledge, and have value as cognitive references (Krapp, Hidi & Renninger, 1992). A reluctance to be engaged as an active participant has been cited as a problem leading to low mathematics achievement (Fullarton, 1994) and most students need to be galvanised or activated as a precursor to classroom engagement (Bandura, 1997). Interesting problems can serve as a foundation for learning and may offer this role of purposively activating students' prior knowledge (Harris et al., 2001). While interests are not necessarily indicative of intellectual strengths, a special or personal relationship with a topic, *knowledge domain*, or subject matter such as computers or music can lead to altering an individual's psychological state, creating motivation (Hidi, Renninger & Krapp, 1992). Gardner (1995) has defined a knowledge domain as "any cultural activity in which individuals participate on more than a casual basis, and in which degrees of expertise can be identified and nurtured" (p. 202).

People have preferences for engagement that develop on the basis of three critical factors: innate ability; environmental opportunity; and interpersonal social contexts that allow intrinsic motivation to be developed from autonomy, self-perceptions of competence, and encouragement (Deci, 1992). Factors that influence interest are both individual such as culture, background knowledge and emotions, and are situational, involving manipulatives, social interaction, content, games and puzzles (Bergin, 1999). Particular classroom activities may enhance understanding because they are interesting and stimulating to the mind's stronger cognitive structures. As a result of these particular interactions between aptitudes and opportunities within the learning environment, interests can emerge (Hidi et al., 1992) and intelligence can develop (Eisner, 1985; Sternberg, 1999, 2000), supporting the Multiple Intelligences perspective that intelligences as psychological potentials may be evoked as a consequence of the experiences, cultural influences and motivational factors that affect a person (Gardner, 1995).

It is argued here that integrating Multiple Intelligences tasks in which students show interest and ability into the curriculum may be more likely to promote student confidence and achievement through resonant cognitive and affective schemata, positively altering those four input principal sources of information by which self-efficacy is derived, namely past performances, vicarious evidence, persuasion, and physiological reactions. Behaviours associated with engagement in interests include prolonged focus, attentiveness, and feelings of pleasure, equating in schools to greater concentration, persistence, and positive affect.

5.6.2 Profiles of student intelligences

Obtaining indications of student strengths in the form of a student profile is an essential pre-cursor of planning and preparing individualised mathematics tasks. Information on student strengths is necessary to construct mathematics tasks. However although obtaining a broad indication of student abilities is part of Multiple Intelligences learning practices there is little research information on the form of that data collection. In a study to investigate the effectiveness of Multiple Intelligences instruments in predicting academic achievement Osborne, Newton and Fasko (1995) found that the reviewed self-descriptive types of instruments had a poor correlation with academic achievement.

The literature search on mathematics education revealed few studies using validated instruments to determine the individual intelligences profile of students. Two instruments that have been reported as field-tested, with reliability and validity data are the Multiple Intelligences Developmental Assessment Scales (Shearer, 1996) and the Teele Inventory of Multiple Intelligences (Teele, 1992). The effectiveness of these and other instruments will only be determined by rigorous application, and publication of results. As Multiple Intelligences learning research is increased, the dependability of data-collection instruments may emerge. However, the lack of available guiding studies means that the selection of a qualitative or quantitative research paradigm will influence the appropriateness of choice of instruments. There appears a tension between the paradigmatic emphases within Multiple Intelligences theory for authentic assessment (which implies the use of qualitative instruments such as interviews), and the call for research-based “hard evidence” of the impact and value of Multiple Intelligences theory in practice.

It is advisable on the grounds of reliability that data from the assessment of students’ multiple intelligences should only be construed as an indicator of students’ potentials, implemented to assist learning and not used for defining limits to those potentials.

5.6.3 Characteristics of Multiple Intelligences learning

The key characteristics of a program implementing a Multiple Intelligences approach to teaching and learning are summarised as follows:

- Learning must be personalised to student needs
- Student strengths should be matched to relevant parts of the curriculum
- Assessment should be contextual using intelligence-fair measures
- Knowledge imparted should be culturally valued
- A variety of tools and media should be used in learning

Multiple Intelligences learning requires at least three specific criteria for assessment, in order for that process to have some fidelity with the theoretical principles (Kornhaber, 1997). These are:

- That assessment goes beyond traditional abilities of verbal-linguistic, logical-mathematical and visual-spatial capacity
- That assessment is intelligence-fair in that it does not solely rely on pencil and paper, and verbal comprehension tools
- That assessment is domain based, taking place within the sphere where the intelligences are relevantly assessable.

In addition to these requirements, five general conditions are placed on assessment:

- That students understand the tasks
- Students are encouraged to do their best work
- The observers are adequately trained
- There are clear scoring procedures
- Observers' judgements are reliable

The term "*observer*" is used here in the sense of an expert assessor. Observers are differentiated from classroom teachers because the use of intelligences other than the traditional ones is expected to be involved in assessment. Teachers are presumed to have expertise in verbal and logical assessment, but different sources of expertise are required to assess performance in the diverse other intelligences (Kornhaber, 1997).

Methods by which Multiple Intelligences theory can be applied in mathematics learning have been described in this section. The thesis proposes that by using the principles of Multiple Intelligences theory to provide a mathematics intervention, student self-efficacy for performance in mathematics may improve as a result of their feeling more confident about mathematical tasks, and through applying themselves more. It is therefore necessary to examine how mathematics self-efficacy is measured in a mathematics classroom, in order to determine if the Multiple Intelligences program does have a positive effect on that construct.

5.7 Operationalising self-efficacy in classroom mathematics learning

5.7.1 Measuring mathematics self-efficacy

Mathematics self-efficacy has been defined as “a situational or problem-specific assessment of an individual’s confidence in her or his ability to successfully perform or accomplish a particular task or problem” (Hackett & Betz, 1989). Self-efficacy for performance in mathematics tasks has been operationalised in mathematics as a score in the measure of an individual’s self-beliefs about the capability of performance in some particular aspect of mathematics (Pajares & Miller, 1995).

Measurements of perceived self-efficacy aim to identify the upper limits of people’s perceptions of their capabilities, along with scaled measures below that (Bandura, 1989). Strength of efficacy belief is determined by a Likert scale, usually ranging from zero (no confidence) to a scale maximum such as 8 or 10, representing total confidence. The measure of personal self-efficacy for mathematics performance is obtained as a score calculated by summing the response values, thereby demonstrating strength of confidence in one’s capability for certain tasks (Fouad & Smith, 1996; Hackett & Betz 1989; Lopez et al., 1997; Lopez & Lent 1992; Randhawa et al., 1993).

5.7.2 Self-efficacy task conditions

The strength of efficacy beliefs varies over tasks, and strength in one learning area is not necessarily related to or comparable in strength to another. In practical terms, this means that the items used in a mathematics self-efficacy scale should be comparable, and related to the course. It also means that conclusions about student efficacy should be limited to the particular aspect measured. For example, if high self-efficacy is obtained for arithmetic, it does not automatically imply that students have high self-efficacy for algebra.

Bandura (1997) has specified certain conditions for measuring self-efficacy that have been applied in this thesis and are briefly described to allow for replication of this study. One condition is that because efficacy beliefs differ in level, efficacy scales need to include a range of challenging tasks. This can be refined by the inclusion of differing contexts within those tasks, although the scale items used in this thesis were restricted to standard classroom mathematics tasks. It is essential to refer to perceptions of whether one “can do”, rather than “will do”, as the judgement of capability is different from intention (Bandura, 1997). It is believed that this advice is used in the instructions to the self-efficacy instrument used in this study.

A second condition is that because the effectiveness of determining student self-efficacy in mathematics can be blurred by the use of instruments that only offer general contexts (Bandura, 1997) there needs to be a specific correspondence between the tasks on which efficacy judgements are made and on which performance is measured for credence to be attached to conclusions about the predictive power of self-efficacy (Bandura, 1986; Pajares, 1996). This requires that the achievement assessment tasks and tasks used in the self-efficacy instrument need to be congruent. It is believed that the recommendation is adopted for this study.

In terms of the literature review exposing similar or replicable measures of self-efficacy for mathematics for use in this study, conditions for specificity have meant that much of the disparate research using efficacy scales is not generalisable because the scales may not be validly applicable outside of their particular contexts. In a review of self-efficacy measures found in educational and psychological literature, the majority of self-efficacy instruments were found to deal with small samples, were inadequately normed, and few had reliability or validity data (Vispoel & Chen, 1990).

This raised the problem of how to generate an appropriate mathematics self-efficacy scale for this study. The literature review for this thesis showed that the Mathematics Self-Efficacy Scale (MSES) created by Hackett and Betz (1989) has been used in studies that involved refinement and validation of the instrument (Pajares & Langenfeld, 1993; Pajares & Miller, 1995). The MSES model was adopted here because its prior use represents research environments educationally similar to this study involving year eight mathematics students in Australia.

Research on the interaction of Multiple Intelligences with self-efficacy and effects on mathematics achievement was not evident at the time of developing this study (1997) and recent electronic searches have indicated research in this is still sparse. While Multiple Intelligences application in middle school mathematics education has been described in one emergent study as creating increased confidence for students as mathematics learners (Eilers et al., 1998), self-efficacy was not used as a major descriptor of that confidence and the research was limited to a single Action Research model. The review of literature has shown professional interest in the interaction of these theories but no research publications have been evident in the sources reviewed. No research descriptions on the application of Multiple Intelligences learning on mathematical self-efficacy and mathematical outcomes in Australian settings were evident at the time of writing. However, it is pertinent to note that self-efficacy is mentioned as important in planning for teaching-learning programs in middle schools in Western Australia. The mechanism for involving self-efficacy has been suggested as operating through a “negotiated curriculum” and through “negotiated assessment” (Department of Education Services, 1999, p. 61) aiming to provide children with some capacity to exert control over their lives congruent with their developing the independence found in adolescence.

This advice for the local context has been co-incidentally adopted in this thesis. Multiple Intelligences theory is applied in this thesis in the form of mathematics tasks that offer choice to students in terms of engagement with learning opportunities. This choice also allows students to select from a number of ways they may feel most confident in showing understanding of mathematics concepts. The use of Multiple Intelligences interventions involves a cooperative and consultative learning process, and meets the pedagogical recommendations for negotiated curriculum and assessment.

5.8 Conclusion

It is proposed that using personalised tasks incorporating individual student's cognitive strengths can widen learning opportunities, leading to greater levels of comprehension of mathematical concepts for more students. The choice of tasks aims to allow a richer sense of concepts, and permits a degree of control, enhancing self-efficacy for change. These factors aimed at academic success are proposed to be assisted by a classroom that conveys an atmosphere of mutual respect for school values, for different backgrounds and abilities. Such an atmosphere is offered to impart emotional support to learning in the form of increased self-efficacy for academic success, for social engagement, and for teacher engagement. These skills have been shown to be important for schooling.

Chapter five has drawn attention to the low availability of research studies involving Multiple Intelligences learning, self-efficacy, and mathematics education. There has been an absence of methodological information related to obtaining student intelligence profiles or to the guidance in implementation of Multiple Intelligences theory to mathematics programs. Basic principles that have formed recommendations for this learning program have been derived from Multiple Intelligences theory and from the few formal studies in Multiple Intelligences available at the time of writing.

Although self-efficacy in mathematics is well researched, efficacy is context-specific and requires precision in instrument items (Bandura, 1997). The literature review has provided a model for the self-efficacy instrument used in this thesis.

Chapter six contains the descriptions of the research design, data collection methods, and the intervention procedure.

CHAPTER SIX

METHODOLOGY

6.1 Research design

The purpose of the study was to demonstrate the effects of a Multiple Intelligences learning program on Middle School mathematics achievement and self-efficacy. The review of research literature showed that most studies on Multiple Intelligences learning used qualitative or "Action Research" approaches to data collection. However these approaches do not permit the investigation of a cause and effect relationship between the independent variable of Multiple Intelligences learning and the dependent variables of student self-efficacy and mathematics achievement and therefore this study adopts a quasi-experimental design.

A quasi-experimental design was chosen rather than a strict experimental design because the Intervention and Control groups were accepted as established school classes. Random allocation of students to the control and intervention groups in much of education research is not readily available. The essential aspects of the design were the measurement of student mathematics achievement levels and mathematics self-efficacy at the beginning of the study, the implementation of the learning program, and the measurement of mathematics achievement and self-efficacy post intervention. The major sets of data generated were on mathematics achievement and student self-efficacy in mathematics.

The study incorporated the measurement of other student data in order to both develop the learning program and to provide supporting evidence of the outcomes. An important factor influencing the outcomes of the study was the degree of fidelity between the learning program implementation and the theoretical tenets of Multiple Intelligences theory underpinning the program. The degree to which the intervention reflected Multiple Intelligences learning was assessed quantitatively through measurement of the classroom learning environment.

Data were collected on students' multiple intelligences in order to devise the mathematics learning program, and student engagement was measured as a behavioural outcome of the intervention program. Students' diary records were described in order to further inform the study on affective outcomes of the learning intervention. Except for the student journals all measurements of outcomes were proposed to be quantifiable and able to be analysed statistically.

6.2 Participants

The target population was the year eight cohort of a rural government senior secondary school. The school educates students from years eight to twelve and has a combined male and female population of 550 students. Year eight operates as a transition point between the regional feeder primary schools and the secondary school system. The school is the only major public senior secondary school in the district, which has a population of about 10,000 people.

The year eight student population operated under the name of a "Middle School" which meant that students were taught in a localised number of classrooms, had fewer teachers and smaller class sizes than year eight populations of previous years. This "sub-school" was led by a coordinator responsible for year eight classes.

The year eight population of eighty-eight students was divided into four classes, and these were further grouped into two teams, with two classes per team. The same subject teachers taught both classes within a team. Meetings between team members occurred on a weekly basis to discuss courses, student progress and operational needs. The requirements associated with pastoral care, such as monitoring children identified as at educational risk also formed part of weekly programs.

The year eight student population was placed in four classes after consultation between their teachers in the feeder primary schools and the secondary school Year eight coordinator and teachers. The children were allocated to classes on the basis of forming heterogeneous groups with respect to known ability levels and gender.

Known pre-existing negative relationships between students were included as a further factor in the allocation of students, in that such students were dispersed among different groups.

Four students from one primary feeder school were allocated to the same class on the advice that they would be at educational risk during transition from the primary system to that of the secondary school. They were assessed as being unlikely to adapt sufficiently in the short term to high school functioning.

For the purpose of the research, two classes were randomly selected from the four. These were then randomly designated as the control and intervention groups. The classes were accepted for the study as determined by the school. Students were not randomly assigned to classes. This represents the realistic circumstance of attempting innovative educational practices in schools within a context of real-life demands.

Table 6.1 Summary of student class data

	Mean Age	Standard Deviation	Males	Females
Control Class	152 months	4 months	11	11
Intervention Class	150 months	4 months	12	10

Both groups were taught mathematics by the researcher. Any bias this introduced was controlled through the year eight coordinator having access to both classes to ensure that the delivery of essential components of the curriculum occurred over the intervention period. The coordinator set the educational agenda and the term assessment in mathematics. The researcher was known to school staff as one of the teachers in the district, and was a year eight mathematics teacher during term one from the students' perspective.

The time allocated and used for the field research was nine weeks, from February 1, 1999 to March 31, 1999. This represented the first term of the school year for the year eight students.

6.3 Setting

Mathematics lessons for both the intervention and control group were conducted in regular classrooms at the school. Students in both classes were seated at desks, in groups of four, with self-selected partners.

For the control class, this seating remained as first established for the term of the research. The intervention class was allowed the freedoms of seating and working such that projects could be undertaken. This also meant that the intervention class students could move about the school grounds during class-time as needed.

Class resources included the standard instructional material available to all year eight mathematics students, such as exercise books, textbooks, photocopied exercises and problem sheets. The materials for the intervention class were sourced by the researcher from other departments within the school, or were specifically prepared (as presented in the appendix). These included keyboards, tapes, biological specimens, printed materials and varied materials such as sporting equipment.

Classes were scheduled for four lessons per week per class. Each lesson had a standard length of sixty five minutes. In practice, the school determined that there was a need to introduce technology skills to all year eight students. The intervention class involved in the research lost one class period of time from mathematics instruction per week for four weeks of the term. This resulted in the intervention class receiving four fewer mathematics lessons than the control class.

6.4 Instrumentation

6.4.1 Mathematics self-efficacy

Mathematics self-efficacy was measured using an eight-point Likert scale on which students were asked to rate their confidence to correctly solve problems they would be presented with at the end of their course. The scale ranged from zero representing "no confidence", to eight as "completely confident".

Table 6.2 Sample self-efficacy items

INSTRUCTION	SAMPLE ITEMS
For each question, make a judgement on how confident you feel that you can show your understanding by satisfactorily answering the question.	Nina and Ricci were sisters. They were given $12 by an aunt to spend. Nina was to have twice as much money as Ricci because she is twice the age of her sister. How much did each receive? Show how you worked it out
	Write down three different ways of making the number 24 using the numbers 3, 6, and 12 and the four operations of add, subtract, multiply and divide.

The instrument consisted of twenty five questions, each requiring a selection on the scale. The children's self-efficacy was operationalised by the score obtained from their responses. This score was determined by summing the scale values selected for each question. The sum formed a measure of a student's self-efficacy for mathematics problems, with higher values indicating stronger self-efficacy beliefs.

The Mathematics Self-Efficacy Scale used in the current research was modelled on the problems sub-scale of Pajares' *Mathematics Self Efficacy Scale-Revised (MSES-R)*, with alterations made to reflect the local West Australian mathematics curriculum and teaching schedule (Pajares & Miller, 1995).

The origin of the self-efficacy problem scale lies with the *Mathematics Self-Efficacy Scale (MSES)*, devised by Betz and Hackett (1983), who incorporated a subscale assessing students' confidence to perform mathematics related tasks in that instrument. Mathematics self-efficacy was operationalised by Betz and Hackett as the total score of the MSES. A revised form of the MSES was developed that used a confidence scale based on mid-range difficulty items in mathematics (Pajares & Miller, 1995).

Problem items were selected directly from students' course material, having a similar range of type and difficulty to those items students would experience in the course, and with a concentration on mid-range difficulty. The similarity between efficacy and performance items is relevant in the context of theoretical principles emphasising that the predictive value of self-efficacy to performance requires a matching of tasks in each domain (Bandura, 1986). This need for specificity of assessment in achievement correspondence with self-efficacy has been was confirmed in research (Pajares & Miller, 1995).

Construct validity was derived from the replication of the MSES-R self-efficacy scale for confidence in solving problems. The construct is domain-specific (Bandura, 1986). Given that the instrument used in this research asked students how confident they were in their ability to perform the particular mathematics tasks, and that self-efficacy refers to personal beliefs in the capability to carry out some performance (Bandura, 1997), construct validity was established through correspondence with the operational definitions.

Content validity was investigated through discussion and consultation with the Head of Department (mathematics), Year eight Mathematics Coordinator, and classroom teachers. Alterations were made to the number and type of items on the basis of these discussions to reflect the course content and difficulty range.

Reliability was not determined, but was assisted on the basis of reviewing the items, on replicating the procedures for conducting the measures as set out in the *Mathematics Self Efficacy Scale-Revised (MSES-R)*, on administering the measures in the same way and same locations to respondents, and by using an objective scoring mechanism. The Self-Efficacy Problem Scale was not assessed for test-retest reliability as time and school circumstances did not allow for this.

A copy of the Mathematics Self-Efficacy instrument employed in the study is in Appendix A.

6.4.2 Multiple Intelligences Developmental Assessment Scale (MIDAS)

The multiple intelligences possessed by students within the Intervention class was indicated using the MIDAS instrument which was developed and designed by Shearer (1996). The instrument was developed around the Theory of Multiple Intelligences as described by Gardner (1983). It allows for the development of personalised instruction and assessment programs based on data about students' cognitive strengths and weaknesses.

The instrument has a number of forms catering to different age groups. The form used in this research was the "MIDAS-KIDS", applicable to students in the 9 to 14 year age group. The form used consists of eighty items reflecting intellectual disposition in the eight intelligences. Item questions include self-evaluation of time spent on activities, of ability and performances, and of attitudes to certain activities or circumstances.

Table 6.3 Sample MIDAS items

Logical-mathematical	Interpersonal intelligence
Do you like science, solving problems, measuring and doing experiments? A = Not really B = Maybe a little C = About average D = More than most kids E = More than anyone else I know F = I do not know	How well can you help other people to settle an argument, like between two friends? A = Not very well B = Fairly well C = Well D = Very well E = Excellent F = I do not know

Each item uses a five-point Likert scale to permit a range of responses from "All the time" (4), to "Never" (0). The MIDAS instrument consists of the questionnaire item set and a response form. It may be administered to groups or individuals for self-completion, or as an interview. Time taken for this administration is stated as "typically" requiring thirty five to forty five minutes for self-completion (Shearer, 1996, p. 26). The instrument was reviewed in class as to the instructions and purpose and given to students to take home for self-completion. Self-completion has a legitimate role, according to the author (Shearer, 1996, p. 27), and the students were of a capable reading age to complete the questionnaire.

The questionnaire is computer scored, resulting in a three-part profile giving an indication of specific skill areas and intellectual development profile across the intelligences. Subscale scores are provided in each intelligence printout, giving a qualitative background to the profile. These printouts are obtained by entering the data from student responses into a computer program used to score the instrument. This program is available from the author (Shearer, 1996) as part of the MIDAS instrument package. The MIDAS profile then provides general information which "can be used to formulate personalised educational and career plans by recognising, valuing and focussing attention on areas of strength and potential" (Shearer, 1996, p. 9). Goals of the MIDAS assessment are the development of intrinsic motivation in students and the use of self-knowledge about potentials to enhance achievement.

Shearer (1996) cautions that MIDAS scores are not absolute values of intelligence. They are to be interpreted under the assumption that intelligence is a malleable facility, sensitive to the influences of affect and motivation. The author of the MIDAS instrument (Shearer, 1996) asserts that information about the validity of the instrument results from a large-scale study, including determination of validity and reliability.

Construct validity has been derived from factor analysis, leading to the selection of items of discriminatory ability among the intelligences, although some items (about 30%) were not unique to a particular scale. *Concurrent validity* was evident from an examination of the correlation of MI scales with suitable measures of aptitude, interest and achievement across the intelligences. Correlations were described (Shearer, 1996, p. 80) as meeting expectations. Good internal reliability has been quantified with alpha co-efficients at an approximate level greater than 0.8 across scales.

Inter-rater agreement between children's self-report scale scores and those of parent ratings is reported to be variable, although only the Interpersonal intelligence scale was not statistically significant in correlation calculations. The author of the MIDAS instrument comments that "additional research is needed regarding the MIDAS validity and reliability, but at this time we are just beginning to learn how an MI Profile can be used to increase personal growth/achievement and to facilitate community integration" (Shearer, 1996, p. 94).

A copy of the MIDAS instrument and a sample MIDAS profile are provided in Appendix B.

6.4.3 Mathematical achievement

Data on pre-intervention student achievement levels were obtained using a commercial instrument, the *Student Outcomes in Mathematics Tests-Form A:* SOMS (Mathematics Today Series, 1996). The instrument provides information on individual achievement or mastery in mathematics, including diagnostic information with respect to areas of mathematical deficiency.

This instrument consists of sixty items based on the mathematics curriculum taught to year seven (final year) primary school students in Western Australian schools. The items are composed from four learning strands, given as Space, Number, Measurement and Working Mathematically. The instrument is being refined on the basis of the delivery of education changing to Student Outcome Statements, rather than being determined by external curriculum requirements. Item selection is thus ongoing as the outcomes evolve or are formalised. Items use a combination of written and objective answer forms, and are hand-scored. Scores are determined by summing answers within each strand, and expressing these as a percentage. The scores are converted to stanines, allowing class or school results to be compared to standardised data.

Reliability and validity statistical data have not been available, on the basis of this instrument being developed concurrently with the introduction of the delivery of education under the WA Curriculum Framework (Curriculum Council, 1998). Since the delivery is based on individual mastery of stated outcomes, rather than comparative data, statistical procedures have not been applied to the instrument by the authors.

Content validity is implied by the development of items taken from current year seven mathematics curricula in Western Australian primary schools. Reliability of the data obtained has been improved by item refinement, concise administration instructions, standardised scoring and in testing the instrument across a range of schools, using approximately 2500 students (Mathematics Today Series, 1996).

The pre-intervention achievement scores were used to identify students on the basis of assigning scores below the 25th percentile to the low-achieving group, above the 75th percentile to the high-achieving group, and scores in the range between the 25th and 75th percentile comprising the average-achieving group. Percentiles have been used to divide students into mathematics achievement performance groups by the International Study Centre in the reporting of student achievement in the TIMSS (ISC, 1999). A percentile represents one percent of the population, so the 25th percentile has at least 25% of the scores below that point.

The post-intervention measures of achievement were developed by the year eight Mathematics Coordinator and the Head of Department (Mathematics). These assessments were in the form of written items based on the “Number” and “Space” strands taught during the term. The Number instrument consisted of seven questions on sequences and patterns, requiring students to complete mathematical sequences, apply and derive rules. The Space instrument required students to complete twelve problems on paper, interpreting three-dimensional objects.

These measures of achievement were intended as classroom assessments in keeping with school assessment procedures common to Western Australian mathematics assessment. Such assessment measures are not subject to statistical analysis for estimating reliability or validity. However, they are reliable in that their form has been traditionally used in mathematics, therefore confidence can be placed in judgements of achievement based on results of these classroom tests. Content validity of the classroom assessment instruments was established because the items were sourced from the curriculum taught over the intervention period, and were selected to act as evidence that the outcomes of the course would be achieved by satisfactory performance in the assessment. All the item tasks reflected or matched curriculum outcome tasks in the selection process.

Copies of the pre-intervention and post-intervention assessments are contained in Appendix C.

6.4.4 Student engagement

While student engagement can be manifested through a range of behavioural, cognitive, and affective indicators (Chapman, 2003), it is defined for this study as time spent with class activities, and was considered in this research as interchangeable with “time on task”. It included circumstances in which children were contributing to a productive and positive classroom, therefore was not limited to performance of academic tasks. Student engagement may be considered as the way in which persistence has been operationalised.

A qualitative assessment was made on the degree of engagement it was felt each child gave to the class environment. On a scale of one (disengaged) to five (fully engaged), the researcher assigned a score for each student once per week of the school term, based on participation in class. The student scores of the control and intervention classes were summed to provide a class score for the week. Within each class, achievement level group scores were also calculated. Weekly scores were graphed to provide an indication of variation between classes, and between achievement level groups over the period of the study.

Of all the judgements made, that of engagement may be viewed critically as having the least validity or reliability. However teachers’ judgements are called upon regularly in providing estimations or opinions about such things as student behaviour, attitudes, peer relationships, emotional states, motivation, and the possession of practical school competencies such as getting to class on time or arriving with the necessary books. None of these opinions is necessarily based upon the collection of quantitative data with some instrument nor are the opinions purposely developed with deliberate forethought given to an occasion when that opinion may be called for. Such opinions may be considered informal assessments, yet are judgements that carry authority due to the possession by the assessor of appropriate qualifications and experience. Examination of teacher-judgements about classroom behaviour has been critical of the lack of range in described behaviours, and lack of psychometric rigour in scales although teachers show a capacity for stable ratings over time and for discrimination between criteria (Yates, 1997).

A sample of the record form devised by the researcher to record "Engaged Time" is given in Appendix D.

6.4.5. Individualised Classroom Environment Learning Questionnaire (ICEQ)

This instrument was developed by Fraser (1990) to assess the nature of the learning environment in the classroom.

The ICEQ assesses "those dimensions (namely, *Personalisation, Participation, Independence, Investigation and Differentiation*) which distinguish individualised classrooms from conventional ones" (Fraser, 1990, p. 1). The perspective of either students or teachers is allowed. Both Long and Short forms of the instrument are available, with the long form having the advantage that it is more reliable and accurate. The short form takes about half the time of the long form, which is estimated as requiring up to thirty minutes for high school students to complete.

The Actual Classroom Long Form was used in this research. This is the recommended form (Fraser, 1990, p. 3) when an accurate assessment of the classroom environment is sought. It contained fifty items covering three dimensions related to the factors of human environments. Student views were obtained with this instrument to compare the actual classroom environments of the control and intervention classes.

Five scales variables are measured, on which students rated their opinion of what actually happened, on a Likert scale:

a) *Personalisation* reflects the degree to which the teacher considers student feelings. In the classroom, this would be evident in creation of opportunities for interactions between the teacher and students. There would also be evident concern for students with respect to their welfare and social interactions.

Eg: *The teacher considers students' feelings*.

b) *Participation* reflects the degree to which students are encouraged to participate, as opposed to passive receivers of information.

Eg: *The teacher lectures without students asking or answering questions*.

c) *Independence* refers to the extent to which students have control and make decisions. An example would be that students choose co-workers for group work

Eg: *Students choose their partners for group work*.

d) *Investigation* would place emphasis on problem-solving skills and researching answers.

Eg: *Students find out the answers to questions and problems from the teacher rather than from investigations* (reverse-scored item).

e) *Differentiation* refers to the degree to which a difference is recognised in terms of individualised learning characteristics being used in the classroom.

Eg: *Different students use different books, equipment, and materials*.

(Fraser, 1990, p. 5).

The ICEQ is administered to groups using a standard booklet of instructions and items. The data are collected on an answer sheet which may be hand or computer scored. Student scores on the Likert scales are summed to give a value for each dimension scale. In most applications, the means of dimension scale scores are calculated and used for class comparisons, using statistical methods such as t-tests. The researcher hand-scored the answer sheets in this study. The ICEQ has been investigated for internal reliability. Alpha reliability coefficients are provided and indicate acceptable internal consistency (Fraser, 1990, p. 14). Scale independence information has been provided (Fraser, 1990, p. 14). As well, cross-cultural validity has been demonstrated for the instrument through administration of the instrument to Australian and international students (Fraser, 1990, p. 15).

A recent meta-analysis of research interventions aimed at improving mathematics achievement in low achieving students and those considered at risk of mathematics failure (Baker et al., 2002) cited uncertainties in assessing the effects of context-based interventions because of quasi-experimental designs and a lack of measures of implementation fidelity. This study deliberately includes the ICEQ as an indicator of the implementation of MI principles.

The ICEQ is reproduced in Appendix E together with a sample copy of the answer sheet.

6.4.6 Student diaries

The use of student diaries was included to collect data on students' opinions of their mathematics experiences. The use of diaries was not a requisite or standard practice in mathematics education at the school. Diaries were initiated in the second week, with time allocated each Friday for students to record their feelings. Diaries were not collected or viewed by the researcher until the end of the period of the study, when they were reviewed for attitudinal changes.

Table 6.4 Summary of implementation

WEEK	INTERVENTION CLASS	CONTROL CLASS
1	DAY 1: SELF-EFFICACY 1, DAY 2: MIDAS ADMINISTERED'	DAY 1: SELF-EFFICACY 1, DAY 2: MIDAS ADMINISTERED
2	DAY 1 SOMS ASSESSMENT 1 DAY 5: DIARY	DAY 1: SOMS ASSESSMENT 1 DAY 5 DIARY
3	DAY 5: DIARY	DAY 5: DIARY
4	DAY 5: SELF-EFFICACY 2	DAY 5: SELF-EFFICACY 2
5	DAY 5: DIARY	DAY 5: DIARY
6	DAY 5: DIARY	DAY 5: DIARY
7	DAY 4: CLASSROOM ENVIRONMENT QUESTIONNAIRE DAY 5: DIARY	DAY 4: CLASSROOM ENVIRONMENT QUESTIONNAIRE DAY 5: DIARY
8		
9	DAY 1: SELF-EFFICACY 3 DAYS 2 & 3: SCHOOL MATHEMATICS ASSESSMENT DAY 4: DIARIES COLLECTED	DAY 1: SELF-EFFICACY 3 DAYS 2 & 3: SCHOOL MATHEMATICS ASSESSMENT DAY 4: DIARIES COLLECTED

6.5 Ethical issues

Permission was sought from the school and education authorities to conduct the study and obtain and use data collected as part of teaching and learning (letter of approval Appendix F). Data were collected and coded to ensure confidentiality of students and kept secure. No names or personal identification labels were attached to data used in statistical analysis. As per University regulations, original data will be kept for a period of five years at Curtin University's Bentley Campus.

6.6 Mathematics program procedure

The following sections describe the teaching, learning and assessment procedures in some detail. Given that there is no prescriptive standard for the implementation of this Multiple Intelligences program in mathematics, it was considered important to include such detail. The aim has been to provide a realistic indication of the variation from traditional classroom procedures that has occurred through using Multiple Intelligences principles in mathematics learning. The lack of other studies in the application of Multiple Intelligences theory to Middle School mathematics and the specificity needed for measuring mathematics self-efficacy has necessitated a detailed description of the intervention procedure. The detail is considered necessary for replication of the learning program should that be required.

The delivery of the learning programs to the Intervention class and the Control class are described in three-week intervals. Independently of the researcher, the Year eight mathematics coordinator determined

- the strands of mathematics to be taught
- the time available for each strand
- what to assess
- what form of assessment was to be used for determining school reporting levels
- what achievement level was applicable to student performances.

Teaching aims were determined by the Student Outcome Statements associated with strands chosen (Appendix G). Daily work for the control class was determined and provided by the year eight coordinator and delivered by the researcher who functioned as their regular mathematics teacher.

The content and modes of presentation of coursework for the intervention class were determined by the researcher, and are described in the procedural sections 6.7.1, 6.7.2 and 6.7.3. The student learning environment operated in accordance with the school's student management practices (Appendix H) and with the school's model for assessment (Appendix I). The Curriculum Framework provided five criteria for assessment. These are that assessment must be valid, educative, explicit, fair and comprehensive (Curriculum Council, 1998, p. 210). In assessing student progress, an overarching set of objectives and guides were used for both classes in order to make judgements of performance attainment (Education Department of Western Australia, 1998b).

Feedback to students in relation to general progress was achieved through the usual classroom interactions of observation, correction, discussion and guidance. Formal assessment gave a level of student achievement for each strand taught in the program. This occurred at the end of term using a test based on Student Outcome Statements, where "The Student Outcome Statements in mathematics provide descriptions of the major outcomes that students will be working towards during the compulsory years of education. While they are not a curriculum, they provide a powerful indication of what is essential and valued learning" (EDWA, 1998c, p. 2).

Student behaviour was managed by creating a positive environment, utilising school-approved methods of dealing with problems as they arose, and encouraging all students to be responsible for themselves and respectful of others (adapted from MSB policy, Appendix H).

Weekly team teacher meetings discussed students who displayed either positive or negative behaviour, and parents were informed by letter in both circumstances.

6.6.1 Intervention class program weeks 1-3: number strand

Standard introductions were made through the student assembly.

a) The Self-Efficacy measure was introduced and implemented in the first teaching period to students. Its purpose was explained as a way of understanding how students felt about the mathematics they had done in primary school and how capable they felt in secondary school.

b) Multiple Intelligences theory was discussed with the intervention class students. It was described in terms of personal interests, the particular ways people exhibit talent, the value of diversity to other people, and how the subject of mathematics could be taught through those multiple talents. A particular emphasis was placed on the importance of personalising learning to help understanding. To this end, students were to have a diary to enter their thoughts about their mathematics learning.

c) The MIDAS was distributed to students on the second day of term. The purposes of responding to the MIDAS were discussed with students before distribution.

Introduction of Content: Patterns in Number

i) Student discussion elicited information on their concept of “patterns” outside of the numerical realm. Patterns were discussed across contexts. Past experience was evident and children responded differently with patterns in numbers, as the topic had been covered to some extent in primary school. With prompting, students were readily able to recognise geometric patterns based on the concept of repetition. Using this relatively simple definition, students could provide limited examples from their areas of interest eg weather, temperature, solar and other patterns. These were drawn as “bubbles” linking different interests into the central theme of patterns on the board. From that, a more complex ideation of patterns such as in behaviour, of lifestyles or sporting rules was developed.

The purpose of this discussion was to establish a connection between meaning and concrete examples, and to demonstrate the variation in context that can occur.

ii) Students received the information from their MIDAS profiles on the third day of term. Some viewed the indications of their strengths with a degree of suspicion, feeling these did not appear to fit their conscious declaration of interests. This was discussed with them in terms of individual differences and individual's preferred strengths amidst a generalised set of abilities.

iii) On the basis of their indications, the students were introduced to the variety of activities that were developed on the topic of patterns across the multiple intelligences. Students selected from those activities that fitted their interests and were instructed to work through them (Appendix J).

Students were allowed to choose their seating arrangements. Those who expressed similar preferences worked together. The distribution of interests for "Number" activities were for the musical-rhythmic, logical-mathematical, bodily-kinesthetic, verbal-linguistic, visual-spatial, naturalistic and interpersonal tasks. No-one chose the intra-personal activities.

Students began work in this fashion from the instruction sheets.

It was intended that the activities cover the work on patterns by including intelligences other than just logical-mathematical. That is, the subject of "Patterns in Number" was partially to be understood through the medium of other contexts. Since the school required the assessment of performance in tasks as set by the year eight coordinator, all students had to be taught the role of patterns in "Number" in mathematical form, and be able to demonstrate understanding and task competence in that mode.

Therefore, concurrent with Multiple Intelligences activities, students were given worksheets (Appendix K) similar to those used in the control class, to work on in class or complete at home. These were then worked through with the whole class, taking approximately fifteen to twenty minutes per period.

The Standardised SOMS assessment was administered at the start of the second week. It had required the first week to organise appropriate forms and obtain approval from the Mathematics Head of Department to assess all year eight students. These were sent to the instrument source for marking. This instrument required approximately one and a half periods to implement.

Adjustments to teaching

After commencing the intervention, it became evident that some children in the intervention class were unable to operate on the activities constructively. That is, they were unable to initiate the work because the tasks were unclear to them.

In discussions with the children about such difficulties, it was evident that the developmental stage at which the work was set, was too high. (At a later date, materials were sourced from those used for children operating at a concrete level in the middle-primary year level of mathematics. In the opinion of the researcher, these would have suited the low-achieving students better as an introduction to Multiple Intelligences activities.)

The homework provided on number patterns was not being adequately done, or was not attempted by some students. This included the same children who were having difficulty comprehending the tasks. It was decided not to pursue homework as a regular policy, although there was a school policy that homework be a regular and regulated component of mathematics classrooms. It appeared that more benefit to students' classroom functioning would result if such work was attempted in class under Multiple Intelligences principles.

Not all students demonstrated an inability for initiation of tasks. Some students were quite capable of recognising the nature of patterns in contexts which interested them and transforming that conception into the patterns involving mathematical notation. These children, clearly higher achievers, worked on their tasks with more independence.

Others did not possess the skills necessary to do the tasks. Some children had difficulty comprehending the instructions. Some were unable to draw up figures, or had difficulty in ordering responses in a logical manner. This raised the practical problem of how much responsibility to leave to the children when operating with assumptions about their personal abilities. It underlines the importance of knowing the children well. The transition year from diverse primary feeder schools to high school restricts an intimate knowledge of student strengths and weaknesses.

The degree of emphasis was subsequently altered from learning through the intelligences (applying the concept within domains), to teaching to the intellectual array (using examples from other domains). The activities were partly taken and modelled by myself, with their mathematical equivalent presented concurrently. More control and direction was assumed. At the time, some concern was felt that the children may somehow "lose out" or fall behind other classes because of what seemed a diversion from teaching the standard mathematics program. A factor of such new programs is that teachers need confidence in their value.

This modification altered delivery from *teaching through* the spectrum of intelligences to *teaching to* (or appealing to) diverse modes of understanding. Effectively, delivery moved between the more standard method of modelling using varied media and the alternative method of students operating within the medium of their preferred strengths. For example, in using the musical intelligence domain, examples of patterns were played to the class by one of the musically competent students in a simple form. These were numerically written on the board and increasingly complex patterns were played and written in numerical form (see Appendix J).

This modification was made in order to compensate for some students' lesser ability for initial self-direction. It was evident that Multiple Intelligences learning requires such adjustment periods, which again make an "enemy" of time constraints.

In keeping with the benefits of concrete operation and intrinsic motivation, the visual-spatial intelligence was appealed to with students working on sheets involving patterns developed by colouring geometric shapes after discussion and research on artefacts of other cultures (Appendix L). Students worked different patterns using different colours and then established number relationships to the series.

From the colour patterns evolved the explicit derivation principle of rules for establishing order within the pattern. Students would colour the series, write out the number appropriate in the series and attempt to find the rule.

At certain points when the concept had sufficient *exposure* via activities, the emphasis would shift from Multiple Intelligences tasks to traditional tasks. This is required for maintenance of access to required student outcomes. The purpose of varied tasks was to make concepts more meaningful to students before they attempted to embed or express relationships in symbolic forms.

An emphasis was generated on context. Patterns in student environments were utilised (as opposed to mentally constructed images or pictures from books). Because the children had evident difficulty in constructing the methods of recording information from varied tasks, these were provided in simple form to scaffold the tasks. Children were given suggested contexts within the school environment (for example, they went out as a group and noted the brickwork and flagstone pattern arrangements). They were permitted to go about the school grounds to seek out the provided patterns and any others that could be found.

Behaviour and conduct of the work was appropriate. Students noted varied pattern relationships as cars to tyres, cars to painted bay lines, fence rails to uprights, and window panes to windows. Although simple, these examples gave support to subsequent decontextualised discussions when the rules of the found relationships were developed back in the classroom.

These concrete tasks appear simplistic but do not exhaustively represent the spectrum of students with traditional abilities present in the class. The children who were very mathematically capable participated, derived their rules and moved onto work-sheets where they were able to progress independently and confidently. Any limited focus on the nature of these simpler tasks concealed the social benefits of the program (which introduced fun, realism and successful engagement for the class).

Classroom consolidation and linkages between the varied tasks led students to the underlying outcome statements, that they be able to recognise, represent and describe patterns. The Multiple Intelligences program enabled these three factors of understanding to be embedded in personally comprehensible contexts.

“Sequences and Series” were introduced using the *theme* of Fibonacci numbers. Themes are important components of Multiple Intelligences learning, because they increase the opportunity for entry points of different perspectives. Students worked in groups for theme activities. The decontextualised descriptions of Fibonacci series are difficult to comprehend, but practical examples gave a context to the numbers, using diverse methods such as the “Body Count”, “Making Music”, and “Flowers and Fruit” (Appendix M).

Students worked in groups through these activities in rotation, attempting to find and then verify the Fibonacci rule in diverse contexts. The requirement to work together and function appropriately drew upon their inter-personal skills.

Work on patterns, number series and sequences was completed with a co-operative activity (Appendix N). The groups were used to undertake two problem tasks needing strategic competence, guess and check strategies, pattern recognition and induction of pattern rules.

Groups that contained children who were very competent made good progress in this activity. Groups that comprised only average capability and low-ability children were not as adroit at achieving the solutions but they persevered.

The development of cooperative learning, recognition of shared interests and diverse contextual learning were useful in raising children’s awareness of their interpersonal intelligence. The valuing of self and the encouragement of respect was important to students feeling good in class, and was included directly and indirectly in interactions between the students and their teacher.

6.6.2 Intervention class program weeks 4 – 6: space strand

The second set of lessons comprised activities associated with the “Space” strand. Students were by now familiar with the idea of working on activities that they felt allowed them to understand the content material better. The space strand was expected to be more familiar to students, since they are more familiar with the concept of space than number patterns.

As a result of the researcher's reflection on the lack of confidence students showed initially with the introduction of variation to their standard experiences of instruction, indicators of outcomes were discussed with students in more detail for this strand than in the "Number" strand. It was necessary to show students how they might demonstrate achievement of outcomes in tasks. These goals were recognisably non-threatening because they were not "tests" but were embedded in performance tasks. By being given choices, it was felt that students may have been more motivated to attend to the tasks, leading to enhanced chances of success.

The activities covered the outcomes for students to be able to visualise, draw and model shapes, and ways of embedding SPACE outcomes in diverse tasks were devised (Appendix O: SPACE activities).

Students were allowed choices of tasks. For some, the choice conflicted with indicated preferences from the MIDAS. Again, this was not seen to be problematic since a primary function of Multiple Intelligences learning was to encourage engagement. For other students (and it was particularly noticeable for the mathematically high achievers), the task choices matched their proclivity.

Particular care was taken to range the activities over a wider set of cognitive levels of comprehension than was initially done with "Number", in order to enable the concrete operational levels to be catered for.

The importance of catering to diversity in order to encourage engagement is evident in that the "Feely-bag" activity (chosen as the first task by two low-achieving students) equated to Level One in the Outcome Statements (a junior primary task). The secondary school levels provided in the Interim Teacher Support Document (EDWA, 1998c) begin at Level Three, indicating the discrepancy between developmental levels and the symbolic proficiency expected for secondary school levels of mathematics learning.

The activities covered the range of intelligences and included differing levels of difficulty (in order to reflect Multiple Intelligences theory identifying differing developmental levels across domains of functioning). For example, the "Imagining shapes" task involved students writing a story description of how to locate an article in their house. A partner then read the article and attempted to reproduce a 2-D diagram from the description. This activity uses interpersonal, intra-personal, verbal-linguistic and spatial intelligences. The "Seeing is Believing" task involved intra-personal intelligence with the optical illusions of 3-D cube colouring, as did the "Feely-bag" — a good starting point for low-achieving children who lacked confidence in the face of the more complex tasks. The 3-D "Lego" and isometric constructions suited the logical-mathematical students.

Students were informed that they could select activities, carry them through and present their performances if they felt they had matched the Outcome indicators provided. Ten periods were allocated originally for this strand.

All students were intensively and constructively engaged in these activities. Developmental levels ranged from the concrete ("Feely bag") to the abstract (Isometric drawing). Some students followed a developmental approach to the tasks, through selection and completion of 2-D leading to the 3-D tasks. Others expressed a desire to begin at the higher outcome level. This reflected the different confidence levels, but students were strongly motivated.

Students were very comfortable with the "no-failure" continual assessment as they worked through the activities. They preferred to make their own constructions and did not seek to imitate. In a competitive, abstracted task environment it would have been expected that children may imitate others' work as a means of completing tasks, avoiding work or covering their lack of skills. However, avoidance behaviour was not evident. The multiple activities introduced an enabling process for all children to enhance understanding of mathematical concepts.

The low achievers were willing to attempt the activities. The high achieving children began with developmentally advanced tasks in the logical domain (the 3-D isometric drawings). Assessment was informal at this stage, but students were required to generate products reflecting outcome levels.

It was arranged for the music teacher to do some choreography with the children so as to link the concept of 3-D space with dance, creating the opportunity to view the subject through the musical-rhythmic and bodily-kinesthetic intelligences, but inflexible timetabling precluded that happening. This problem also occurred in the topic of “Number”, where an “outside” expert in another learning area was to have demonstrated patterns in dance.

As the students progressed through the activities, their initial choices kept them involved. As the choice of preferred media diminished, students’ engagement diminished somewhat. It emerges that motivation again becomes a problem similar to standard instruction once choices become restricted, or move away from being contained in domains reflecting strengths. Gender factors (which were not focussed on in this study) may also have had an influence on task choice. The low achieving girls showed some reluctance to engage in the abstract tasks of 3-D isometric drawing, although the low achieving boys attempted this readily. Engagement seemed directly influenced by the degree of interest or strength.

An interesting area was the computer program tasks, which interested most students. Because of a primary school equity program, some of the mathematically low-achieving children had a relatively high degree of competence in computing. Several of these children were very adept as a result of that past opportunity and were able to demonstrate this valued competence to high achieving mathematics students. This represents a situation where technology can enable students to gain emotionally as well as cognitively from class if suitable tasks allow skills and interests to be factored into learning.

6.6.3 Intervention class program weeks 7 – 9: chance and data strand

The third strand originally planned for the term was introduced. This was “Chance and Data”. The basis of discussion was how society goes about finding out answers to questions. The students were invited to reflect on, formulate and list questions on topics that interested them, or about something they were particularly involved in.

In order to demonstrate the concept of research to answer questions, it was proposed that students find who could make a paper plane fly further than others. Students were challenged to derive the method of answering the question, arrange the data and validate it. This led to their constructing planes (individual designs) from identical materials (controlled data). The experiment took place with data recording, measurements and prizes. The requisite skills of collecting data were thus modelled in a real context.

Each student then determined a realistically achievable question answerable in the school environment and worked on the way to find answers, record data and present conclusions. Questions were as diverse as interests. For example, one student wanted to know "where is the optimal position to shoot from in basketball". Another sought public opinion, asking "do students like my drawing skills?" Some were ordinary: "what is the most common pet in the class?" Whatever the question's content, the process of involving student interests in the answers caused activation, appropriate learning behaviours and a positive classroom climate. Students worked their way through the methods each had devised. Students emulated the "flight" model in recording and presenting data in their research.

Class low achievers had difficulty in clarifying and selecting questions that could be answered within the school, and had difficulty with methods to collect and record data. They required individual assistance and guidance. The Multiple Intelligences tasks did not replace teacher instruction, but they served to include students' interest in constructing mathematical principles and skills. By simplifying their goals, these children built up competence, and were happily engaged.

The actual investigations appeared chaotic and were difficult to cater for in a diversity of interests. The duty of care obligation sometimes conflicted with the requirement that students needed free movement about the school. The Kinesthetic activities required close supervision, and trust in the students was necessary to enable them to complete the tasks appropriately.

Of importance was the need to make judgements as to whether the students were demonstrating performance proficiency in terms of outcomes. Multiple tasks meant multiple modes of assessment and the need to specify when assessment was appropriate. Assessments included qualitative judgements based on observing the students in the task performance, and were restricted to informal feedback in this early stage of the school year.

Throughout the term a record was kept of students' attentiveness to tasks. The data included consideration of student interactions as well as application and persistence, as some tasks required cooperative engagement in order to be satisfactorily completed. This may be considered as the inclusion of interpersonal intelligence in the data. Again this was a qualitative assessment of multiple variables acting through the learning program. The intra-personal intelligence of students was considered to be reflected in part by the journal writing, and through the revelation of self-efficacy judgements. The third self-efficacy measure, and school term tests were administered in week 9.

6.6.4 Control class program weeks 1 – 3: number strand

The standard procedure of instruction applied to the control class. Expectations of behaviour and work habits were delineated. Students were given a general idea of the type of content they would encounter through handouts on the strand outcomes, in the form of behavioural objectives. Materials for the control group were mainly prepared by the year eight mathematics coordinator.

Work was done in workbooks and derived from such sources as photocopied instruction sheets, worked material on the board or from textbooks. The workbooks were monitored informally during lessons for completeness and proper practice. The books were collected twice in the term for comprehensive judgement of working habits.

For the first set of lessons on the strand of "NUMBER", students manipulated number sequences (Appendix K), transferring the constructions to diagrams. These formed the basis of several lessons built around a variety of patterns that could be equated back to number series.

The introductory set of lessons led to the formal use of the textbook for the remainder of work on the "Number" strand. This standard school approach was intended so that students possessed a resource designed for their development levels, allowed regulation of progress, and provided answers to problems for self-checks.

Student groups were initially self-chosen, but were ultimately re-assigned by the teaching teams on the basis of effective interaction for learning. As standard practice, each lesson began with a brief review of previous work, a description of the new material and then students worked on the tasks. Ongoing assessment was undertaken by assignment (Appendix P).

6.6.5 Control class program weeks 4 – 6: space strand

The set of lessons for the "Space" strand was introduced as a discussion on how different occupations represent real situations and require different perspectives. Using worksheets (Appendix Q), student activities initially were based around freehand drawing of simple constructions made from small blocks. Students worked within groups on these drawings. Most students were capable of performing these tasks quickly. They were given several periods in which the tasks were to be completed. Students were supported in their work by individual assistance. They were able to progress within the task sheet at different rates.

Once the introductory concepts of representing objects in space had been covered, students were moved onto the use of a commercially available resource, the "Points of View" set of lesson plans.

Rotating task sets for 3 groups were used in order to share resources. Students were organised into these groups based on combining class groups, and the need for students to be collectively constructive. Each group would then work on the tasks using instructions and materials made available in a work package. Within a task set, students would perform the tasks, record their results in a results sheet then present that for checking by the teacher (Examples of the plans, task sheets and record sheets are found in Appendix R).

In this way, both the rate of progress and the degree of performance for the tasks were assessed. The level at which students were able to demonstrate competent functioning was also recorded on the sheet, using Student Outcome pointers or examples as a guide (EDWA, 1998a). These levels and task performances were then discussed with the year eight mathematics coordinator to establish comparability of assessment.

Student records and sheets were kept in a file in the classroom. Because the students were always taught in the same room, they had ease of access to their records.

Ongoing assessment was by assignment (Appendix S).

6.6.6 Control class program weeks 7 – 9: chance and data strand

The "Chance and Data" strand was introduced in a similar type of discussion that occurred with the intervention class, in that we were interested in how information could be collected and used to answer questions.

The difference was that the content of data about which learning of mathematical principles occurred was supplied to students. These data comprised information on athletic activities students had engaged in during Physical Education lessons. The list comprised information about performance in six activities for every year eight student.

Students were to operate on the data collected from all year eight students. This was part of an intended cross-curricular process of learning in year eight.

As an introduction model to dealing with the data, use was made of a similar, simpler set of data. The operations involving extraction, selection, sorting and categorising were modelled to students from this smaller data set. This represented demonstration of strategies which could be used in problem-solving. Students were required to copy information into books, make calculations such as "average number", collate data into highest-to-lowest and draw graphs. As is common in maths classes, these practices were first modelled by the teacher on the whiteboard, and students followed by operating on their data (Appendix T).

From the ways in which they had different presentations of data (i.e. as graphs, lists, or in statistical form), students were able to answer prescribed questions associated with the Physical Education records, such as "who is the fastest", "what is the shortest time", "are girls generally faster than boys in…." and other types of information. In this way, the Student Outcome Statements were observable as a performance goal. For example, the Level 1 statement of "students participate in classifying and sequencing objects and pictures and, with guidance, pose questions about them" could be readily matched to students' work to see if the outcome had been attained. This was the basis for monitoring progress.

The time available to pursue this strand was less than the first two strands, due to implementing the third self-efficacy measure, and the School assessment requirements for year eight mathematics. The pressure of time is a persistent control on the delivery of content.

Students in the control class were working on averaging data, using frequency figures with intervals of data, plotting histograms and interpreting results. There were clearly differentiated levels of capacity for these tasks. A few children were able to understand the nature of tasks and complete the work with ease. Students identified as being within the sub-group of low-achievers struggled with organising data into lists, had difficulty with the concept of frequency intervals and had confused ideas of graphing and scale. Access to peer modelling of work had advantages, but the rate of progress of higher achieving students soon precluded transfer of learning from that vicarious source. Low achieving students became less sure, less visible and required more re-direction to tasks.

During the last week of the term, week nine, school assessment and operational requirements meant no teaching time was available. As with the intervention class, the final self-efficacy measure was implemented at the start of week nine. The year eight coordinator required two periods for the term assessment of year eight mathematics achievement. The school held a Gala day during the week, and the school closed one day early.

Measuring achievement for the purpose of investigating hypothesised effects of differentiated instruction was intentionally left to this last week, allowing any impact of the intervention to be maximised. It was planned to be early in the last week of term, because experience has shown that student absenteeism is very high in the last days of terms. Some participants were not present for the third self-efficacy measure, given at the start of the last week. The opportunity to implement a measure of achievement performance parallel to the pre-intervention SOMS was not available. However, comparative measures of achievement for both classes were undertaken using the term tests (Appendix C).

Table 6.5 Summary of curriculum delivery

Week	Intervention	Control
1 – 3 Patterns in Number	• Students exposed to concept of personalised learning through strengths • Choice of activities • Using real contexts • Student mastery of tasks before changing • Not textbook dependent • Entry point catered for varied developmental levels	• All students exposed to similar material at similar times • Progress occurred at similar time for all students • Decontextualised, stylised • Directed group settings • Textbook and pencil/paper based • Ability entry level at minimum of Level 3 presumed
	Similar major work-sheets used for both classes, similar school assessments of pencil and paper type	
4 – 6 Space	• Choice of activities • Independent progress • Development level catered for "low" or concrete abilities	• Activities as instructed • Group rotation on fixed term periods for each activity • Task Entry level at minimum of Level 3
	Same computer activities, same major work-sheets, same school assessments, control also used "hands-on" activities for "Space".	
7 – 9 Change and Data	• Students used personal interests as basis of research questions • Students undertook the research within diverse domains of interest • Students devised ways of representing and describing data • Contextual data collection	• Data to be used supplied as lists • Research questions supplied to students • Students used textbooks as source of information • Students supplied with modelled methods
	Same school assessment	

6.7 Data analysis

6.7.1 Self-efficacy data analysis

Self-efficacy data were obtained for the intervention and control classes. It was scored using an interval scale. Students selected values from an eight-point Likert scale in response to items in the instrument. Five subscales constituted the Self-Efficacy instrument. For both mathematics classes, student scores on each scale were summed to provide a total sub-scale score. The mean class scores for each sub-scale were analysed using ANOVA in order to investigate if significant differences existed between classes, using a significance level of alpha = 0.05.

6.7.2 Data analysis of student Multiple Intelligences information

An intelligences profile was obtained for each student in the intervention class only, as the purpose was to construct a range of tasks associated with each intelligence. The data were generated through the use of a self-report instrument, the Multiple Intelligences Developmental Assessment Scale (Shearer, 1996). Using a five-point Likert scale, student responses to items generated scores for eight Intelligence sub-scales. Student scores were collated within each sub-scale to provide a quantitative measure of student strength in each intelligence. These data were used to assist in verifying that class tasks and activities covered the range of intelligences outlined in Multiple Intelligences theory.

6.7.3 Data analysis of mathematics achievement

A comparison between the control and intervention class in terms of relative gain in achievement was intended in the study. Ratio scale achievement data in mathematics were generated prior to the study using a standardised assessment instrument (SOMS) for the total year eight population. The mean scores for each class on this assessment were analysed using Analysis of Variance (ANOVA) to determine whether initial differences between classes were significant to the study. Significance was calculated at the alpha = 0.05 level.

The total assessment scores for each student were calculated and ranked within each class. Upper and lower quartiles were found as a basis for dividing students into high, average and low achieving sub-groups.

Post-intervention achievement data were not generated using the same assessment instrument used prior to the study because of school requirements on available time at the end of term. The school undertook assessment of students using items reflecting the course over the term, and scored according to students demonstrating levels of understanding. These data provided individual outcome levels. The mean level for each class in the study was calculated.

The validity of applying statistical procedures to Outcome Levels represents a practice that has not been evident in literature, although its use here was supported within the mathematics faculty of the school. The problems of collecting comparative data in addition to individualised outcomes are discussed in chapter eight. However, recognising the uncertainty attached to statistical treatment of outcomes, a frequency distribution of outcomes comparison is provided between the intervention and control class results for the post-intervention achievement data.

6.7.4. Data analysis of student engagement

Student engagement in the intervention and control classes was assessed using an ordinal scale of one (low) to five (high), with scoring based on the researcher assessing the level of participation made by each student at weekly intervals. Achievement level sub-group scores were summed. The means of data within achievement level sub-groups of each class were obtained and graphed to provide information about trends of engagement as a result of differentiated learning.

6.7.5 Data analysis of the individualised classroom environment information

Classroom environment data were obtained for the intervention class and control class using a standardised instrument, the Individualised Classroom Environment Questionnaire (Fraser, 1990). A five-point Likert scale was used to collect student responses on five subscales representing aspects of the classroom environment. The means of each sub-scale were calculated for each class and differences were tested with ANOVA using a significance level of alpha = 0.05.

6.8 Conclusion of methodology

The aim of the study is to use Multiple Intelligences learning as a classroom intervention in mathematics in order to investigate its effect on student achievement in mathematics. A particular focus is placed on low-achieving students' achievement performance in mathematics.

Using a differentiated curriculum based on mathematical tasks centred on student interests, the methodology section has set out an approach by which the outcomes of the intervention can be compared quantitatively and objectively to the mathematical outcomes of students taught under standard classroom conditions.

Qualitative and quantitative data have been collected. The research requires a valid and reliable measure of the student outcome of mathematics achievement as a reflection of the effect of the learning intervention. The impact of that implementation has been assessed by both quantitative and qualitative data obtained from measures of student achievement, self-efficacy, perceptions of the classroom environment, and student diaries.

The findings of these data are used to test the research hypotheses, to validate the intervention, to reflect on the appropriateness of the methodology, and to contribute to research knowledge in mathematics education.

CHAPTER SEVEN

RESULTS AND OUTCOMES

The study aimed to investigate the effect of using Multiple Intelligences learning on student mathematics outcomes, with a particular focus on the influence of factors affecting low achieving students. The outcome measures have included the cognitive outcome variable of mathematics achievement, the affective outcome variables of student mathematics self-efficacy and student perceptions of classroom environment, and the behavioural outcome of classroom persistence or time on task.

It was hypothesised that teaching mathematics to a year eight class using Multiple Intelligences learning will have positive effects on mathematics achievement such that:

- Multiple Intelligences learning will produce higher student mathematical achievement than in a standard class.
- Multiple Intelligences learning will raise the perceived mathematical self-efficacy of students more than in a standard class.
- Mathematically low-achieving students will show higher achievement gains under Multiple Intelligences learning than other students.
- Mathematically low-achieving students will show greater gain in mathematical self-efficacy than other students.

These hypotheses were based upon the use of different and personalised tasks as pathways to understanding mathematics with improvements attributed to two expected effects of Multiple Intelligences learning. The first is that mathematics concepts will be understood better as they are learned within a resonant intellectual context. The second is that a positive effect on academic achievement should result from improved cognitive constructions about personal competence, improved attitudes to mathematics tasks, and increased engagement as a result of tasks matching personal interests.

Each section of Chapter seven relates to an outcome and contains the results of measurements, statistical data, tables, figures, and a description of the outcome.

7.1 Pre-intervention achievement measure

It was hypothesised that student achievement in mathematics would show higher gains as a result of learning taking place using Multiple Intelligences theory, in contrast to the achievement of standard classroom teaching. It was also hypothesised that due to the personalised nature of instruction in terms of understanding mathematics by individualised paths, the achievement gains would be higher for mathematically low-achieving students in the intervention class than for other students.

In order to measure changes in student achievement both over time and between the intervention and control classes, it was necessary to obtain a base level of achievement for students. This was done using a standardised instrument developed for use within the mathematics education framework in which the research took place.

A second purpose to establishing pre-existing achievement levels relates to the research design. The research methodology used a quasi-experimental design. School classes were accepted as intact groups for the research, which meant that random assignment from the total year eight population to the control and intervention groups did not occur. The pre-test of mathematics achievement was therefore essential to reduce initial selection bias differences being a threat to internal validity.

All year eight students were administered a measure of mathematical achievement. Students were given the Student Outcomes Mathematics standardised assessment instrument, referred to as the SOMS. The standardised assessment instrument SOMS contained four sub-scales in the mathematics strands Space, Number, Measurement and Working Mathematically. These were coded as SOMS1, SOMS 2, SOMS 3 and SOMS 4. The total scores were expressed as a percentage and coded as SOMSTOT.

Class means and standard deviations were calculated for the total year eight student population, as groups of pre-determined school classes. This appears as Table 7.1.1.

Table 7.1.1 SOMS Mean And Standard Deviation for Year eight

CLASS class code		SOMS1	SOMS2	SOMS3	SOMS4	SOMSTOT
8.1 N = 20	Mean	46.2	64.7	68.7	27.0	57.3
	Std Deviation	14.3	22.6	12.1	25.3	9.1
(CONTROL)	Mean	45.7	62.2	64.9	41.7	58.6
8.2 N = 23	Std. Deviation	17.3	26.0	18.7	19.9	17.4
8.3 N = 22	Mean	42.0	61.2	58.0	18.1	51.1
	Std. Deviation	21.8	22.7	21.8	26.1	20.1
(INTERVENTION)	Mean	39.2	59.0	60.5	36.5	55.0
8.4 N = 23	Std. Deviation	28.7	25.4	26.7	28.0	24.4
Total	Mean	43.2	61.7	62.9	31.1	55.5
N = 88	Std. Deviation	21.3	24.0	20.8	26.2	18.7

Analysis of Variance (ANOVA) calculations were made to examine differences between means. The results are presented in Table 7.1.2. There were no statistically significant differences between the four intact classes except on the SOMS 4 measure.

Post-hoc comparisons (see Appendix U) indicated that the difference was attributable to the comparison between the control group 8-2 and the non-intervention group 8-3. It was therefore irrelevant to the study. The intervention and control groups showed no statistical difference on the four sub-scales of mathematical achievement.

Table 7.1.2 ANOVA Results

		Sum of Squares	df	Mean Square	F	Sig.
SOMS1	Between Groups	728.402	3	242.801	.526	.666
	Within Groups	38797.052	84	461.870		
	Total	39525.455	87			
SOMS2	Between Groups	349.130	3	116.377	.196	.899
	Within Groups	49798.325	84	592.837		
	Total	50147.455	87			
SOMS3	Between Groups	1431.215	3	477.072	1.105	.352
	Within Groups	36271.228	84	431.800		
	Total	37702.443	87			
SOMS4	Between Groups	7286.917	3	2428.972	3.879	.012
	Within Groups	52599.447	84	626.184		
	Total	59886.364	87			
SOMSTOT	Between Groups	716.063	3	238.688	.669	.573
	Within Groups	29936.834	84	356.712		
	Total	30679.898	87			

7.1.1 Achievement level sub-groups

The pre-intervention measure of achievement was used to obtain a stratification of students into high achieving, normal achieving and low achieving levels in mathematics. These sub-groups were then used in the research to investigate if Multiple Intelligences learning had different effects upon students who were achieving at different levels within the same class, and under different learning conditions.

For both the intervention and control group, a frequency table was formed using the SOMSTOT scores in the pre-test of mathematics achievement as percentages. The frequency tables were then used to determine student placement into achievement sub-groups of low-achievement, normal achievement and high-achievement based on scores below the 25th percentile being defined as low achieving, and above the 75th percentile cut-off being defined as high achieving. The data for the Control group are presented in Table 7.1.3 and for the Intervention group in Table 7.1.4. Six students were removed from various subgroups because of enrolment in individualised education programs.

Table 7.1.3 Control class achievement sub-groups

SOMSTOT[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	25.00	1	4.3	4.3	4.3
	32.00	1	4.3	4.3	8.7
	37.00	1	4.3	4.3	13.0
	38.00	1	4.3	4.3	17.4
	43.00	2	8.7	8.7	26.1
	45.00	1	4.3	4.3	30.4
	48.00	1	4.3	4.3	34.8
	50.00	2	8.7	8.7	43.5
	62.00	2	8.7	8.7	52.2
	65.00	1	4.3	4.3	56.5
	67.00	1	4.3	4.3	60.9
	70.00	2	8.7	8.7	69.6
	72.00	1	4.3	4.3	73.9
	73.00	1	4.3	4.3	78.3
	75.00	1	4.3	4.3	82.6
	77.00	2	8.7	8.7	91.3
	83.00	1	4.3	4.3	95.7
	85.00	1	4.3	4.3	100.0
	Total	23	100.0	100.0	

a. CLASS class code = 8-2 ZHB

N = 4 Low Achievement Control Sub-Group (SOMSTOT = 25 – 38%) (loss of 1 student during the study)

N = 13 Normal Achievement Control Sub-Group (SOMSTOT = 43-72%)

N = 6 High Achievement Sub-Group (SOMSTOT = 73-85%) (loss of 1 student during the study)

Table 7.1.4 Intervention class achievement sub-groups

SOMSTOT[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	7.00	1	4.3	4.3	4.3
	15.00	1	4.3	4.3	8.7
	23.00	1	4.3	4.3	13.0
	25.00	1	4.3	4.3	17.4
	28.00	1	4.3	4.3	21.7
	42.00	1	4.3	4.3	26.1
	45.00	2	8.7	8.7	34.8
	48.00	1	4.3	4.3	39.1
	50.00	1	4.3	4.3	43.5
	52.00	1	4.3	4.3	47.8
	55.00	1	4.3	4.3	52.2
	57.00	1	4.3	4.3	56.5
	62.00	1	4.3	4.3	60.9
	63.00	1	4.3	4.3	65.2
	67.00	1	4.3	4.3	69.6
	75.00	1	4.3	4.3	73.9
	77.00	1	4.3	4.3	78.3
	78.00	1	4.3	4.3	82.6
	83.00	1	4.3	4.3	87.0
	87.00	1	4.3	4.3	91.3
	90.00	1	4.3	4.3	95.7
	93.00	1	4.3	4.3	100.0
	Total	23	100.0	100.0	

a. CLASS class code = 8-4 ZHD

N = 5 Low Achievement Intervention Sub-Group (SOMSTOT = 7-28%)

N = 13 Normal Achievement Intervention Sub-Group (SOMSTOT = 42-77%)

N = 5 High Achievement Sub-Group (loss of 4 students during the study) (SOMSTOT = 78-93%)

7.2 MIDAS outcomes

The research aimed to seek the effects on student outcomes in mathematics as a result of teaching and learning which took account of natural proclivities, personal interests and intellectual strengths. By presenting and experiencing mathematics in a personalised way, it was argued that both increased understanding and engagement as a result of increased self-efficacy would be supported.

Therefore the construction of lessons required knowledge of the students' interests, strengths and weaknesses, as well as an awareness by them that traditional notions of mathematical class practices and media were not definitive. This was obtained by the use of the Multiple Intelligences Developmental Assessment Scales (MIDAS) instrument (Shearer, 1997). This self-report instrument allowed a profile to be obtained, and an interpretation to be made about each student's intellectual disposition.

The responses were converted by the scoring program to percentage scores, representing the profile of intellectual disposition for each of the eight intelligences for each student. The "High" profiles (representing student strengths) and "Low" profiles (representing weaknesses) were then distributed among the eight intelligences to obtain a frequency figure of relative intelligences represented in the class (see Table 7.2).

Table 7.2 shows there is a relatively uniform spread of strengths and weaknesses across the intelligences. The only particular intelligence that has a common expressed value is that of verbal-linguistic ability. It had the highest representation as a strength, and fewest students felt it was a weakness. The diversity of student interests is demonstrated in the spread.

Table 7.2 Intervention class frequency distribution of MIDAS-KIDS student strengths and weaknesses

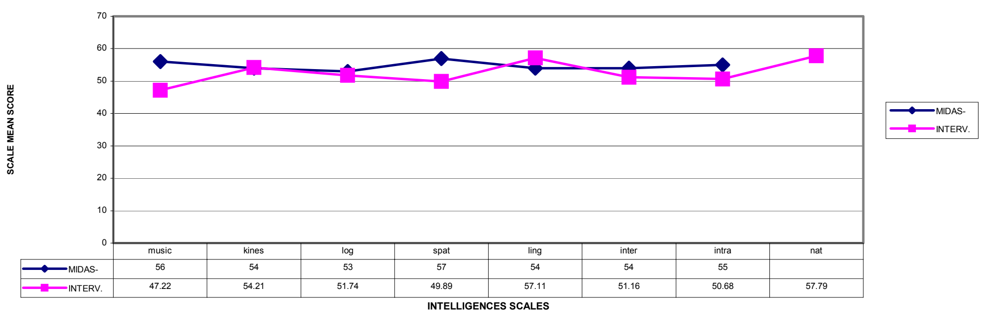
	MIDAS RESPONSE RANGE					
	Weaknesses					TOTAL
	10	20	30	40	50	
VERBAL		1		2		3
LOGIC		1	2	3		6
SPATIAL			5	1		6
MUSIC		1	4	3		8
KINESTH	1		2	2		5
INTRAP	1		1	3		5
INTERP			3	5		8
NATURAL			1	7		8
	Strengths					TOTAL
	60	70	80	90	100	
VERBAL		6	2	1		9
LOGIC	1	6	1			8
SPATIAL		3	2	1	1	7
MUSIC	1	2		2		5
KINESTH		3	3	1		7
INTRAP		3	2			5
INTERP		6	1			7
NATURAL		2	1	3		6

To support all students in their mathematics understanding, the information from table 7.2 was used to construct lessons that allowed the mathematical principles to be both demonstrated and experienced in a variety of ways. The Multiple Intelligences approach to teaching required an answer to the question of what particular activities and methods would increase successful learning experiences. Table 7.2 was used in the formulation of those answers through the preparation of a range of activities covering each intelligence area.

Although tempered by inherent reliability and validity problems associated with self-report, the MIDAS allowed a more detailed and better personalised knowledge about individual children in the intervention class compared with many standard classes in mathematics. The MIDAS profiles were discussed in class with students in terms of its purpose in assisting learning in mathematics, emphasising that engagement can optimise opportunities to learn and meaningful experiences may enhance understanding. This used the proposal that personal satisfaction is likely to enhance engagement.

The means of each intelligence scale for the intervention class were calculated and compared to the MIDAS-KIDS means available in the handbook (Shearer, 1997, p. 58). A general comparison between the intelligence profiles of the intervention class means and the MIDAS-KIDS scales are represented in figure 7.2.1. No statistical analysis has been made because of possible violations in the validity of assuming a normal distribution with intervention class data. However, no gross differences appear when comparing the means drawn from the US sample (n = 2200) and the intervention class (n = 19).

Figure 7.2.1 MIDAS-KIDS and intervention scale means



7.3 Self-efficacy outcomes

The independent variables involved in the factorial design were

- Factor 1: Time
- Factor 2: Effect of Multiple Intelligences Learning
- Factor 3: Achievement Level

The first hypothesis related to the outcome variable of student self-efficacy was that Multiple Intelligences learning would cause a higher development of perceived self-efficacy in mathematics within the intervention class than in the standard class. The second hypothesis was that mathematical low-achieving students in the intervention class would show a greater relative gain in mathematical self-efficacy than other achievement level groups.

Self-efficacy for mathematics was measured three times during the term for the intervention and control class. The first measure was made in the first teaching period of the school term. The second measure was made at the mid-point of the term, and the third measure was made in the last week of the nine-week school term.

Statistical analysis of the self-efficacy scores was based on the intervention and control classes containing three groups derived from the three levels of mathematics achievement, and three measures of self-efficacy. The self-efficacy scores for the intervention and control classes were collated for the three occasions on which the construct was measured. Means and standard deviations were calculated. Information on each class is presented in Table 7.3.1.

Table 7.3.1 Class means of self-efficacy over time

CLASS		SE1TOT	SE2TOT	SE3TOT	TOTAL
CONTROL 8.2	Mean	155.18	163.98	174.58	164.42
	N	21	21	20	
	Std. Deviation	27.93	34.71	29.18	
INTERVENTION 8.4	Mean	150.26	157.46	164.81	157.37
	N	19	19	18	
	Std. Deviation	38.41	36.44	37.28	
Total	Mean	152.84	160.88	169.95	
	N	40	40	38	
	Std. Deviation	32.97	35.24	33.17	

The self-efficacy mean and standard deviation data for the sub-groups of high, normal and low achievement in mathematics is contained in Table 7.3.2.

Table 7.3.2 Sub-group achievement level self-efficacy means over time

CLASS			SE1TOT	SE2TOT	SE3TOT	TOTAL
CONTROL 8.2	low	Mean	123.14	145.85	135.61	134.87
		N	3	3	3	
		Std. Deviation	48.76	30.85	58.46	
	medium	Mean	156.72	169.77	180.90	168.82
		N	13	13	12	
		Std. Deviation	20.54	23.04	16.50	
	high	Mean	170.40	159.80	182.80	171
		N	5	5	5	
		Std. Deviation	27.93	34.71	29.18	
INTERVENTION 8.4	low	Mean	106.38	120.22	120.80	115.8
		N	5	5	5	
		Std. Deviation	27.93	34.71	29.18	
	medium	Mean	166.08	169.74	180.38	171.8
		N	13	13	12	
		Std. Deviation	19.45	21.69	14.90	
	high	Mean	164.00	184.00	198.00	182
		N	1	1	1	
		Std. Deviation	.	.	.	
Total	low	Mean	112.67	129.83	126.35	122.95
		N	8	8	8	
		Std. Deviation	45.09	41.04	45.87	
	medium	Mean	161.40	169.76	180.64	170.34
		N	26	26	24	
		Std. Deviation	20.17	21.92	15.38	
	high	Mean	169.33	163.83	185.33	172.83
		N	6	6	6	
		Std. Deviation	17.57	54.42	15.32	

Factor 1: The effect of exposure to the mathematics curriculum over time

Self-efficacy means of total student scores from the combined classes increased over time, as shown in Table 7.3.1. ANOVA data is shown in Table 7.3.3.

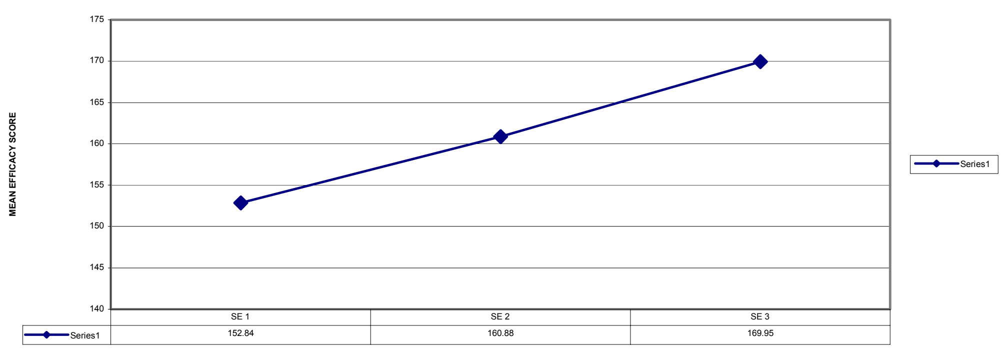
Table 7.3.3 Statistical data for within-participant contrasts

TESTS OF WITHIN-PARTICIPANT CONTRASTS					
SOURCE	SS	df	mean sq	F	SIG
Time	3015.289	1	3015.289	17.328	0.000**
Time X Class	50.788	1	50.788	0.292	0.593
Time X Ach Level	110.505	2	55.252	0.318	0.73
Time X Class X Ach	401.918	2	200.959	1.155	0.328

Data in Table 7.3.3 indicate there is a statistically significant difference between the combined student means over time. The conclusion is that student perceptions of self-efficacy for performance are enhanced by exposure to the curriculum material whether through participation in the standard or intervention class procedure.

It is likely that this reflects the effect of increased student experience and facility in the performance of the mathematics items. Initially, confidence in ability to perform and answer the item questions would be low, as the curriculum had not been covered. As the class lessons unfolded perceived self-efficacy to perform rose as a result of the teaching and learning program in accord with expectations.

Figure 7.3.1 Factor 1: The effect of exposure to the curriculum over time on total student self-efficacy



Factor 2: The Effect of Multiple Intelligences Learning

The means and standard deviations for all students' scores in each of the control and intervention classes were calculated and presented in Table 7.3.1.

ANOVA data on the two classes is presented in Table 7.3.4.

Table 7.3.4 Statistical data for between-participant effects

BETWEEN-PARTICIPANT EFFECTS					
SOURCE	SS	df	mean sq	F	SIG
Class	44.129	1	44.129	0.024	0.879
Ach Level	40204.35	2	20102.17	10.8	0.000**
Ach Level X Class	2451.588	2	1225.794	0.659	0.524

These data indicate there is no statistically significant difference between the self-efficacy of the class taught using Multiple Intelligences learning and the class taught under standard instruction when measured with the Self-Efficacy instrument used in this study.

Factor 3: The Effect of Achievement Level on Self-Efficacy for Mathematics

The intervention class and control class each were comprised of sub-groups based on high, normal and low achieving students in mathematics. The mean and SD of these achievement level sub-groups within the control and intervention class were calculated and appear in Table 7.3.2.

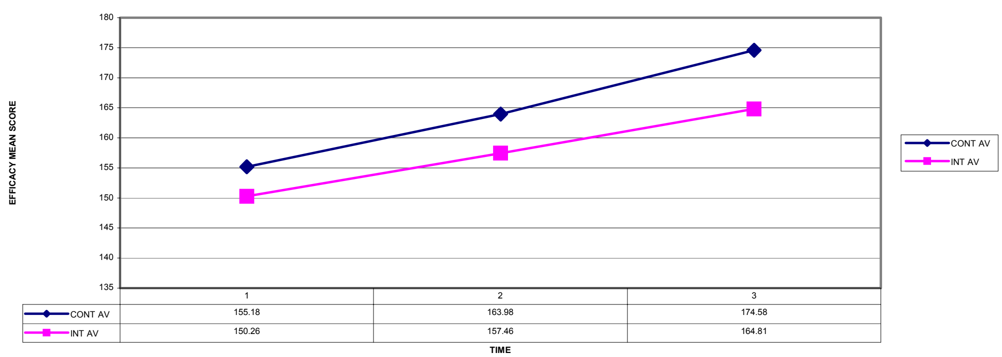
The ANOVA data shown in Table 7.3.4 indicates there are statistically significant differences between the self-efficacy means for each sub-group and inspection of the means indicates that mathematical high achievers have higher self-efficacy than other achievement groups. Low achieving students in mathematics have lowest self-perceptions of capability to undertake the mathematics tasks presented. The absence of a significant interaction (Achievement X Class) means that this trend is evident in both the intervention and control classes.

The Interaction of Multiple Intelligences Learning and Time

Means of self-efficacy scores for both the intervention and control class were used for ANOVA repeated measures analysis. The purpose was to see if Multiple Intelligences learning influenced student perceptions of self-efficacy over time to a different extent than standard instruction influenced self-efficacy.

It is evident from Table 7.3.1 that the intervention class began with a lower mean self-efficacy than the control group. However, the relative positioning of the mean values remained similar over time and there was no statistically significant difference over time between the classes in self-efficacy. The ANOVA data are presented in Table 7.3.3 as Time x Class.

Figure 7.3.2 The interaction of Multiple Intelligences learning and time



Both the intervention class and control class demonstrated increased self-efficacy for mathematics over time, with exposure to the curriculum having similar effects. The conclusion is that exposure to Multiple Intelligences learning did not have a differential effect on student self-efficacy for mathematics.

The Interaction of Achievement Level and Time

The effect of exposure to the curriculum on achievement levels was investigated. The means of the achievement levels for low, normal and high achievement in mathematics self-efficacy were calculated for the three occasions on which it was measured. These data were used to see whether perceptions of student self-efficacy varied for a particular achievement level group over time. Figure 7.3.3 indicates the interaction of self-efficacy, achievement level, and time.

Figure 7.3.3 The interaction of achievement level and time

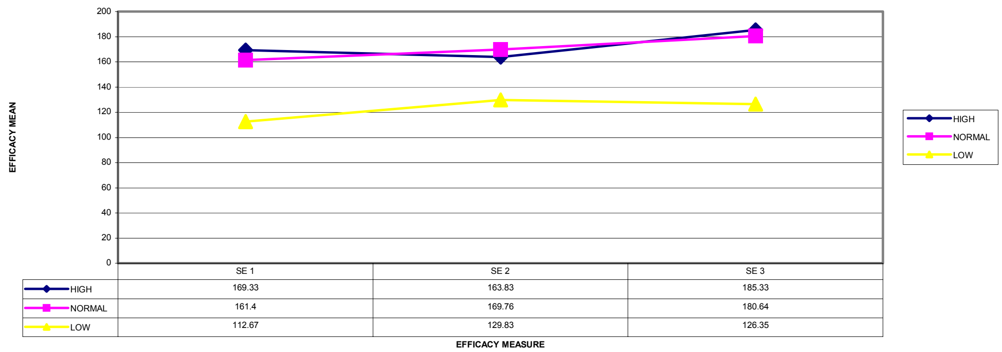


Figure 7.3.3 suggests an initial present difference between the mean self-efficacy of low-achieving students and normal or high achieving means. This relative difference continues over time, indicating that the low achievement group self-efficacy was not differentially influenced by exposure to the mathematics. The normal and high achieving sub-groups show similar rates of change in the mean self-efficacy scores over time.

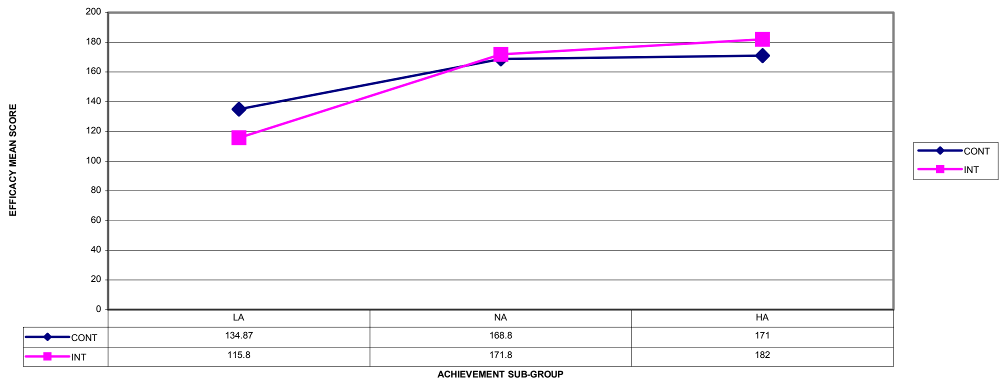
The ANOVA data in Table 7.3.3 are presented as Achievement Level x Time. It shows there is no statistical difference between the rates of change in self-efficacy over time for the achievement level groups.

The Interaction of Multiple Intelligences Learning with Achievement Level

The effect of Multiple Intelligences learning on the different achievement level subgroups was investigated to see if the instructional intervention affected a particular achievement level sub-group differently to standard teaching.

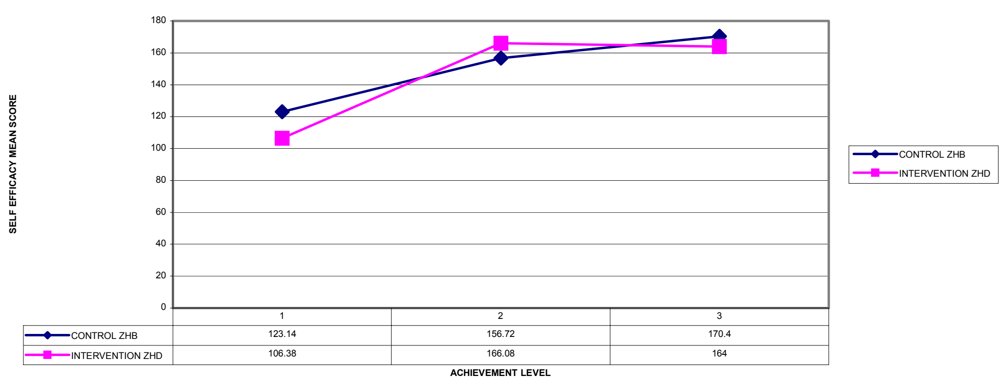
The self-efficacy mean scores of each achievement level sub-group within each of the intervention and control classes were calculated. The data are presented in Figure 7.3.4. ANOVA data are displayed as Achievement Level x Class in Table 7.3.4. No statistically significant difference between achievement level sub-groups is indicated.

Figure 7.3.4 The interaction of Multiple Intelligences learning with achievement level



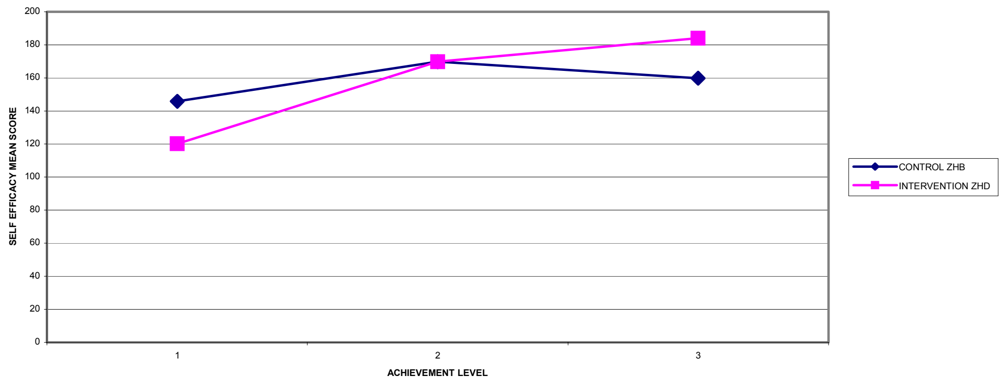
The shift in relative positions of sub-group means over time is noted as a possible emerging trend in the data. The first measure of self-efficacy displayed in Figure 7.3.5 shows the intervention low achievement class mean lower than the control for low achievers, with other class means showing little difference.

Figure 7.3.5 Group level comparisons on self-efficacy measure 1



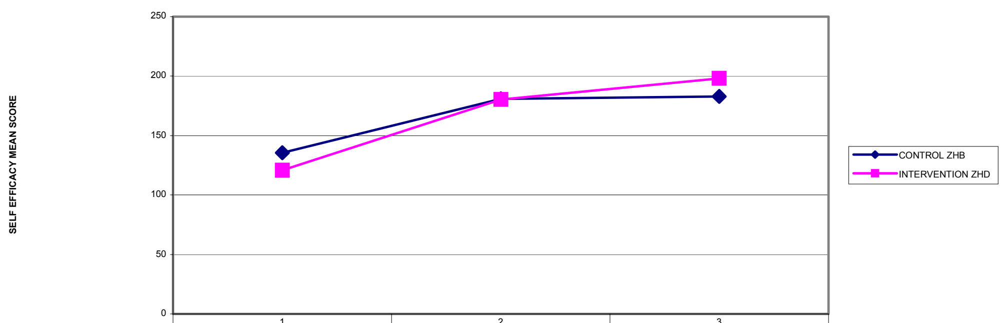
The second measure of self-efficacy shows the intervention high achiever mean trending higher than the control mean, with other class means remaining stable, indicated in figure 7.3.6.

Figure 7.3.6 Group level comparisons on self-efficacy measure 2



On the final measure of self-efficacy, the high achievement sub-group of the intervention class finished higher than the control group as indicated in figure 7.3.7.

Figure 7.3.7 Group level comparisons of self-efficacy on measure 3



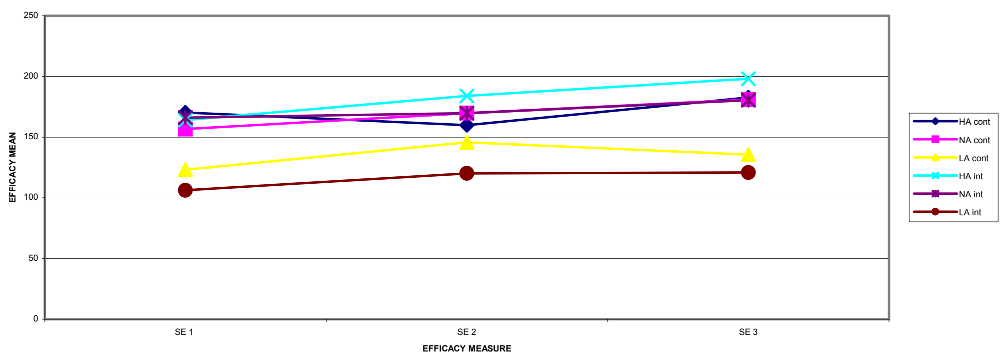
	1	2	3
CONTROL ZHB	135.61	180.9	182.8
INTERVENTION ZHD	120.8	180.38	198

It may be that Multiple Intelligences learning had a positive effect on the high achievement sub-group of the intervention class that has not been detected by the current measures or analysis. This possibility is contrary to hypothesised effects and will be discussed in the next chapter.

Interaction between Multiple Intelligences learning, achievement level and time

The combined effects of time (exposure to the curriculum), achievement level and instructional type on the outcome variable of student self-efficacy were investigated. This was necessary to answer the question of whether Multiple Intelligences learning influenced low achieving students over time more than any other sub-group (which was an hypothesised outcome). Figure 7.3.8 displays the self-efficacy means.

Figure 7.3.8 Interaction of learning method, achievement and time



The control and intervention class sub-group achievement level efficacy means were used for the ANOVA data presented in Table 7.3.3. There is no indication from these data of an interaction between the independent variables. The second hypothesis of increased effects of Multiple Intelligences learning on low achieving students is therefore rejected.

Figure 7.3.8 suggests evidence of prior and persistent differences between the mathematics self-efficacy of low achieving students compared to other students. The Intervention and Control low achieving sub-groups show little gain in self-efficacy for mathematics regardless of instructional type over time. Neither instruction model has produced differentiated effects on the normal achievement groups. There is no statistical significance, but it is possible that learning under Multiple Intelligences instruction over a period of time had positively influenced the high-achiever mathematics student self-efficacy more than standard instruction did to the high-achiever group. Again, this would be contrary to the second hypothesis and invites discussion in the next chapter.

Correlations between intelligences and self-efficacy mean scores

The assessment of perceived self-efficacy for the classroom mathematics was done using standard mathematics items. This was required for the quantitative research method used. Multiple Intelligences theory usually necessitates a variety of methods to ensure fair assessment, but the limitations of time, school assessment requirements and the constraints on the research design allowed only the standard form of written mathematics assessment in the collection of the data. It is recognised therefore that the *logical-mathematical* and *verbal-linguistic* intelligences were favoured in the assessment used for school reporting purposes, for research intervention effects on student achievement, and for measuring student self-efficacy in mathematics.

To acknowledge and quantify that bias, Pearson Correlation Co-efficients were calculated between the MIDAS Intelligence scale scores and the Self-efficacy scores. This information is presented in Table 7.3.5.

From Table 7.3.5, it is evident that the self-efficacy means on each of the three occasions measured correlate significantly with the intelligences described as Kinesthetic and Logical-Mathematical. It is apparent that there is a significant positive relationship between the mean of perceived student Self-Efficacy for mathematics and the Intelligence scale means for Kinesthetic intelligence and Logical-Mathematical intelligence.

Table 7.3.5. Pearson correlation co-efficients MIDAS-KIDS and self-efficacy means

Pearson Correlations	musical	kinesthetics	Math-logical	SPATIAL	linguistic	interpersonal	intrapersonal	Naturalist	SE1TOT	SE2TOT	SE3TOT
Musical	1.000	.321	.500*	.835**	.843**	.639**	.456*	.368	.306	.303	.237
kinesthetics		1.000	.825**	.484*	.548*	.682**	.569*	.454	.652**	.688**	.800*
math-logical			1.000	.543*	.580**	.699**	.514*	.283	.828**	.836**	.902*
SPATIAL				1.000	.827**	.712**	.509*	.588**	.358	.371	.350
Linguistic					1.000	.729**	.698**	.538*	.397	.312	.371
interpersonal						1.000	.618**	.486*	.371	.364	.492*
intrapersonal							1.000	.372	.350	.244	.335
Naturalist								1.000	.125	.093	.086
SE1TOT									1.000	.777**	.852**
SE2TOT										1.000	.683**
SE3TOT											1.000

* Correlation is significant at the 0.05 level (2-tailed)

** Correlation is significant at the 0.01 level (2-tailed)

Since no directional inference may be drawn from the statistics, there is the possibility that the items used in the devised self-efficacy instrument had a resonance with students who had high logical-mathematical intelligences or high kinesthetic intelligences. Alternatively, having strength in these intelligences may have assisted the students in understanding the mathematics as presented in the item form of the self-efficacy instrument.

Summary of results for self-efficacy

a) The hypothesised effect of relatively greater gains in overall mathematical self-efficacy under Multiple Intelligences learning has not been evident in the statistical analyses. Self-efficacy has increased over time for both classes at rates that are not statistically differentiated.
b) There is a trend in the data that suggests that Multiple Intelligences learning may have had a relatively greater effect on the self-efficacy of the high-achiever sub-group of the intervention class. This tendency is contrary to the hypothesised outcome.
c) Self-efficacy in the control and intervention low-achieving groups initially and over time remains lower than other achievement groups.
d) Although not statistically demonstrated, there appears to be a trend of divergence between the self-efficacy over time of the intervention class and control class in that the control group may be showing increased mathematical self-efficacy over time if the trend continued. This is contrary to the hypothesised outcome and is discussed in chapter eight.

7.4 Post-intervention achievement outcomes

A specific test of achievement in a parallel form to the pre-test was unable to be implemented because of school restrictions on available assessment time. As a result of the pre and post intervention mathematics assessment not being the same it was not possible to measure gains in mathematical achievement either within the classes in terms of achievement level comparisons, or between classes as a measure of instruction effect.

However, the school's standard classroom tests were given to all four year eight mathematics classes in the strands NUMBER and SPACE. These were constructed by the year eight coordinator of mathematics instruction and were based on the course requirements indicated to be taught at the start of term. As such, they assessed student achievement in the strands of mathematics introduced during the term, therefore any relative achievement differences between the intervention and control could still be demonstrated.

The tests were constructed independent of the researcher, and were distributed in similar ways on the same days to both groups. The level associated with test items was determined by the year eight coordinator, and assigned levels were compared for equivalence between the year eight mathematics teachers during marking.

The results recorded were based on the highest outcome level indicated over the range of items. That is, the level at which the student was understood to be performing was taken to be reflected by the highest level demonstrated.

The results of the term tests are expressed as levels within the framework of Student Outcomes, as exemplified in the document "Implementing Student Outcome Statements in Mathematics", 1998. Given that the levels used in this research were early formal measures in the school's introduction and development of Outcomes as mathematics instructional goals, it is prudent to note their tentative status.

A frequency distribution compared student outcomes in the post-intervention assessment strands of Space and Number, and are provided in Table 7.4.1. Attrition towards the end of the school term resulted in student losses from the Intervention and Control groups for the post-intervention data collection. The standard student numbers are given in parentheses in Table 7.4.1.

Table 7.4.1 Outcome comparisons

High Achievers (I = 1, C = 5)

Level	Interv. Number N = 1	Control Number N = 5	Interv. Space N = 1	Control Space N = 5
ND	0	0	0	0
1	0	0	0	0
2	0	0	0	0
3	0	1	0	0
4	0	4	0	1
5	1	0	1	4

Average Achievers (I = 13, C = 13)

Level	Interv. Number N = 11	Control Number N = 12	Interv. Space N = 10	Control Space N = 10
ND	0	0	0	0
1	0	0	0	0
2	0	0	3	0
3	4	2	2	2
4	7	9	4	6
5	0	1	1	2

Low Achievers (I = 5, C = 3)

Level	Interv Number N = 5	Control Number N = 3	Interv. Space N = 5	Control Space N = 2
ND	0	0	0	0
1	0	0	0	0
2	0	0	3	0
3	5	3	2	2
4	0	0	0	0
5	0	0	0	0

While the small student sample and the student attrition at the end of term must be considered in conclusions from the data, it appears that the Intervention class achieved similarly to the Control class when measured on the school-based assessment, with some suggestion of normal and low achievers in the Intervention group being progressively negatively affected. This is contrary to the expected outcome and raises the question of assessing MI instruction with standard school tests that emphasise limited dimensions of intelligence. This will be discussed in chapter eight.

Statistical methods have also been used on the Student Outcome levels. For the mathematics courses used in this study, levels were interpreted as interval scales. This assumption was discussed with mathematics staff and accepted for the tasks used in this research. The problem of making comparative assessments between groups of students with Outcomes-based instruction is raised in chapter eight.

Mean values of assessment are displayed in Table 7.4.2.

Table 7.4.2 Class means of assessment in terms of outcome levels

GROUP		STRAND	
		NUMBER (mean outcome level)	SPACE (mean outcome level)
High achiever	INTERV	5	5
	CONTROL	4	5
normal achiever	INTERV	3.5	3.5
	CONTROL	4	4
low achiever	INTERV	3	2.5
	CONTROL	3	3

Results

a) The pre-intervention assessment Figures 7.4.1 and 7.4.3 compared NUMBER and SPACE scores for both classes over three levels. The means of the intervention group were below those of the control group at all levels of achievement.

b) The post-intervention term assessment comparative means for NUMBER and SPACE are shown in Figure 7.4.2, and Figure 7.4.4. For the high achiever comparison, the intervention mean slightly exceeded the control group mean on both NUMBER and SPACE strand measures. For the average and low achieving subgroup comparisons, the Control group means exceeded the Intervention group means for both NUMBER and SPACE strands. However, although the means suggest a differentiated effect on intervention class high achievers, this group contained only one student because of losses to the Talented And Gifted Students program, therefore reliability and validity are not assumed.

Figure 7.4.1 Pre-intervention achievement in “number” strand

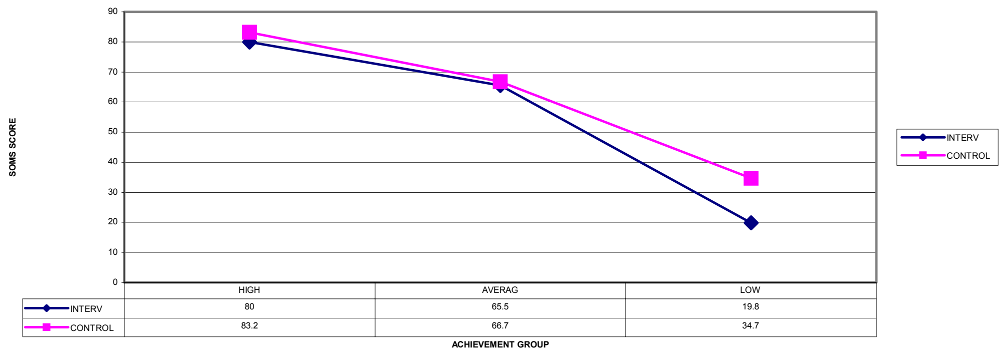


Figure 7.4.2 Post-intervention achievement comparison in “number” strand

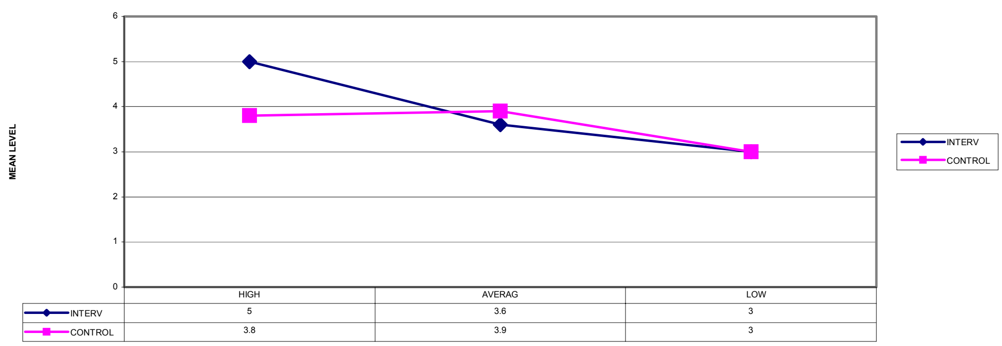


Figure 7.4.3 Pre-intervention achievement in “space” strand

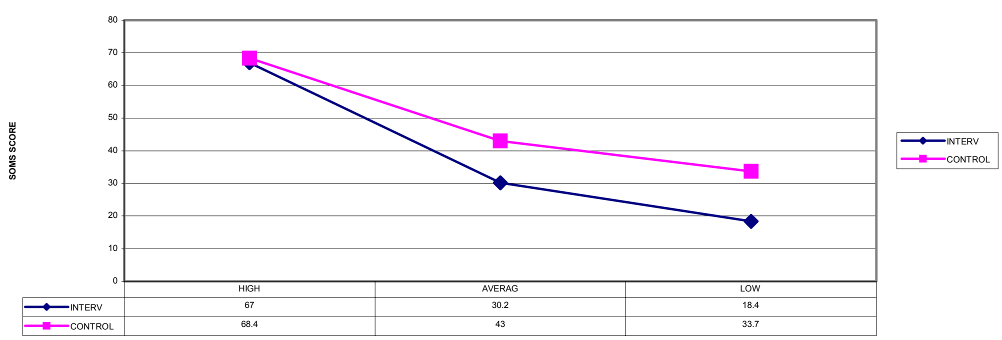
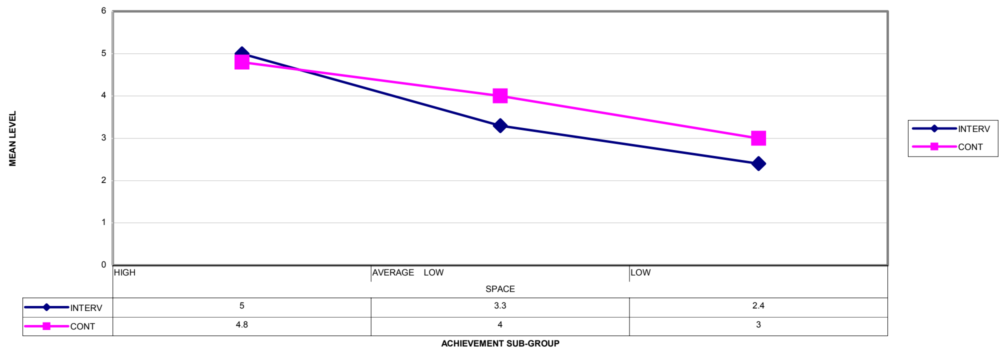


Figure 7.4.4 Post-intervention achievement comparisons in "space" strand



The results require the null hypothesis to be accepted, and intervention effects were not observed. It was hypothesised that students in the Intervention group would show greater performance than students in the Control group, since the use of Multiple Intelligences instruction would assist to a greater extent in the comprehension of mathematical concepts. There does not appear to have been an overall higher gain for the Intervention class in mathematical achievement.

It was also hypothesised that low-achieving students would show greater improvement in performance levels than other levels within the Intervention group, since the effect of Multiple Intelligences learning would act upon the self-efficacy beliefs to a greater degree in the low-achievers, influencing their achievement gains more. This was not observed.

7.5 Engagement outcomes

Time on Task

This term, also referred to as engaged time, is defined by Woolfolk (1998) as "time spent actively involved in specific learning tasks" (p. 443).

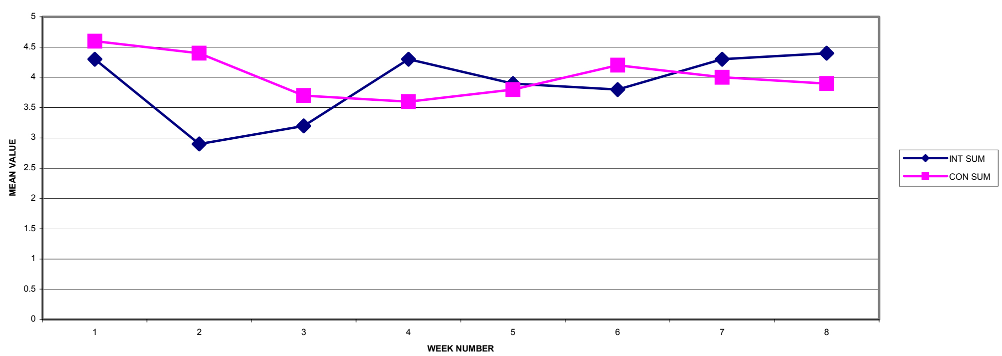
A basis for hypothesising greater gains in mathematical achievement and student self-efficacy within the intervention class and particularly for the mathematically low achieving student was the expectation of increased engagement under Multiple Intelligences learning. Information on behavioural outcomes under Multiple Intelligences instruction was partly obtained through the data on student engagement, where time on task was quantified and examined for comparisons within and between the intervention and control class.

The scores allocated to students on the basis of engagement were summed within achievement level sub-groups to obtain mean values. These data are presented in Appendix V.

The effect of Multiple Intelligences learning on engagement over time

The data comparing the engagement means of the intervention and control groups is presented in Appendix V, Table 7.5.1. The trends are displayed in Figure 7.5.1.

Figure 7.5.1 Engagement mean comparison between classes



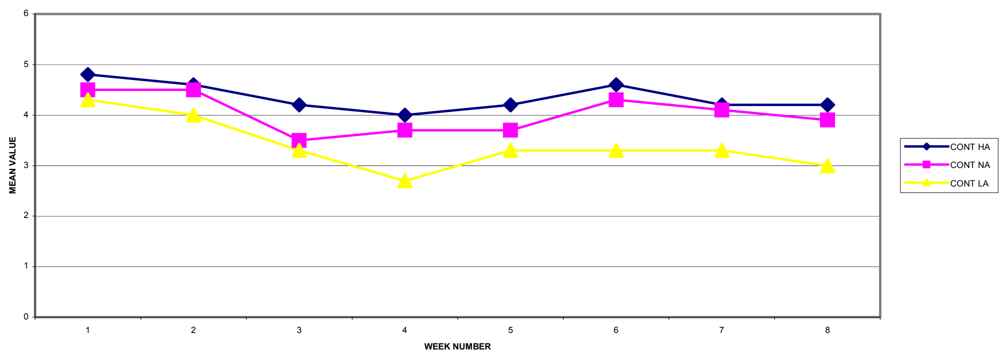
Both classes began the term with approximately equal mean levels of engagement. The pattern of engagement differs between the classes in that the intervention class mean decreased quickly for the first week and then rose as sharply in the second week. This rising trend of time-on-task and engagement continued for the intervention group over the term of instruction.

The mean engagement of the control group reflected a gradual, persistent decrease in engagement over a longer period of time, until the mid-term of instruction. In the latter part of the term, both groups exhibited similar levels of engagement.

Control class achievement level engagement over time

The sub-groups of high, normal and low mathematics achievement were separately assessed for engagement means. The data are presented in Appendix V, Table 7.5.2. The trends over time are displayed in Figure 7.5.2.

Figure 7.5.2 Comparison of achievement level engagement means within the control group



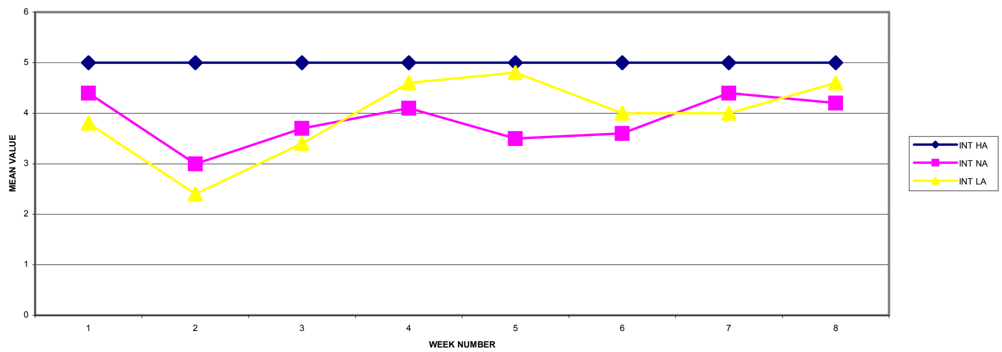
The means of the three achievement levels – low, normal and high – indicate that students within the control group began the term with similar levels of engagement, or attention to tasks. All students, regardless of past history of mathematical achievement appeared to be responsive to the curriculum initially.

Over time the engagement means of all 3 achievement level sub-groups in the control class show a gradual decrease until the middle of term, where the normal and high achiever means indicate a small rising trend. The control group low achiever means for engagement show a continued decreasing trend over the full teaching term.

Intervention class achievement level engagement over time

The sub-groups of high, normal and low mathematics achievement were separately assessed for engagement means. The data are presented in Appendix V, Table 7.5.3. The trends over time are displayed in Figure 7.5.3.

Figure 7.5.3 Comparison of achievement level engagement means within the intervention group



The means of the low and high achievement sub-groups in the intervention class show initial engagement levels of a slightly wider spread than the control group, with the high achievement at the higher engagement level, and the low achievement mean at the lower engagement level. The means were all in the upper level of engagement.

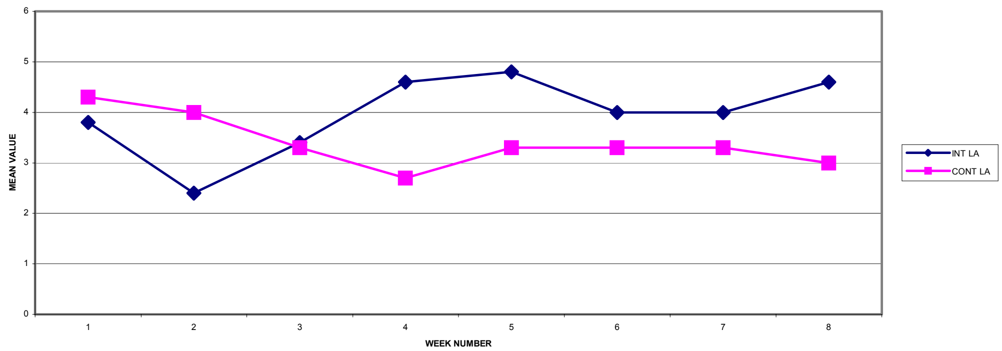
The normal and low achiever group means show a sharp drop in the first week, followed by a steep rise to regain initial engagement levels.

The low achievement means over time show that sub-group having a faster rise in engagement, and that at the mid-point of term, low achievers were more engaged than normal achievers. the rise in engagement mean is interpreted to be a "recovery" from the differentiated nature of Multiple Intelligences learning. In effect, that learning may be viewed as creating "culture shock" for the low achieving students.

Engagement comparisons between class levels

The engagement of low achieving students shows most separation. Figure 7.5.4 indicates that the intervention mean engagement underwent an early initial fall, then rose in accordance with expectations from a curriculum that appealed to their intellectual strengths. The low achievement mean of the control group shows a general downward trend in accordance with diminishing expectations of students learning under a traditional mathematics curriculum. The data are presented in Appendix V, Table 7.5.4. The trends over time are displayed in Figure 7.5.4.

Figure 7.5.4 Engagement mean comparison of low achievement sub-groups



Summary of engagement outcomes

- The intervention class engagement showed a brief but sharp decrease before a general rising trend.
- The control class showed a general decline in engagement.
- The intervention class means suggested a positive effect from Multiple Intelligences instruction on engagement of low achievers.
- The control class showed a persistent decline in engagement for low achievers over the term.

7.6 Classroom environment outcomes

The Individualised Classroom Environment Questionnaire assesses "those dimensions (namely, *Personalisation, Participation, Independence, Investigation and Differentiation*) which distinguish individualised classrooms from conventional ones" (Fraser, 1990, p.1).

It was hypothesised that Multiple Intelligences Learning would positively influence mathematical achievement and perceived student self-efficacy for mathematics. This was assumed on the basis that Multiple Intelligences learning acts positively on student attitudes and beliefs, limits competitive atmospheres in class, ameliorates the emotional stresses through a caring class atmosphere, and places importance on linking personal interests and strengths with the curriculum. The ICEQ intended to assess whether student perceptions differed in the intervention class on these affective characteristics as a result of Multiple Intelligences Learning.

Statistical treatment

The control class 8-2 and intervention class 8-4 were taught as intact school classes. Four students from the intervention class and one student from the control class were withdrawn from mathematics to attend Gifted and Talented classes in mathematics. These Gifted And Talented students were deleted from subsequent statistical treatments. The control group ICEQ measure was reduced by one student due to attrition near the end of the term.

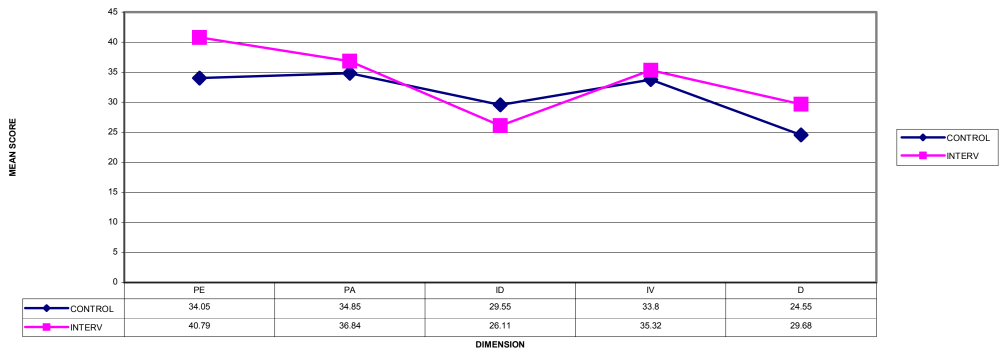
The control class 8-2 and the intervention class 8-4 were administered the Individualised Classroom Environment Questionnaire. The administration and scoring was conducted according to the manual (Fraser, 1990). Scores were calculated according to the instruction manual for each sub-scale. The means and standard deviations for each sub-scale were then calculated and displayed in table 7. 6. 1.

Table 7.6.1 ICEQ sub-scale means

CLASS class code		N	Mean	Std. Deviation
PERSONALISATION	8-2 CONTROL	20	34.05	6.68
	8-4 INTERVENTION	19	40.79	4.61
PARTICIPATION	8-2 CONTROL	20	34.85	6.34
	8-4 INTERVENTION	19	36.84	4.65
INDIVIDUALISATION	8-2 CONTROL	20	29.55	6.48
	8-4 INTERVENTION	19	26.11	5.62
INVESTIGATION	8-2 CONTROL	20	33.80	6.14
	8-4 INTERVENTION	19	35.32	3.87
DIFFERENTIATION	8-2 CONTROL	20	24.55	3.56
	8-4 INTERVENTION	19	29.68	6.51

A comparison of means is presented in Figure 7.6.1

Figure 7.6.1 Comparison between intervention and control classrooms on ICEQ scale dimensions



Student-t statistical calculations about the subscale means for the control and intervention groups were undertaken to assess for equality of means, as displayed in Table 7.6.2.

Table 7.6.2 Statistical data of student-t test for equality of means

t-test for Equality of Means				
	T	Df	Sig. (2-tailed)	Mean Difference
PE	-3.646	37	.001**	-6.74
PA	-1.114	37	.273	1.99
ID	1.770	37	.085	3.44
IV	-9.17	37	.365	-1.52
D	-3.078	37	.004**	-5.13

Analysis shows that there were statistically significant differences between the two groups on the *Personalisation* and *Differentiation* subscales.

The interpretation placed upon the difference in Personalisation is that students felt the teacher was empathetic with their feelings, that the teacher was approachable, and that their personal wellbeing was of concern to the teacher.

The perception of altered Differentiation is interpreted as students perceiving there was an increased emphasis on their interests and abilities being factored into the curriculum, with tasks being suited to suit their own learning style and rate of working.

The findings on Personalisation and Differentiation are of particular importance, since a *personalised* classroom is an important criterion for teaching and learning using Multiple Intelligences theory, according to Gardner (1995). No significant differences were indicated for the Participation, Individualisation or Investigation subscales. The instruction used within the intervention class aimed at influencing these factors and it may be that the impact of Multiple Intelligences learning was not sufficient to create student perceptions of differences in these. This raises methodological questions about the time of exposure of Multiple Intelligences interventions and is discussed in chapter eight.

7.7 Conclusion

The aim of the thesis was to demonstrate the positive impact of a Multiple Intelligences program on the mathematics achievement and mathematics self-efficacy of year eight students. The hypothesised gains were not indicated in the results. However, there are indications that Multiple Intelligences learning may have a selective effect on students, offering future research directions and methodological revision.

It has emerged that positive behavioural and affective components in the forms of engagement and classroom environment have resulted from the intervention program. These are factors that the literature review has indicated are significant for raising student achievement in mathematics. These aspects will be discussed in the next chapter.

CHAPTER EIGHT

DISCUSSION

The central issue driving this study has been that the dependence of mathematics instruction on logical-mathematical and verbal-linguistic abilities has precluded the opportunity for many students to understand concepts and principles through other modes of intellectual influence. The *thesis* argued that this is achievable through the reconceptualisation of intelligence, allowing the recognition that a variety of cognitive strengths are legitimate ways of shaping mathematics concepts for better understanding.

The research literature review in chapter two examined the roles of both cognitive and affective factors on students' mathematics achievement. The review of research showed that using engaging and intrinsically motivating tasks that offer personally relevant challenges has significant advantages in promoting students' cognitive skills and personal agency. Research descriptions included a range of equity-driven initiatives and reforms, many of which have had specific target groups. A variety of programs emphasised culturally valued activities, student interests, and authentic linkages between learning and the classroom. However while the review showed that understanding of mathematics concepts can be enhanced for low achievers if they are more able to make rich connections between school mathematics and their personal experiences, a general benefit to mathematics achievement has not been demonstrated in that many students have continued to show low mathematics achievement and self-efficacy.

It was concluded from the review of research literature that it may be that students with high natural logical-mathematical and verbal-linguistic intelligence were advantaged by standard mathematics education and achieved at a higher level because of limitations on conceptual representation in mathematics education. A new approach was needed to introduce equitable learning opportunities for low achieving students. The thesis proposed that performance levels in mathematics education could be assisted by broadening connections between concepts and cognitive abilities beyond logical-mathematical and verbal-linguistic intelligence. The reconceptualisation of intelligence was seen as an important consideration in the provision of this equitable learning. Gardner's Multiple Intelligences theory (1983) offered a basis for investigating the impact of a differentiated presentation of mathematics tasks appealing to a spectrum of intelligences.

Supported by the literature review's recommendations for including affective as well as cognitive components in mathematics learning programs, the study has investigated the effect of instruction through Multiple Intelligences theory on students' mathematics achievement and self-efficacy. This study has been situated in the transition period within Middle School where significant cognitive and socio-emotional developmental demands occur for students. There has been little quantitative research into Multiple Intelligences instruction in Middle School mathematics that addresses low achievement and its associated factors of student affect and behaviour. The synthesis of Multiple Intelligences theory with Self-Efficacy theory has offered a distinct and original contribution to mathematics education in terms of the study's theoretical and methodological development. A lack of implementation descriptions has been a source of criticism for Multiple Intelligences theory (Levin, 1994) and this study contributes to the field of mathematics education through its description of the application in a Middle School mathematics context.

The study has been conducted under challenging conditions that emerged as a result of implementing an innovative program within a traditional context. The loss of high-achieving participants from the Intervention group was a significant constraint in interpreting the outcomes, creating as it did a relatively less heterogeneous class, and the school requirements on instruction time affected the full implementation of the intervention program.

The study investigated the effect of engaging a range of intellectual strengths as a means of providing cognitive support to the diversity of students in a mathematics class. It assessed the outcomes in terms of students' mathematics achievement, mathematics self-efficacy, engagement, and perceptions of their classroom environment. This concluding chapter considers the success of the approach taken to overcome low mathematics achievement. The findings are discussed in relation to each of the hypotheses stated in chapter one, identifying strengths and weaknesses of the approach. Limitations of the study are discussed, the implications for research and teaching practice are outlined, and avenues for future research are suggested.

8.1 Conclusions about the research hypotheses

8.1.1 Achievement effects

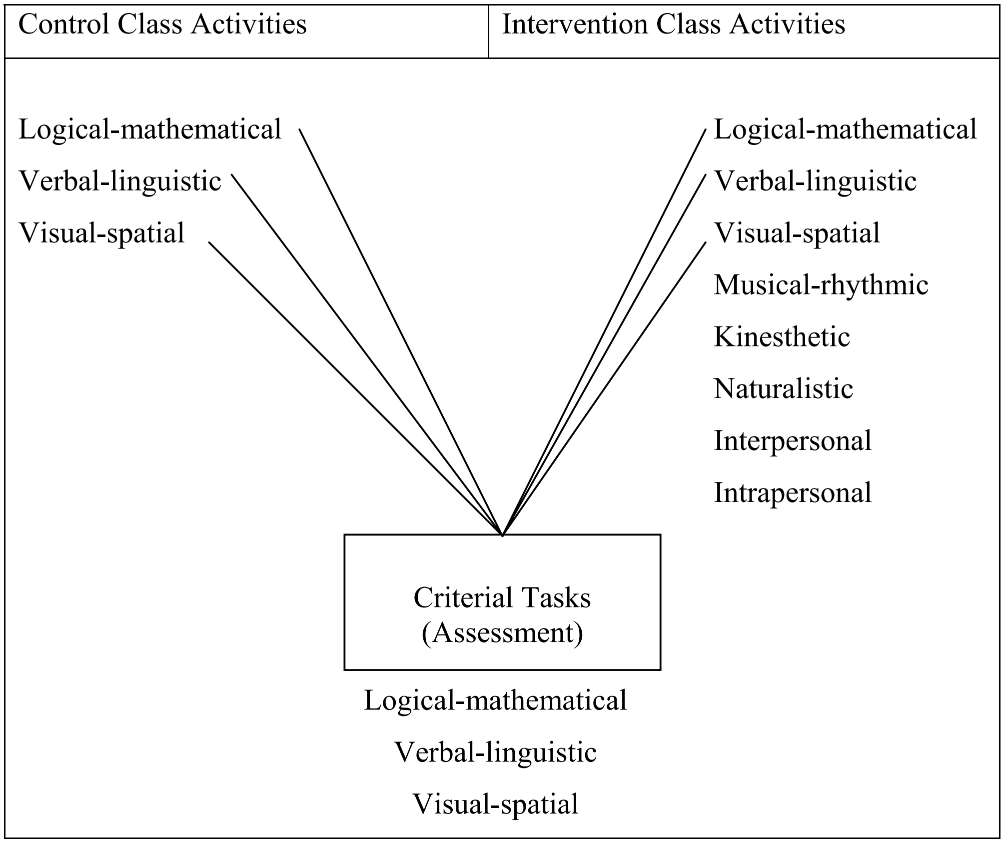
It was hypothesised in chapter one that exposure to the Multiple Intelligences program would result in improved mathematics achievement for those students in comparison to students exposed to a traditional mathematics program. It was also hypothesised that achievement gains would occur to a greater degree for low achieving students than other levels exposed to the intervention program. Section 7.4 showed that the influence of Multiple Intelligences instruction on mathematics achievement was not demonstrated in terms of greater overall gains for Intervention group students compared to Control group students, and low-achievers did not show a differentiated gain in achievement over the average or high achievers within the Intervention group. Contrary to the hypotheses on achievement outcomes, there is some suggestion that Multiple Intelligences instruction may have influenced the performance of the Intervention high-achievement level but not that of low or average achievement levels.

The question of whether the principles of Multiple Intelligences theory were applied with integrity to class activities must be considered in interpreting the outcomes. It is argued that the mathematics program implementation did adopt the criteria associated with Multiple Intelligences instruction. This assumption is supported quantitatively through the statistical outcomes of the Individualised Classroom Environment Questionnaire (section 8.3.2) indicating that Gardner's (1995) criteria were incorporated. It is also supported qualitatively, through the demonstrated adherence of the program to recommendations on how MI theory can be applied to classrooms (Campbell, 1997; Latham, 1997) in that it provided a number of entry points to understanding, aimed to reach as many students as possible, and promoted self-learning awareness skills.

The key to explaining the observed outcome that mathematics achievement was not influenced by the Multiple Intelligences program is proposed to lie in the instrument used to measure changes in mathematics performance. Mathematics achievement was measured in the pre-intervention and post-intervention assessments using traditional tasks. When the Control and Intervention students were assessed for performance, they were limited by the post-intervention assessment task profile to logical-mathematical, visual-spatial and verbal-linguistic tasks, in traditional media (Table 8.1). This was a requirement of the Head of the Mathematics Learning Area and illustrates the difficulty associated with innovation located within a traditional context. The intellectual strength most represented in these traditional assessment items is logical-mathematical, and is characteristic of the high achiever sub-groups of both the intervention and control groups.

The outcome that Multiple Intelligences learning program had no significant effect on Intervention average achievers and particularly on the intervention sub-group of low achievers (figures 7.4.2 and 7.4.4) is attributed to a lack of opportunity for these students to display their understanding gained under the Multiple Intelligences program. These intervention-group students spent less time learning through this intelligence, spent less time with pencil-and-paper tools, and spent less time on discussion about the techniques of working with standard representations of mathematical concepts. Their reduced opportunity to acquire understanding through traditional modes is evident from inspection of table 8.1, which illustrates the correspondence between classroom activities and criterial outcome tasks.

Table 8.1 Criterial outcome tasks and classroom tasks correspondence



Although it is suggested that benefits can occur through transferred understanding from learning in non-traditional settings into traditional representations (Hiebert & Carpenter, 1992), any conceptual understanding gained from the multiple tasks used in the Intervention class may not have been sufficiently developed within the program's time frame to support students' performance in those formal assessment tasks that predominantly required logical-mathematical intelligence.

As a consequence of this reduced exposure to mathematical concepts expressed in logical-mathematical form that comprised the post-intervention assessment of achievement, it is argued the normal and low Intervention groups were disadvantaged in their end of term assessment tasks. The low-achieving students in particular had not practised these kinds of tasks as much as either the high achiever sub-group in their own group or any student in the Control group, since they were least likely to choose logical-mathematical tasks (as the research literature and the study outcomes have shown).

Under the same reasoning, the high achiever sub-group in the Intervention class would have felt a resonance between a personal intellectual strength in logical-mathematical intelligence and the logical-mathematical tasks found in the post-intervention assessment. Only this high achiever sub-group of the Intervention group would therefore be expected to benefit from Multiple Intelligences learning when completing assessment tasks. This supports the suggestion in figure 7.4.2 that the Multiple Intelligences program may have only influenced the Intervention high-achievement sub-group, contrary to the hypotheses.

It is concluded that it is impossible to determine whether Multiple Intelligences learning had positive effects on all mathematics achievement levels within the Intervention group, given that the outcomes were not measured appropriately. *The requirement of Multiple Intelligences theory to provide intelligence-fair measures was not implemented across a range of intelligences in measuring achievement.* The post-intervention assessment instrument may have selectively demonstrated the positive effects of Multiple Intelligences learning only on the high achievement sub-group, while perhaps suppressing the capacity of other Intervention class students to display understanding.

The results demonstrate that an equitable opportunity for students to show their understanding requires a congruent variety of assessment forms, consistent with mathematics reform goals advising that inferring achievement in mathematics generally from a non-representative sampling of the curriculum outcomes or through a narrow sampling of methods of assessment may be unfair to many students (AEC, 1990). This finding of the limited value of assessing through traditional modes of intelligence also reaffirms the primary research of Kornhaber (1997) into the recommended use of intelligence-fair assessment in Multiple Intelligences programs.

The use of a proscribed assessment tool to measure mathematics achievement in Multiple Intelligences learning does not provide equitable opportunities for all students to display understanding and represents a weakness in the design imposed by the demand characteristics of the traditional context. This section of the study has revealed that it is difficult to demonstrate the impact of Multiple Intelligences programs on mathematics achievement if components of assessment are restricted by the traditional educational practices associated with Piagetian modes of intelligence.

8.1.2 Self-efficacy effects

It was hypothesised that Multiple Intelligences learning would result in increased perceptions of mathematics self-efficacy for the Intervention students when compared to the self-efficacy of students in the traditionally taught class, and that low-achievers in the Intervention group would have higher gains in self-efficacy than medium and high achievers. These hypotheses were based on Bandura's proposal (1997) that self-efficacy would be raised by successful experiences. Multiple Intelligences learning opportunities provided in this study aimed to increase the likelihood of more students being successful in mathematics. In particular the equitable introduction of successful opportunities for low -achievers offered them the highest potential for gains in self-efficacy, and the relationship between self-efficacy and performance has been shown to be strongest for low achievers (Multon et al., 1991).

The hypotheses about the influence of Multiple Intelligences learning on self-efficacy were not confirmed by the statistical analysis of outcomes (section 7.3). There is some suggestion that the Multiple Intelligences learning appeared to positively influence the high achiever sub-group of the Intervention class, contrary to the hypothesised outcome that Multiple Intelligences learning would assist the self-efficacy of low achievers more than other learners. However, the questionable validity due to loss of participants limits this suggestion to that of a possible influence.

As with the achievement outcome, the null findings were initially perplexing. Multiple Intelligences learning was implemented in order to create opportunities for the Intervention group students to understand the work in diverse ways. If learning through the stimulation of diverse intelligences was to exert an influence on students' perceptions of self-efficacy, it was expected to operate across the range of individuals.

The question as to whether the principles of Multiple Intelligences theory were applied to learning with integrity in the instructional program has been answered in the affirmative in section 8.2.1. The students in the Intervention class received Multiple Intelligences learning activities which allowed them to pursue understanding of mathematical concepts in ways that encouraged engagement, utilised their interests and allowed successful and progressive self-comparative performances to be measured in non-competitive ways. Bandura's sources of self-efficacy (1986, 1997) were a focus of the development of the MI mathematics classroom program. Students within the Intervention class were offered opportunities for positive, successful experiences in tasks. Tasks previously associated with failure were replaced by more preferred activities, and low achieving students were able to observe a number of different circumstances in which peers of similar ability could apply themselves to mathematics understanding. The tasks were personalised within a supportive emotional atmosphere that aimed to reduce the traditional anxieties associated with mathematics that some students carry into mathematics classes. In contrast, the Control group received the standard teaching and learning program, with all students exposed to the same traditional learning activities.

The observed lack of impact on student self-efficacy may be explained by considering students' reactions to the Self-Efficacy instrument that was originally chosen for its virtues as a replication of a standardised, published instrument. It consisted of a set of 25 mathematics questions, presented as logical-mathematical, verbal-linguistic and visual-spatial decontextualised problems. It is concluded that this limited task representation meant that the students with the greater self-perceptions about capability would be those most influenced by and practised in working such problems. The Self-Efficacy instrument items particularly differed for the Intervention low achievement sub-group from those tasks on which efficacy perceptions were constructed during classroom tasks. Only the high achiever sub-group (derived by filtering out those with highest logical-mathematical intelligence using the SOMS measure) spent most time in the Intervention class on these types of logical-mathematical tasks.

Therefore within the Intervention group*, the efficacy tasks were congruent only with the classroom tasks of the high achiever sub-group*. The explanation why this sub-group may have showed a relative gain in self-efficacy contrary to the hypothesis is that perceptions of self-efficacy were measured with tasks that high achievers would be more capable of, more practised in, and felt good about. By similar reasoning, although the average and low-achiever sub-groups in the Intervention class received learning in ways conducive to raising their mathematical efficacy *in class tasks*, they were measured for perceptions of self-efficacy using tasks that were not intelligence-fair. Hence it would be expected that their mathematics self-efficacy mean values would be relatively stable over the intervention, or perhaps even fall, as suggested in figure 7.3.8.

The logical-mathematical form of the tasks in the Self-Efficacy instrument also accounts for the Control group's self-efficacy outcomes fitting theoretical predictions. Given that standard mathematics items were used in the self-efficacy instrument, there would be no reason for the perceptions of mathematical self-efficacy possessed by the students within the control group to change from their historically determined levels, apart from the increases associated with traditional learning and experience. The uniform presentation and learning would not have been expected to alter the ranking of self-efficacy perceptions across the achievement levels within the Control group. Past abilities had set the "entering" levels of perceived efficacy for the tasks, and these have been uniformly addressed during the term. Low-achievers in the Control group continued to be taught in abstract media, emphasising symbolic language and decontextualised representations of real situations, consistent with their past experiences. The course material was presented uniformly to the control class with the consequence for low achieving students seen in a diminishing sense of self-efficacy for success over the three measurements of self-efficacy. The low-achiever Control group reactions to their course in terms of perceived efficacy for performing the tasks confirmed theoretical predictions and research findings. With increasing time, the work became more difficult, efforts diminished, and concentration losses effectively caused a lowered ability to do the work. The self-fulfilling prophecy of failure to be able to cope eventuated in practice in this study's outcomes for low achievers.

The task content of the Self-Efficacy instrument also offers an explanation for the general trends of a relative improvement shown in self-efficacy perceptions between

Control and Intervention students (Figure 7.3.2). The trend of the Control group self-efficacy mean appeared to be that of increasing over time, relative to the Intervention group. *Control group students were effectively receiving more practice on the type of items about which they were being asked to judge their confidence to perform*. The outcomes for the Control group fitted theoretical predictions in that students with varying achievement levels extrapolate efficacy beliefs about what they are capable of, from what happened in the past. The Control class efficacy and achievement outcomes are neatly summed up in the observation that: "Under invariant conditions, both perceived efficacy and performance quickly stabilise, and so there is little, if any, change to explain" (Bandura, 1997, p. 69).

The restriction of self-efficacy assessment tasks in the standardised instrument to the use of verbal-linguistic, visual-spatial and logical intelligence tasks offers an explanation why the Self-Efficacy hypotheses were not realised. While Multiple Intelligences learning may have had resonant effects across diverse learners in the Intervention group in terms of raising students' self-efficacy for some varieties of mathematical tasks, the measurement instrument for self-efficacy was biased in its item profile to traditionally used intellectual strengths. This is supported in hindsight by the literature on self-efficacy research in that for accurate judgements of self-efficacy to be made, there needs to be a strong correspondence between assessment tasks and the academic tasks under which beliefs are formed (Bandura, 1986; Pajares, 1996; Pajares & Miller, 1995), and the self-efficacy beliefs should be measured in close correspondence with performance tasks (Pajares, 1996).

The lack of sufficient breadth in resolving power of the self-efficacy instrument used in this study is clear, indicating the need for revision of the design and a review of the data collection instruments. Restricting the instrument to the use of standard items to measure mathematics self-efficacy in Multiple Intelligences learning represents a weakness in the design. This requires an improved means of identifying self-efficacy changes and represents a logical extension to this study.

The study has contributed knowledge about the validity of instruments to measure mathematics self-efficacy under a Multiple Intelligences program in year eight mathematics. It has demonstrated that standard forms of instruments are insufficient to meet theoretical criteria.

8.2 Conclusions from associated outcomes

Additional information on the influence of Multiple Intelligences learning in Middle School mathematics has been obtained in this study as associated variables of the program. These included the level of student engagement within both mathematics classes involved in the study, and student assessments of the classroom environments.

8.2.1 Student engagement

The Middle School years have been shown to be a particular time when student achievement in mathematics can fall and negative attitudes can develop towards mathematics. The review of research literature revealed that affective factors become as important as cognitive ability in influencing students' success during their transition into Middle School. The Multiple Intelligences learning program implemented in this study aimed to provide improved affective states for more children through devising tasks that differentially appealed to students through their strongest intelligences. Measures of student engagement are suggested to reflect this increased student confidence with mathematics.

Under Multiple Intelligences learning the Intervention class students were provided with descriptions of their intelligences profile (the MIDAS profiles) and a choice of tasks that represented the mathematical concepts in different ways. It became clear during those first matchings of tasks to intelligences that the functional skills of many students did not match the comprehension required to undertake the tasks. The descriptions and purposes of the Multiple Intelligences activities were not readily assimilated by the low achievers or by some average achievers, and this led to poor initiation of those activities. In terms of Self-Efficacy theory, some Intervention group students were lacking activation and possessed self-doubts about their capabilities to work outside of traditional mathematics instruction. The Multiple

Intelligences model for learning requires students to understand the tasks in order to undertake and usefully apply them (Kornhaber, 1997). It appeared that at the outset of this study this condition was not met, accounting for the initial steep fall in engagement in the Intervention group. Observations from this study support the assertion that many secondary school students are not developmentally ready in terms of logical-mathematical intellectual strength or schema-structuring capability for utilising abstract forms of mathematics (Gardner, 1991). The importance to school staff of having a broad personal student profile in order to provide classroom support has been made by Bailey (2001) in that until all students are supported through a personalised knowledge of their cognitive and socio-emotional needs, school systems may make uninformed decisions about student capabilities that can contribute to student failure through inappropriate interventions.

As a consequence of the observed foundering of some students in the Intervention group, tasks were re-fashioned into forms with more direction and students were provided with strategic modelling of how to use their abilities for mathematics in differing contexts. For example, some parts of the music tasks were demonstrated to the class as a process of teaching *to* intelligences rather than the small group learning *through* their personal competences. As well, the introduction of Multiple Intelligences learning was altered to a more gradual form in that traditional content was included with intervention activities in order to assist the idea of transfer. Kornhaber (1997) recommends that the history and practices of traditional assessment are not completely abandoned in applying Multiple Intelligences theory. As a result of this study's outcomes it may also be prudent to apply the same advice to introducing non-traditional instructional practices, particularly in the early stages when student strengths and weaknesses are unknown.

8.2.2 Student journals

Changes to task presentation were made to encourage and enable students to be more self-confident in trying the new forms of learning without reflecting on their perceived inadequacies in ability. Intervention group students became more confident and continued to improve in their engagement. Each student in the

Intervention and Control class was asked to record their thoughts about their mathematics experiences in weekly journals.

The engagement history of Intervention group students is reflected in these journal entries, showing positive changes in their behavioural and affective states. At the start of the term, one student made the single journal entry:

"*I don't like maths*".

Comments made by the same student in subsequent weeks were:

"*Everything is coming a lot easier than before. I'm having a lot of fun*", "*I have learnt a lot of different things in the past week*" and "*In maths, I chose to do investigations. I liked it because I had to make graphs etc. I think I learned a lot. I think next time I might change it (the selection*)".

This student's journal comments show a pre-existing alienation to the subject. That alienation is replaced by a positive affective state, self-activation, and personal agency in initiating further involvement in classroom activities. Another student who lacked confidence and had extremely poor numeracy skills wrote the following entries over time:

"*When I first started 'Patterns and Numbers' I looked at the sheet and thought 'Oh my God!' somehow I don't like the look of this. It took a lot of explaining to make me realise how fun patterns can be*".

This was followed by the entry

"*This week I learned how to draw isometric or birds-eye view. And I learned some things in maths can be fun. I think I did my house well and for the first time I wrote it neatly*", and "*I liked problem-solving. I liked it because it took my mind off a few things and made me think work. It helped my maths because instead of chatting I do my work. I would like to improve my neatness in writing*".

The literature review has noted the value that immersion in engrossing activities has in putting despondent thoughts out of mind (Bandura, 1997; Mantzicopoulos, 1997). The journal extracts described a low achieving student's circumstances where classroom mathematics experiences have created a better frame of mind for working.

These comments suggest that the Multiple Intelligences intervention resulted in students who were supported in feeling comfortable in their mathematics classroom through the inclusion of interests in tasks, and who experienced lowered anxiety when anticipating their ability to meet the cognitive demands of tasks successfully. An outcome of this positive atmosphere is suggested to be the raised engagement observed in the Intervention class.

Therefore in terms of self-efficacy having an effect on engagement, the early dip and rise in the Intervention class engagement (Figure 7.5.1) is explained as a lack of student confidence in starting new tasks in a mathematics environment where the traditional structure was not provided. Student confidence developed as engagement was encouraged, and the concept of "wrong" was replaced by discovery. The modelling of ways in which the mathematical concepts could be understood in different contexts appeared also to lower rigid conceptions of "proper" ways to learn mathematics. This may be demonstrated by further quotes from various Intervention group students' journals:

"*I felt quite surprised with what I knew about numbers and patterns! I also never really thought about using numbers and patterns in things like music and nature*".

"*I went out and shot baskets because I've never went out and played a sport during maths class. It helped me have the most fun in maths ever!"*

"*I have been having fun working out the isometric stuff and today we are going to go and work on the computer. At first I did not like maths but now I enjoy it, it's fun. I am just about finished the isometric thing."*

Although not statistically embedded, these journal entries reflect the success of the study in assisting students to gain greater confidence about their mathematics. The journal statements also reveal Multiple Intelligences instruction as changing some perceptions about the nature of what mathematics should be from the traditional view. These Intervention group students were participating in activities through which they could experience mathematical concepts and in which their familiarity gave some autonomous control in developing understanding. As a result, their anxiety about perceived lack of performance skills is reduced through that sense of controlling the situation. The journal comments contain evidence of ameliorated anxiety and indicate a sense of personal agency brought to tasks. Within the Intervention group, the use of Multiple Intelligences activities did not differentiate engagement for low and average achievers. They followed the "dip" and rise. However, fitting with theoretical expectations, the high achiever level remained relatively unaltered in engagement even with initial high cognitive-functioning descriptors in the tasks designed for that group. High achieving students are already able to function well in mathematics classrooms, and are likely to have confident views of their efficacy for school functioning in mathematics. From self-efficacy theory, a history of success had contributed to their active engagement. The use of tasks congruent with interests is seen to further accommodate and foster high-achievement level engagement. It is evident that opportunities for successful mathematics learning outcomes can be offered to students of different ability levels, supporting the literature that indicated heterogeneous grouping did not necessarily have negative consequences for high achievers.

The engagement attainment data of Intervention students is consistent with findings of other research in learning based on Multiple Intelligences theory (Beuscher, Keuer & Muehlich 1997; Dare et al., 1997; Ellingson, Long & McCullough, 1997; Layng et al, 1995; Miller, 1995; Outis, 1994). Each of these studies referred to positive affective gains or improved engagement in students, with an emphasis on low achievers. Similar outcomes have been observed in the current study. Five students in the Intervention class were initially identified as "at risk" of poor learning or developing inappropriate behaviours through their transition to secondary school. Their common presence in the one class was due to the prior determination that they had poor school skills, were at risk of social isolation, and showed a poor performance history in measures of mathematics achievement. The evidence is that their enjoyment in the mathematics class caused positive attitudes and actions towards mathematics that had not developed under past standard instruction. Particularly, the increase over time of their self-regulated engagement upon arriving at class is attributed to stimulating tasks aligned with interests. This represents a potentially transferable school skill that may enable such students to cope more effectively in secondary school.

Within the Control group, engagement data showed a consistent decline over the period of the study for the low achiever sub-group (Figure 7.5.2). The average and high achiever sub-group engagement also fell over the first part of term, followed by a small rise to the second part of term although initial levels were not fully attained. Self-efficacy theory offers an explanation for the outcomes observed within the standard classroom conditions. Engagement with tasks is a critical factor in learning. It is linked to motivation but may be mediated by perceptions of self-efficacy for participation. Engagement is also affected by feelings of anxiety and inadequacy. Low achievers in mathematics have past negative experiences, low outcome expectancies and often attribute poor performance to their low innate ability. There are few goals that low achievers in mathematics can set for themselves such that they are motivated to adopt the self-regulation to strive for success. The Control class used a standard mathematics learning program which did not set out to address self-efficacy. Work was presented as a common requirement for all students to master, using traditional tools and assessments. Therefore the structure of the learning environment in their first contact with secondary school mathematics would have been (perhaps disappointingly) familiar to the students in the control group.

For the low-achieving control group, familiar past experiences may have included poor performance attainment, lowered completion of tasks, poor understanding and a lack of meaning. No matter how hard these students have tried, past experiences suggest that success will always be lower for them than others. The literature review has shown that some mathematically low achievers have poor perceptions of a personal capacity to effect changes in performance in the future. The transition to secondary school or getting a new teacher perhaps offered little reason for the Control class low achieving students to change those beliefs. The standard classroom transition placed increased curriculum demands uniformly on students and a behavioural pattern of increasing disengagement was shown. The engagement data for the Control class low-achievement group supported literature in chapter two that showed disengagement of low achieving students is a cause for poor school success.

Some Control group students' comments over time are presented:

- " *I learnt about Pascal's Triangle. I also learned about Fibonacci. I also learned about terms, rules and sequences*".
- " *I learnt how to use a computer and use symmetrical paper*".
- "*I learnt how to do a frequency figure and graph, histogram. I think I did the graphs well. Make the activities fun or people will not do it. (I learned about) BIMDAS and algebra".*
- "*This week I have learned how to draw 3-D drawings much better than I did last week.... I think I need to speed up my maths because I'm lagging way behind*".
- "*This week was good I learnt lots about patterns and numbers. I reckon I did very well with the shapes. I reckon in the future I should concentrate*".
- "*We learnt about dimensions and shapes. It was hard. I did well in constructing the shapes. I reckon in the future I could work quicker*".

Many of the Control group comments related to completion of work, the pace of instruction, and the difficulty level of the work, with the journal comments indicating little change to students' affective histories over the study period. These journal entries reflect the traditional emphasis on content, the time-based nature of progress, and the compartmentalised approach to concepts. A characteristic quality of the Control group comments was the relative absence of a sense of enjoyment or fun, a common comment in mathematics classes (eg Vale, 1999). Middleton (1995) has particularly noted an association of "fun" with hands-on activities, higher-order thinking skills, and links between concepts. "Fun" is valuable in mathematics, but the tasks of traditional mathematics appear to work against it developing.

By contrast the journal outcomes of students learning with Multiple Intelligences instruction showed enjoyment and indicated increasing levels of engagement over the period of the study. The raised engagement of the Intervention group is proposed to account for the parity demonstrated in achievement and efficacy outcomes between the groups, which occurred despite the Intervention group's loss of learning time. The results of engagement data have agreed with the literature (eg Bryan & Bryan, 1991; Mulryan, 1992) where it has been shown that students who enjoy their lessons are more likely to adopt behaviours and develop positive attitudes at school. While achievement gains were not evident as a result of Multiple Intelligences instruction within the space of one term, it is suggested that the Intervention group students were willing and active participants in classwork, leading to their parity in mathematics achievement and self-efficacy outcomes with the Control group.

Although some caution has been advised in assuming persistence is positively correlated with self-efficacy when operationalised only as time on task (Multon et al., 1991), the observed results of raised engagement, positive affect and improved selections in behaviour are predicted from theory as outcomes of improved self-efficacy (Schunk, 1985). The differentially raised engagement observed in the Intervention class is taken here as evidence for a positive influence on mathematics self-efficacy from the Multiple Intelligences program. Although the self-efficacy instrument did not show students were positively influenced by Multiple Intelligences instruction, it is argued that it has proven methodologically inadequate within this research program that had few guiding principles on assessing self-efficacy and Multiple Intelligences interactions. The adequacy of self-efficacy measures can only be evaluated by "evidence that they are measuring what they are purporting to measure and by their level of specificity and by the range of task demands they include" (Bandura, 1997, p. 45). Item specificity and task range appear problematic in this study and are addressed in the limitations. It is concluded that the improved behavioural and affective outcomes support the contention that MI learning did have an effect on Multiple Intelligences students' perceptions of self-efficacy, but the self-efficacy instrument was not congruent with the range of tasks and learning experience used in the Intervention group and was therefore inadequate, requiring revision.

This result of the study has produced a new, quantitative description of raised engagement in Middle School mathematics under Multiple Intelligences learning that is consistent with MI research in other learning areas. The outcome adds a new and substantial contribution to the field of mathematics education where alienation and disengagement by Middle School students is reported as a significant factor in low mathematics achievement. It is acknowledged that engagement data would be strengthened in validity with the use of independent observers, similar to the recommended condition of Kornhaber (1997) for the acceptance of Multiple Intelligences assessments.

8.3 Classroom environment

The Middle school arena has been identified as an unstable developmental time and place for students. The transition from primary to secondary education environments represents a complex interaction between cognitive, socio-emotional and biological forces (Elias, 2001), involving emotional shock and alienation (Rasdien, 2000). Multiple Intelligences learning offers to create more positive frames of mind for more students during this transition.

The review of research literature on Multiple Intelligences theory revealed that this study offered a unique application of Multiple Intelligences theory into Middle School mathematics, focussing as it did on cognition and affect. This new view of how to approach the problem of low mathematics achievement meant that the research literature did not provide a description of a methodology that would allow a measure of the degree to which Multiple Intelligences criteria are incorporated in education programs. Two essential components in applying the theory of Multiple Intelligences in education environments are that learning is personalised, and that it considers the individual nature of learners (Gardner, 1995). The outcomes of the learning program applied in this thesis will have been affected by how well these components of Multiple Intelligences theory were developed and incorporated into the mathematics program.

Therefore an instrument that provides indicators of fidelity offers valuable new information for the application of Multiple Intelligences theory in learning environments. The Individualised Classroom Environment Questionnaire (ICEQ) has played a central role in establishing whether the principles of Multiple Intelligences theory were applied in this study with integrity in the instructional program. The ICEQ showed there was a statistically significant difference between the groups in two dimensions of the classroom environment, "Personalisation" and "Differentiation". Personalisation is operationalised as the degree to which opportunities are created for personal interactions with the teacher with respect to such factors as social growth, or personal student welfare (Fraser, 1990), and Differentiation is operationalised as the degree to which individual learner is considered in terms of needs based about ability, interests, working rate or learning style (Fraser, 1990).

This section discusses the findings of the ICEQ and shows that the research appropriately interpreted and utilised the theory of Multiple Intelligences as the basis of the learning program in the intervention class, and demonstrated a fidelity to the principles. A key criterion in establishing this fidelity between a learning program's characteristics and the tenets of Multiple Intelligences theory is that if a more personalised education results then the theory is being appropriately applied (Gardner, 1995). The Individualised Classroom Environment Questionnaire (ICEQ) outcomes showed that the intervention class experienced a significantly more personalised and differentiated classroom learning environment than the control class. Students who learned under the Multiple Intelligences program indicated they felt the teacher comprehended their needs, was amenable to their ideas, and that their personal wellbeing was of concern to the teacher.

The affective influence of a personalised classroom is significant in influencing student attitudes and emotions towards more positive values. Students have emotional responses to teacher behaviours, and the use of affinity-generating behaviours by teachers has been shown to have positive bi-directional correlations with student emotions. This in turn has a positive effect on learning (Beebe & Butland, 1994). The increased personalisation of the Intervention classroom is attributed to the influence of the Multiple Intelligences learning program. There was a persistent and consistent development of an appreciative environment aimed at promoting and utilising the Interpersonal intelligence in order to share perspectives on mathematics concepts. This observed peer acceptance of a diversity of approaches to understanding tasks is embodied in the term "social validation" of cognitive capabilities (Bandura, 1997, p. 174). To this end, students were encouraged to include each other and share their different perspectives in a cooperative environment, developing a respect for the value of using abilities other than logical-mathematical skills in learning mathematics. When students receive acknowledgement and appreciation for their particular abilities, they are likely to show increased pleasure towards their learning environment.

From the viewpoint of Self-Efficacy theory, a personalised classroom produces higher self-perceptions of capability, and generates less reliance on outside sources such as the teacher for the formation of such self-perceptions (Bandura, 1997). The personalised classroom environment was therefore an agent for cultivating self-efficacy for independence, and is proposed as explaining in part the differentiated engagement outcomes for the Intervention group. The personalised classroom meant also that the Intervention group was able to feel emotionally comfortable. Cognitive development takes place within a social environment and students are sensitive and susceptible to their peer values and attitudes. Those who feel inadequate in establishing their presence in class are unlikely to have confidence for class participation in tasks. By reducing anxieties associated with peer affiliation, a stronger sense of efficacy for participation can be formed. The mainstream or traditional tasks in which students with strong logical-mathematical intelligence were successful are unlikely to draw low-achieving children into classroom discourse, and restricting mathematics discussions to explanations in abstract terms denies many students the psychological and academic benefits arising from the interchanges of ideas and values.

The ICEQ showed a statistically significant difference between the Intervention and Control groups on the Differentiation subscale with students in the Intervention group perceiving themselves as receiving a greater consideration of their individual needs in learning. Under Multiple Intelligences theory in educational settings, the recognition of student differences is considered by Gardner (1995) as essential in order to provide equitable, fair and emotionally supportive learning opportunities. The primary feature of Multiple Intelligences theory is that recognition is given to the differentiation of intelligences, which then requires the consideration of these differences in learning programs. According to Gardner (1994), “the biggest mistake of past centuries has been to treat all children as if they were variants of the same individual and thus to feel justified in teaching the same subjects in the same ways" (p. 564). This position allows cognitive advantage to be provided through Multiple Intelligences instruction, but there is also the affective advantage resulting from students seeing their personal abilities recognised and brought into class.

The learning program developed in this study catered to individual differences through two main ways. The first was to seek out and consider individual cognitive strengths. The second was the provision of multiple representations of the same mathematics concept in order to allow a resonance between those strengths and the contexts of concepts. A benefit of the differentiated environment in the Intervention class is evident from the Year eight Staff Team weekly meetings on matters related to negative student behaviour. The Intervention group was taught as an intact class across the four learning areas of Mathematics, Science, English, and Society and Environment. Separate teachers taught the class in each learning area. The Intervention class contained a higher proportion of students whose circumstances and negative behaviour were regularly represented at those meetings. The expectation that there would be a disproportionate representation of disciplinary matters within the Intervention mathematics group did not result. This is attributed to their increased motivation for engagement. The consequences for facilitated learning in mathematics under the study's intervention were that these students came to class on time, arrived prepared to work, organised themselves readily without instructional time losses, pursued activities with interest and were happy to do so. These *school skills* were generated and activated by the personalised classroom environment and were reflected in engagement data.

The outcome from Multiple Intelligences that these students perceived they were receiving an empathetic learning carried consequences for their behaviour. This was reflected in the school commendation letters sent home for valued academic or social behaviours in Year eight. The mid-term tally showed that the Intervention class students were poorly represented, receiving 2 of 32 commendations issued. By contrast the Control class had 10 of the 32 issued. It may have been expected that the intervention class students would be represented more in the school's behaviour management program, but this was not evident in the engagement data, where

Intervention students showed greater engagement in mathematics than the control group. This supports literature in the review that indicated student enthusiasm and on-task behaviour arise at least in part from differences in teaching practices and approaches and have consequences for student learning (Smith & Bourke, 1997). Pedagogically informed teachers can make a difference, which has been the call in mathematics education on the basis of equity (Darling-Hammond, 2000), providing teachers with pedagogical knowledge (Middleton, 1995), and for resourcing qualified and pedagogically aware teachers (National Research Council, 1997).

Implementing classroom climate measures as part of the study's methodological model has made a genuine, substantial and original contribution to Multiple Intelligences applications to mathematics education in Middle School. The results of the ICEQ have provided mathematics education research with an independent means by which programs that use Multiple Intelligences theory can demonstrate that they are implementing learning under theoretical guidelines. This study also has shown Multiple Intelligences learning to have a demonstrable role in improving the emotional climate of a year eight mathematics classroom. Students learning through this Multiple Intelligences program have perceived their relations with their teacher to be more harmonious and supportive in helping them see the value of mathematics in their lives. The study has contributed to knowledge of how to raise the emotional climate of Middle School mathematics classes with Multiple Intelligences learning.

8.4 Limitations of the study

The originality of the study's methodology resulted in the exposure of limitations in instruments that traditionally have been adequate for measuring the outcome variables of mathematics achievement and mathematics self-efficacy. A number of other limitations became apparent during the progress of the study that were not predicted prior to its implementation. As these emerged, they had a direct impact on the outcomes and are described and discussed in this section.

8.4.1 Loss of participants

A loss of participants occurred in the Control and Intervention groups during the program as a result of some students withdrawing from the classes. Public schools are required to allow students to participate in the Western Australian Education Department's "Talented and Gifted Students" program (TAGS). Students who are identified as talented in any or all of four learning areas (Mathematics, Science, English, or Society and Environment) do not have to attend the regular class in that learning area, but may study through separate programs. The identification of students involved in this study occurred in primary schools in the preceding year to their enrolment in secondary school, but their option to withdraw from school classes was not indicated before the study began. One week after the start of the study, the TAGS program caused the loss of four "high achiever" students from the Intervention class and one "high achiever" from the Control class.

This had a significant effect on the Intervention group. The high achiever student population total decreased from 5 students to 1 student (from 25 % to 4.3 % of the class). Only one high achieving student was removed from the Control group, changing its high achiever component from 6 to 5 (or 26 % to 22 % of the class). The sub-groups of achievement level were derived from the upper and lower quartiles of standardised test scores obtained from the SOMS measure. Combined with the presumption of equal distribution of other student variables, this initial distribution within sub-groups was seen to heighten external validity. However, the resulting participant loss for the intervention class diminished the validity of statistical data, since only one student formed the Intervention class "high achiever" group.

The changes also introduced non-equivalence in classroom dynamics. An important source of self-efficacy information comes from vicarious experiences (Schunk, 1985). The self-appraisal of capabilities and adequacy of performance derives in part from relative comparisons, with the value of these comparisons in generating accurate self-perceptions or as motivators being affected by role-models. The high achievers who were lost to the study may have represented positive models of competence or demonstrated persistence in the face of difficulties. As well, their loss represented a loss of a variety of available student interests that may otherwise have contributed to the task diversity in the classroom. Therefore overall, this attrition may have reduced the variability within the groups, creating a relatively more homogeneous sample.

The problem of participant losses highlights the tenuous control an “outside” researcher has over the study conditions, which can be very dependent on the researcher becoming part of the school society. A few more withdrawn students from either group involved in the study may have removed the presence of a “high achieving” sub-group entirely. The loss of participant may create problems for validity of data, including affecting the assumption that the intelligences are normally distributed within and across class populations. It is recommended that future MI research using a quantitative methodology may need to widen the student sample in order to lessen any impact of participant loss.

8.4.2 Loss of instruction time

There was a significant discrepancy between the number of teaching periods potentially available when constructing the Multiple Intelligences learning program before the term began, and the realities of implementation within the functioning secondary school instructional program. Significant losses in instruction time came from three main sources:

- The first source related to institutional school requirements involved with student induction, information dissemination on school matters such as behaviour, public holidays, a swimming carnival, and a “sports” day. A total of four lost instructional time periods occurred for both the Control and Intervention classes because of these factors.
- The scheduling of class-time to developing skills in electronic technology, for which all year eight students were enrolled, represented a loss based on policies to have students become technically literate in computing. Severe constraints on timetabling exist in an age-based, course-based curriculum in relatively small senior secondary schools (of which the majority are in rural locations). Instructional class-time for the computer technology skill development course was allocated from the four learning areas of

Mathematic, Science, English, or Society and Environment. Each year eight class lost one period per week from its program to attend computer instruction. For the Intervention group, the computer time came from the mathematics learning area, while the Control group time came from another learning area. Therefore the Intervention group lost one period of mathematics per week over the time the computer course ran, whereas the control class lost no mathematics instruction time. This caused a loss of 4 periods of instructional time for the Intervention class.

- Assessment for both regular school purposes and for this study affected available instruction time. The Self-Efficacy instrument and Student Outcome Mathematics instrument took a total of three periods from each class. The MIDAS took one period of instructional time from the Intervention group. School assessment using class tests took at least three periods over the term. This represented the loss of 7 periods for the Intervention group and 6 for the Control group.

Therefore the average loss from instruction time in mathematics during the term was 10 periods from a theoretically available 35 periods the school timetable made available for year eight mathematics. Four periods represents one week of instruction. This history was approximately the same for both groups.

The loss of learning time is summarised:

Total periods "lost" by Control class = 10 from 35 = 28%

Total periods "lost" by Intervention class = 15 from 35 = 43%

As a result there were differences between the Intervention class and Control class in terms of student opportunities to learn the mathematical concepts. The research program did not factor in these losses, but it is evident that the achievement of parity in achievement by the Intervention group is notable in these circumstances.

The problem of the loss of instruction time demonstrates a difficulty when undertaking research in education environments and the differential loss is a significant confounding component in the present study. The problematic factor of time losses from instruction may be diminished if the study is conducted over a longer time (eg 2 terms), or occurs in the middle terms where administration requirements can be less. However, this would result in the loss of access to students at the immediate transition point from primary to secondary education. It is evident that equity of access to instruction is an important consideration in future research.

8.4.3 Establishing equivalence of groups

The Student Outcomes Mathematics Standardised (SOMS) instrument indicated that no statistically significance differences were shown between the Intervention and Control group in measures of pre-intervention achievement. However this did not preclude selection bias or the existence of pre-existing factors that may have had an influence on outcomes. In their meta-analysis of research on interventions to improve mathematics achievement of low-achieving students, Baker et al. (2002) have expressed concern that context-based quasi-experimental research may not sufficiently control for differences between the experimental and control groups. It may be that Multiple Intelligences research is particularly problematic in regard to this uncertainty. Selection bias occurs whenever groups differ on some pre-study characteristic that affects the post-test and when this pre-study difference is not described or accounted for by the difference on the pre-test. The selection of intact school classes as research groups allowed the possibility that they may have differed on characteristics prior to the intervention. The SOMS pre-intervention instrument only measured student abilities in the narrow range of cognitive capacities in mathematical functioning, referred to under Gardner's theory as logical-mathematical intelligence (Gardner, 1983). It is proposed that the SOMS established equivalence between groups in that traditional intelligence. The lack of random student allocation to groups also may have introduced bias in terms of one class containing a greater proportion of students with a similar set of other intelligence strengths other than logical-mathematical.

Several situations arose during the study as evidence for pre-existing differences in the groups in terms of affective and behavioural characteristics. For example, evidence of possible differences between classes may be found from the weekly team meetings. The student commendations showed that as early as week four of the term, a clear difference existed between the Intervention class and the Control class (and the other year eight classes) with regard to students nominated for commendations for aspects of their school academic, social, or coping performances.

The combined learning area commendation figures from weeks one to four are indicated in parentheses for each year eight class as follows:

8-1 (9); 8-2 Control (10); 8-3 (11); 8-4 Intervention (2).

This may have been accounted for in part by the removal of four high ability Intervention group students for the TAGS program, however academic ability was not the only criterion for the class recommendations.

Another source of differences that may have affected outcomes was indicated through the sub-group comparisons between classes. The self-efficacy mean of the low achievers in the intervention class was lower than the control group, as shown in figure 7.3.8. The small sample sizes do not give this as statistically significant, but it represents some support for the groups differing on affective factors, which may have been caused by not using a full experimental model, with random allocation of students to groups.

Conclusion

This section has revealed that a dependence upon current standardised instruments to create independent groups may not be applicable in Multiple Intelligences learning. The assumption that the two classes used in the study represented equivalent samples of the population in terms of the distribution of Gardner's intelligences was not controlled. The study has revealed the difficulty of achieving full control over variables when using intact school classes with possible consequences for validity and reliability. The breadth of factors in Multiple Intelligences learning presents a problem in establishing equivalent groups for future quantitative research. Conducting the study through a combination of quantitative and qualitative methods may establish characteristics more clearly. A recommendation for methodology in the replication of this study is that the MIDAS should be administered to both groups.

8.4.4 An overview of the limitations

The previous sections have revealed a number of circumstances that acted as limitations on the implementation and outcomes of the study. The differential loss of participants and the differentiated loss of learning time were to the detriment of the intervention group. The emergent problems of fairness in the mathematics achievement and self-efficacy instruments were significant limitations on the outcomes supporting the hypotheses. The measure of mathematics achievement was locked into the school's standard requirements and demonstrated an institutional inertia to innovation. The self-efficacy instrument represented a standardised model that proved inadequate for innovative change in mathematics delivery. While the documented teacher-researcher records and the students' journal entries have reflected encouraging progress from Multiple Intelligences instruction on cognitive, affective and behavioural student characteristics and on the classroom environment, events which were linked to the school's institutional requirements have masked this progress. As a result of these limitations being identified, a number of implications for Multiple Intelligences learning in mathematics can be drawn from the study.

8.5 Implications and recommendations

8.5.1 Implications for mathematics education

Traditional mathematics education has been described in the review of literature as highly resistant to change, with this resistance coming from several sources. A major source is public concern about "lowered standards", "lost time", or "poor behaviour" affecting mathematical knowledge and numeracy that can inhibit innovative departures from the traditional curriculum. A significant source of resistance stems from the limited pedagogical support given to mathematics teachers in the form of professional development in how to teach and assess under reforms. The literature review has shown that when teachers in mathematics are unsure, they remain with the traditional methods and practices of their own experiences. Because the majority of material readily available to mathematics teachers is in verbal-linguistic and logical-mathematical form, the inequity in opportunities for students to learn through or with other intellectual strengths is maintained.

This study has shown that it is possible to adapt part of the year eight mathematics curriculum into alternative formats which cater to the diverse needs of more children. When these adaptations were used, higher engagement with tasks resulted, and this was evident particularly for low achieving students. The adapted delivery of the mathematics curriculum encouraged more students to be emotionally comfortable in their mathematics class without affecting their achievement performance. Initially, students involved in the study were perplexed at the presentation of mathematics in non-traditional arenas. This demonstrated their lack of skills using mathematics in contexts other than the traditional model. These skills needed teaching in the form of new approaches to seeing mathematics in action, and were enthusiastically adopted by the students. A new contribution from this study to the application of Multiple Intelligences to mathematics learning is the demonstration that students need to be taught how to become aware of their intellectual strengths, how to move away from the concept of mathematics as logical-mathematical tasks, and how to apply their intelligences in new ways to gain advantage in mathematics lessons. This study provides a clear recommendation for creating metacognitive awareness in students about their multiple intelligences. This is a conclusion that supports the reviewed literature on students' beliefs about intelligence and performance being powerful predictors of achievement outcomes, and influences on student goals and strategies (Stipek & Gralinski, 1996).

In order to gain acceptance of Multiple Intelligences instruction, it is a recommendation that teachers of mathematics need to be shown the advantages in using materials that appeal to the spectrum of intelligences. In particular, teachers have been concerned about the effect on "top students" and on student behaviour. This study has shown that Multiple Intelligences learning does not restrict opportunities for high achievement outcomes and promotes behaviours and attitudes advantageous to learning. It suggests that students who study in Gifted and Talented programs can have their learning needs accommodated under a differentiated approach such as Multiple Intelligences learning. Supporting the literature review finding that streamed or tracked classes in mathematics education may be detrimental to low achievers (Lumpkins et al, 1991), the evidence from this study is that under Multiple Intelligences learning the high achieving student is not likely to be affected negatively by low achievers being taught in the same class, although the validity of that conclusion is limited to this research environment of year eight mathematics.

8.5.2 Implications for the Multiple Intelligences theory and its application in mathematics education

Difficulties with the acquisition and development of resources were exposed in preparing this study and continued to emerge during its implementation. The development of suitable programs required the long-term consultative cooperation of school administration and staff in order to be effective. Consistent with the literature (Campbell, 1992; Emig, 1997) much time was needed for the development of resources and for the arrangement of integrated programs. The school system's needs frustrated some of these efforts. For example, one of the recommendations of Multiple Intelligences theory to education is the use of domain experts to demonstrate particular skills and to assess students in context. This study attempted on several occasions to obtain the school's dance teacher to work with the students in applying the mathematics concept of patterns. Each arrangement was overridden by institutional requirements based on timetabling. Future research should note that a teacher who is part of the school system is more likely to be able to re-arrange curricula, to gain cooperation with other teachers, to have a less fettered access to school resources, and to have the confidence of the students.

A significant factor related to the teacher's duty of care emerged during the study. Multiple Intelligences learning can create a number of learning environments that use non-traditional tools, take place in non-traditional contexts, and may not have students under direct supervision. Duty of care obligations would need to be considered in the implementation of contextual mathematics tasks. Some ways of meeting these legal problems that would prove valuable in creating conditions allowing Multiple Intelligences learning to occur are sharing staff with integrated learning, the provision of Teacher Aides carrying duty of care, and the incorporation of domain experts from the community to provide for the need of student supervision.

The role of assessment was an important component of the study. Intervention group students were involved in understanding mathematical concepts in diverse mediums and in attempting to relate these back to the symbolic representation of traditional mathematics. Monitoring student activities meant looking at the accuracy of each mathematical metaphor. In preparing the Multiple Intelligences program, tasks as metaphors for traditional mathematics content were discussed with the school's mathematics staff with concerns of validity. Equating performance levels from multiple representations into traditional Outcomes performance levels required in school reporting represents a formidable interpretation and recording task for external reporting. Because the majority of assessment is for institutional purposes (Senk et al., 1997) this inherent resistance to changed assessment practices may inhibit mathematics reforms and innovative programs such as Multiple Intelligences programs. It is suggested from the experience of this study that this difficulty can become more problematic if Multiple Intelligences learning in mathematics moves from primary school to secondary school. This study had a high requirement for time which coverage of a syllabus does not allow. Despite an outcomes focus in mathematics education reform, the literature review showed there is still a strong adherence to traditional practices and values in mathematics that has been argued to dampen the advantages of reforms (Schmidt et al., 1997). These difficulties offer possible reasons why Multiple Intelligences learning has a low representation in mathematics beyond primary school. It is evident from the literature review that the majority of reports about the value of Multiple Intelligences learning have emanated from junior schools. The constraints of timetabling, curriculum coverage and specialised learning areas in senior schools may limit the introduction of Multiple Intelligences learning. However, options are opened up with school models such as the Middle School system, where opportunities are created in terms of cross-curriculum learning through team teaching, and where the relatively small school size gives an intimacy of acquaintance with students.

The application of Multiple Intelligences theory in this study took place within the standard school framework. Timetabling flexibility and allocation of resources suited to its optimal application was not available. It is concluded that Multiple Intelligences instruction is educationally desirable for a number of students, but faces large obstacles in the standard secondary school system.

8.5.3 Implications for the research paradigm

The study has used quantitative research indicators to examine relationships between Multiple Intelligences learning and its effects on cognitition and affect. It has been shown that restricting the methodology to these indicators has resulted in incomplete descriptions of possible impacts from the intervention.

In attempting to identify the relationships among Multiple Intelligences learning, mathematics achievement and self-efficacy, the research design may have allowed sensitivity only to a small segment of Gardner's intelligence spectrum. This introduces methodological problems in defining and controlling variables and brings into question the research paradigm used in this study. Eisner (in Bracey, 1994) considers that educational research models are not adequately designed for educational events, reducing rich sources of data into pale reflections of the reality researchers seek to study. A naturalistic setting or an ethnographic study may be more sensitive to the influence of affective variables such as student behaviour changes and emotional states, and the additional use of a qualitative instrument in an appropriate setting - such as interviews - may help provide deeper insights.

In this study an aim was for students to construct their understanding of mathematical concepts through tasks acting as metaphors for traditional representation. However the low achieving students may have possessed different abilities to construct and interpret metaphors than would students of other levels of ability. The possibility of invalid assessments of mathematics understanding has arisen since the instrument of mathematics achievement used in the study at best only inferred a transfer of understanding.

The Self-Efficacy measure had the same difficulty. Under the Multiple Intelligence learning program, reading a numeric response gave only a derivative awareness of each student's perceptions of capability for their mathematics. The problem was that students (and particularly the low achievers) may not have generalised the concepts beyond each specific learning circumstance. This reduces the external validity of quantitative measures. The children may have understood the concepts "in their own way" and may have felt confident in their mathematics but that has been hidden or suppressed by the traditional assessment tasks used to measure achievement and self-efficacy.

The research design has not allowed assessment tools to reflect the individualised nature of the program, producing an insufficient student profile with respect to their understanding and beliefs. The collection of evidence of the effects of the Multiple Intelligences instruction program used in this study may need to be immersed in the learning process under a qualitative paradigm. The quantitative measures have proven necessary but not sufficient in assessing the outcomes at a grouped statistical level. Data could be collected across students' ideas, products, conversations, behaviours and engagement. This triangulation may give more validity to the research but requires the development of a variety of ways to collect data, when and how to record it, and how to interpret it.

This research attempted a research methodology that aimed to establish a cause and effect relationship. In selecting a research model, the present research drew on past studies that examined these same outcomes of mathematics achievement and self-efficacy, but there were no guiding exemplars with respect to the research intervention examining cognitive, affective and behavioural consequences of a differentiated and personalised mathematics curriculum. According to Eisner (1985), "when it comes to educational aims that focus on the cultivation of productive idiosyncracy, the development of imaginative thought, the acquisition of the skills of critical thinking, the invention of new modes of expression, educational research has not been notably productive" (p. 359). Future research designs using Multiple Intelligences theory could inform mathematics education in these areas.

A conclusion for research using Multiple Intelligences theory is that both qualitative and quantitative research methods may provide the fine-grained descriptive detail that appears lacking. This would require a longer period over which to conduct the study, and would probably need access to students outside of instruction hours.

8.5.4 Implications for classroom learning time

Time on instruction is positively associated with performance attainment. The loss of teaching time in this study is interpretable as a loss of exposure to the intervention's influences. The impact of Multiple Intelligences learning arises in part from a change in students' conceptions about personal control, about the role of their interests in classroom learning, and about assessment practices. If students are to experience these varied components of teaching and learning to a significant degree, exposure to the program's factors is important.

This raises the issue of efficient use of student time in classrooms. Multiple Intelligences theory recommends the use of cross-curriculum lessons, with project and thematic work. This would allow a decrease in disjunct within-class activities between learning areas, in turn decreasing losses in instructional time. Using some flexibility in planning, the need for student movement about the school may also decrease such losses. Teachers are familiar with the time spent moving between classes during period changes. Sometimes the teacher waits for late or "tardy" students, and sometimes students wait for the teacher. Regardless of cause, middle and secondary schools create significant losses in available instruction time due to disconnected and disjoint subject areas.

Multiple Intelligences learning may reduce inefficiencies in instruction time through cross-curriculum activities and embedded assessments, which may assist with the engagement of low achievers in learning mathematics. Further research in the area of the impact of Multiple Intelligences learning on increasing student academic engagement is recommended, particularly for Middle Schooling where engagement with mathematics can fall away quickly, yet students are still readily amenable to developing beneficial emotional reactions to school (Anderman, Yoon & Blumenfeld, 1995).

8.5.5 Implications for comparative mathematics assessments

Assessment has been raised in this study as problematic for teachers working within education reforms that require ongoing collection of data using a number of methods

(Senk et al., 1997). Many mathematics teachers are still confronted with difficulties as to the reliability and validity of their judgements, of establishing concordance with colleagues and of finding efficient means to assess and record assessments. Even with relatively prescriptive outcome guides, assessment using Student Outcome Statements is an area of concern and some confusion for teachers using traditional logical-mathematical, verbal-linguistic and visual-spatial tasks. In attempting to introduce a learning program such as Multiple Intelligences learning, educators will need to have self-confidence in producing equitable, valid assessment scoring procedures for performance assessment of student mathematical ability across diverse competencies. Traditionally success in mathematics has been described as pass or fail, using scores or percentages that are quick summations of “ability”, and easily recorded on reports. Getting alternative assessments accepted by staff, parents and the broader community is a potential problem for the application of Multiple Intelligences in mathematics.

Assessment under Multiple Intelligences theory does have guidelines aimed at having the nature of Multiple Intelligences accepted. These guides have been referred to as *enabling* characteristics and recommend that schools “should have built-in, unavoidable, and public sources of critical feedback” and that “the involvement of a group of schools, or perhaps a district, rather than one or two schools” will generate the attention and funding likely to optimise the chances of Multiple Intelligences programs being accepted and successful (Kornhaber, 1997, p. 278-279). Unfortunately, there appears a tension between the demonstration of learning via external, normed benchmarks using standardised assessment instruments, and the emphasis on individual progress under the current philosophy of Outcomes Based Education. Opportunities to broaden the delivery of mathematics through the multiple entry points of Multiple Intelligences learning may be limited by these external requirements.

8.5.6 Implications for staffing the mathematics learning area

There is an indicated shortage of qualified mathematics teachers in Australia (EDWA, 1997), with the Australian Government initiating a review of strategies to attract and retain teachers of mathematics (Commonwealth Department of Education, Science and Training, 2003). Australian newspapers carry interstate and international advertisements for staff, suggesting the shortage may be global. It is not uncommon for schools to place the most qualified and competent staff with classes that are frequently the preserve of the mathematically capable students, destined for tertiary education. These classes usually have students who are motivated, who are socially and psychologically supported by cultural values placed on their abilities, and who possess the highest efficacy for mathematics. Their teachers would be likely also to have a high sense of instructional efficacy for mathematics.

These factors suggest that the teacher shortage can be accommodated in the less mathematically able classes. Less experienced mathematics teachers or those without pedagogical knowledge in mathematics education may be required to create learning environments for raising the competencies of the least mathematically efficacious students, including those with histories of low achievement in mathematics. It is a reasonable assumption that inexperienced staff, or staff teaching outside of their area of expertise may not possess a high degree of instructional efficacy for teaching mathematics. Nor would they be likely to have received as much professional development training in the delivery of mathematics education under curriculum reforms. In the face of students with poor motivation and limited academic success in standard mathematics courses, these teachers may be unlikely to believe that they can play a part in altering negative student qualities, relying on authority and rigid practices for curriculum delivery.

This study has revealed that low achieving students can be assisted in their learning within a program that reflects pedagogical knowledge in mathematics learning. This suggests that the use of experienced, efficacious teachers in low achievement classes is proposed to be educationally advantageous.

8.6 The pedagogical issue of intelligence and its effect on equitable mathematics resourcing

It was noticeable in the year eight mathematics learning area that for students enrolled in the "Talented and Gifted Students" (TAGS) program, the provision of a number of resources appeared inequitably and positively biased towards this group. Schools are required to take part in assessments that identify and cater for these gifted individuals, reflecting the cultural bias on encouraging and prizing high verbal-linguistic and logical-mathematical abilities. This bias underscores Gardner's criticism of education catering for only a few abilities (Gardner, 1991). The degree of intellectual freedom granted for the TAGS students appeared generous in comparison to others. They were allowed rooms set aside particularly for their use, unsupervised access to these rooms, were free to move within the school unsupervised and received specific programs designed to resonate with their particular intellectual strength. The physical resources (including over $30,000 of computer equipment) allocated to these relatively few children also implied the creation of advantaged educational opportunities for learning through preferred intellectual pathways. According to Howley, Howley and Pendarvis (1995), "we teach children identified as gifted that their potential is an entitlement to a privileged life, and we teach other children that this allocation of privilege is perfectly natural" (p. 85).

Little critical educator comment was expressed in relation to the imbalance in resources, reflecting the institutional educational bias in valuing certain competencies over other abilities. The presumption seems to be that society will reap potential benefits from "bright" students, who may repay the costs of present-day programs with future unspecified gains, yet there is little evidence that such gains eventuate. A division within the government's education services for specifically cherishing and nourishing the potential of identified students used enrichment, extension and acceleration in resonant intelligence activities for these students. Apart from the direct impact on cognitive processes, it is reasonable to suggest that gifted programs include affective and behavioural gains for these students from satisfying their psychological and intellectual needs, and from the recognition of their possessing socially valued intellectual qualities. Clearly, these programs used the premise that extremely bright students may get "bored" in standard classes, and that they could engage in off-task negative behaviour and run the risk of not being recognised as a result. Examination of the criteria for identifying TAGS students results in characteristics such as evidence of classroom boredom, lack of challenge, isolation, fear of failure, anxiety, and low self-esteem (EDWA, 1996). These characteristics are proposed as potential contributors to gifted students displaying low achievement in culturally valued abilities, yet are similar to characteristics described for “non-gifted” low-achieving students (Magne, 1991) who remain unsupported by intellectually resonant educational programs.

Educators perhaps should be asking what educational, personal and social benefits would also emerge if low-achieving children were to have equitable access to the kind of resonant, experiential education received by logically-mathematically gifted students. Opportunity and equity of access to resources underwrites the capacity of different students to develop in diverse areas. The concepts of social justice and equity validate programs being developed in education to support the different intelligences, in that giftedness should not be tied to traditionally valued competencies. Support for gifted education in the form of accelerated and differentiated classes is justified, but equity should make resonant programs available to all students. An equitable recognition of differences leading to increased learning opportunities offers more than academic success. This study has shown that more students can develop and improve on classroom attitudes and behaviours that enhance mathematics achievement if their particular talents are recognised and incorporated in classroom tasks. This study has indicated that Multiple Intelligences learning can cause students to become more engaged at school and to have an affinity with the staff and class in which personalised learning occurs. The costs to society from alienated students who have been poorly served in standard classes are grounds for the consideration of equivalent programs experienced by TAGS students.

8.7 Recommendations for theory

Bandura (1997) suggests that in order to have explanatory and predictive power, self-efficacy measures need to be tailored to domains of functioning, and to reflect gradations of task demand within those domains. However Gardner’s theory requires a multiple number of intelligence domains within an individualised classroom. This study suggests it would be difficult to establish a specific correspondence between learning tasks and self-efficacy tasks without a cumbersome set of instruments tailored to different intelligences. It is questionable whether statistically useful instruments can measure self-efficacy under the breadth of implementation of MI learning while adhering to Bandura’s (1997) conditions of task specificity and correspondence. Some research has proposed that Self-Efficacy theory should have a general validity, that generalised self-efficacy for mathematics should also have a mediational role, and that the theory is extendable beyond task-specific circumstances (Randhawa et al., 1993). It may be that Multiple Intelligences theory is applicable to raising generalised student self-efficacy for mathematics. This study can be replicated using generalised mathematics self-efficacy tasks to see if MI learning supports an extended model of self-efficacy, its measurement, and effects.

8.8 Summary and conclusion

The study has focused on overcoming the problem of low mathematics achievement. The content has been directed by the objective to develop a program using Multiple Intelligences instruction aimed at raising achievement levels in Middle School mathematics students. Chapter one has shown that the problem of low achievement is of widespread concern. It has been associated with a lowered student confidence to do mathematics and frequently leads to students' dislike of the subject and withdrawal from class-work. Chapter two has reviewed the research literature on low achievement, providing evidence that mathematical reforms have not succeeded in addressing low achievement to a significant degree.

This study has oriented itself towards assisting low achievers in mathematics through programs that would make the subject more meaningful, enhancing opportunities for students to have successful and enjoyable classroom experiences. It has suggested that mathematics teaching and learning would be more successful if students were able to feel confident about tasks and if they could connect the concepts with their lives. A particular objective in developing the learning program was to make mathematics a less isolated and less abstract activity. For many students mathematics has appeared as an elite area of learning requiring a natural skill in logical, deductive thinking that frequently is associated with high intelligence. This view of intellect is based on the Piagetian description of cognitive development reaching its peak with capabilities for logical-mathematical thought. The study proposed that because schools concentrate on teaching mathematics using abstract language and depend on decontextualised tasks that appeal to the logical-mathematical mind, many students are not given an equitable opportunity to use their strongest cognitive structures to construct meaning out of their mathematics experiences. In order to alter students' conceptions of intelligence, an alternative view of student abilities as cognitive pathways to understanding mathematics was proposed using the theory of Multiple Intelligences (Gardner 1993). This theory is well-suited to developing an equity-based program because it allows a diversity of students' abilities to be considered as cognitive pathways to understanding. The theory of Multiple Intelligences and its application to mathematics learning was outlined in chapter three. It was proposed that students' understanding would be assisted directly through more meaningful and strong connections being made to mathematics concepts.

Attention was then paid to understanding what the effects of Multiple Intelligences learning would be. It was proposed that Multiple Intelligences learning would improve students' confidence for doing mathematics. The theory of Self-Efficacy (Bandura, 1986, 1997) was incorporated into the learning model. Under this theory it was proposed that students would benefit indirectly from improved self-efficacy for tasks, resulting in greater engagement, more concentration and longer application to classwork. Chapter four has described the role of self-efficacy in this study.

The thesis presented a new and original idea in synthesising Multiple Intelligences and Self-Efficacy theories. This synthesis is described in chapter five. A methodology was developed that allowed this innovative Multiple Intelligences program to be compared to standard instruction outcomes. The interaction of theories provided a foundation for developing a range of tasks using an intimate knowledge of students' cognitive strengths. The tasks were constructed to represent mathematics concepts in ways resonating with the array of intelligences. Standard methods were adopted to assess mathematics achievement and student self-efficacy outcomes on the basis of prescription from the school, and prior research replication. Student journals, a classroom climate assessment and engagement observations were included to give breadth to the identification of Multiple Intelligences effects. The methodological model developed for this study has been an original description and gave a successful framework for applying the thesis that low achievers in mathematics can be supported cognitively and emotionally using Multiple Intelligences principles.

Implementing the study's objective provided a number of challenges because of its original nature. A significant challenge existed in demonstrating that the learning program uniquely embodied Multiple Intelligences theory. This and other confronting issues of design and resources were met and a number of new findings were determined that carry strong recommendations for future research. The study has exposed weaknesses in the use of standard research instruments to measure mathematics achievement and self-efficacy under Multiple Intelligences instruction. The key findings were that the relationship between mathematics achievement and Multiple Intelligences instruction, and between self-efficacy and Multiple Intelligences instruction are unable to be confirmed if the assessment tools are restricted to using traditional mathematics items.

The study has shown students' intelligences or cognitive strengths can be identified such that individualised learning in Year eight mathematics can be provided. Engagement data and ICEQ outcomes are consistent with the findings of the seminal research of *Project Spectrum* described in chapter three. This study's results agree with Spectrum findings that the attitude and behaviour of at-risk children improves when these students are allowed to work through their areas of intellectual strength. Project Spectrum was situated in an elementary school setting. This study contributes new knowledge to Multiple Intelligences applications in the Middle School mathematics setting. The use of the ICEQ has provided a validated means of verifying that learning is occurring within Multiple Intelligences theory guidelines.

Multiple Intelligences learning has been shown in this study to improve the emotional climate of a Year eight mathematics classroom. Making students aware that their abilities are legitimate mediums for learning mathematics allowed their stereotypical view of mathematics to be negated. In turn students enthusiastically embraced the mathematics tasks with a constructive attitude and without loss to their level of standard achievement.

The work has opened up a number of future paths of investigation. It has also shown that impediments exist in the application of Multiple Intelligences to secondary mathematics. These comments are combined in the problem of developing mechanisms by which mathematics achievement or mathematics self-efficacy can be assessed under the diversified approach of Multiple Intelligences. Many secondary schools maintain a rigid system of timetables, syllabus delivery, assessment and reporting that limit innovative programs such as Multiple Intelligences learning. The Middle School has provided a more flexible entry option. The timing of the study has been shown to be significant with the recognition of the difficulties many students face moving from primary school environments. Partly as a result of being unable to meet the increased cognitive demands from logical-mathematical tasks, the transition years from primary to secondary school are a period when students can develop and entrench negative attitudes towards mathematics. Many students are uncertain and concerned about what is expected of them when entering the new world of secondary school, yet they are also amenable to change. The literature review showed that Middle School students wanted to be successful in mathematics but that intrinsic motivation was often lacking for low achievers in traditional mathematics learning. The value of using personalised instruction and interesting tasks has been demonstrated in this study in lowering the institutional dependence on logical-mathematical intelligence, and for helping students learn and be assessed without fear of a personal lack of skill. In this way, a confidence that fostered classroom engagement was created.

Apart from pedagogical aspects, this study has revealed other constraints on Multiple Intelligences learning. The optimal duration of quantitative research using a Multiple Intelligences intervention is an area that should be pursued to determine the influence of extended exposure on outcomes. The flexibility of Middle Schools offers the opportunity for several teachers to act in concert, perhaps implementing another of the recommendations made in this chapter, to use quantitative and qualitative modes of inquiry. The study has shown there are clear opportunities for equity with Multiple Intelligences learning, allowing all students to understand the purposes of mathematics, to enjoy learning mathematics and to be confident in using mathematics.

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