Science and Mathematics Education Centre

Confidence and Competence: Developing the Mathematical Literacy of Primary Education Students in the Context of a Multiliteracies Unit

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This thesis is presented for the Degree of
Doctor of Mathematics Education
of
Curtin University

November 2010

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Acknowledgements

This thesis has been a marathon process and my appreciation of those who have supported me throughout the good times and the bad knows no bounds.

To the staff at the Science and Mathematics Education Centre at Curtin University go my thanks for their patience and ongoing encouragement. In particular, Emeritus Professor John Malone and Associate Professor Bill Atweh have kept me on the straight and narrow and ensured that I finally reached the finish line.

I would not have completed this work without my colleagues at Mt Lawley. To Geoff, Graeme, Tony and especially Bridget, thank you for your gentle nagging when I was so close but yet so far. To those who worked with me in the *Becoming Multiliterate* unit: you allowed me to increase your workload without complaint, you tolerated my plans and schemes with good humour and you gave me valuable advice. For all this I am very grateful and if I can return the favours, please let me know.

My family have always been my rock and their love and support have kept me going. They gave me the space to achieve my goals even when it meant time apart and financial challenges. My parents encouraged my first academic and professional adventures, despite the fact that they led me to the other side of the world, and I believe my Dad would have been proud of my achievements, as I know my Mum already is. To my children, thank you for managing to grow up to be the great people you are, despite my poor efforts. And finally, to my husband Bill go my heartfelt thanks for all he has done to allow me the time and freedom to travel and to follow my dreams and for his endless patience when progress has been slow and painful.

I could not have got here without all of you. Thank you.

Abstract

In order to be effective teachers of mathematics in primary schools, pre-service teachers need to be competent in the relevant curriculum content. In addition, many of them enter university education degree courses with relatively low levels of confidence in mathematics. This research examined the efficacy of a newly developed first year core unit, entitled *Becoming Multiliterate*, in developing competence and confidence in mathematics amongst students enrolled in BEd degrees in primary and early childhood education who were identified as lacking in one or both areas. Staff members who taught into the unit were conscious of the need to identify shortcomings in a way that did not adversely affect students' attitudes and confidence and adopted a CRC (Comment, Recommend, Commend) approach during their interactions with students.

Students enrolled in the unit completed a diagnostic assessment in the first week and the results of this were used to determine the extent to which concerns about competence were well founded and to enable targeted support to be provided. Students also indicated how confident they felt that they had answered the questions correctly and this data enabled staff to identify and support students whose confidence levels were low or, in some cases, unrealistically high. Students who did not reach the required benchmark then completed a three week mathematics module (one of four comprising the unit) which included tutor assistance, online resources and access to text based and hands on activities. Following this intervention, students had multiple opportunities to sit an exit assessment and any changes in performance were used to determine the efficacy or otherwise of the module materials and approach. Students were also surveyed at the start of the following semester to identify any changes in confidence levels.

On entry to the unit student competence and confidence levels were lower than was acceptable for effective teaching of primary mathematics, with some variations between genders and between those enrolled in the primary and early childhood degrees. However, there was no significant variation across age groups despite expectations that mature age students would have lower skill and confidence levels.

Particular areas of weakness were noted in the Measurement questions and some aspects of Number.

Following the intervention, student performance levels improved significantly and confidence levels were maintained or improved.

Chapter 1

Introduction

To an educator of pre-service primary teachers, the following version of the job description for a teacher resonates and helps to provide a simple framework for the way in which course content is structured and delivered and graduate outcomes are achieved:

- Teachers must know their stuff
- They must know the students they intend to stuff
- Above all, they must stuff them artistically

(source unknown, cited in Sobel & Maletsky, 1975, p. 2)

The research described in this thesis arose from personal concerns, based on observation, experience and reading of the literature, that pre-service primary teachers often did not “know their stuff” in mathematics. What are the implications for children’s learning of a student on teaching practice demonstrating how to calculate the interval between two times of day by using the same process as decimal subtraction? The student in question then worked out the time interval between 7:45 pm and 8:15 pm by calculating 8.15 - 7.45 = 0.70 = 70 minutes. What would you say to an adult student working out the points percentages for AFL teams, who insisted that you could not divide a smaller number by a larger one and so gave the bottom team a percentage of 150% because you had to reverse the calculation?

These are just a few examples garnered from personal observations but the issue of poor mathematical literacy or numeracy standards amongst pre-service and, perhaps, practising primary teachers seems to transcend differences of geographical location, cultural background, gender, age and educational system. Literature from the UK and USA, as well as Australia, flags concerns about the low levels of mathematical content knowledge of teachers and their potential impact on the numeracy standards amongst the children they teach in schools (Australian Academy of Science, 2006; Conference Board of Mathematical Sciences, 2003; Williams, 2008). Unfortunately, the literature in the 21st century indicates that many of the problems identified earlier have still not been solved. Australian government reports and statements over a number of decades (Ministerial Council on Education, Employment, Training and Youth Affairs, 1989, 1999, 2003, 2008) have stressed the importance of a literate and numerate population and in particular the need for highly skilled mathematicians and scientists to face a highly technological future and to ensure competitiveness in a global business market. If teachers in the early years of schooling do not lay a solid foundation for ongoing mathematical development and, equally important, do not develop positive attitudes to mathematics amongst the children they teach, then these visions of the future are unlikely to come to pass.

Following the introduction of a new degree program at a large Western Australian university, an opportunity was presented to combine new unit development and delivery with a research project about pre-service teacher numeracy and this evolved into the study reported in this thesis. Given the crowded nature of the course, it was not possible to have a whole unit devoted to mathematics, but the introduction of a multiliteracies concept meant that written, scientific and mathematical literacy as well as the use of information and communications technology could be addressed within one semester unit. While it would have been desirable to have more time to address the anticipated student needs, the recognition that students were being accepted into teacher education courses without the required background knowledge and skills in personal literacy and numeracy was in itself a positive step, and it has transpired that the evidence collected in the first years of the unit has led to its expansion into two core units in the primary degree. The constraints imposed by the single unit approach limited a number of aspects of the research but they did provide clear boundaries and forced clear definitions of achievable outcomes. A large team of staff developed the unit but the focus of this study is on the mathematics module which took approximately one quarter of the teaching time available for the whole unit.

Anecdotal evidence such as the examples cited indicated that pre-service teachers would not have high levels of mathematics competence but it was recognised that there would be wide variations in their skills. Some would need minimal assistance whereas others would need lots of support, so it was agreed that an entry assessment test was needed to identify existing strengths and weaknesses. As well as reflecting a constructively sound approach to the unit, this would enable existing skills to be recognised and targeted intervention to be provided. However, this led to a second concern, and the other focus of this study, in that students who were lacking in confidence or who had negative attitudes towards mathematics might react adversely to the intervention and to having their low skill level explicitly identified. By asking students to indicate next to each question in the test how confident they felt that they had answered it correctly, an indication of those who might be at greatest risk was obtained, as well as providing the data for a baseline measure of confidence on entry to the unit.

The need to recognise varying confidence levels amongst students about mathematics meant that staff had to provide feedback on mathematical performance in a realistic but positive way. This was intended to help students to feel good about what they could already do while still accepting that work might be needed to bridge any gaps. This is where this study has the potential to provide new insights, as much of the previous work in this area has involved only skill development approaches. In some previous studies, students worked independently to improve what were often self-diagnosed weaknesses while in others they attended formal mathematics courses offered as pre-requisites or in parallel with pedagogy units and often taught by mathematics staff and not teacher educators (Goulding, 2003; Huntley, 2009; Mays, 2005). All staff involved in this unit were, or had been, practising teachers with an appreciation of what students needed to be effective teachers of mathematics plus experience in working with children and adults with all levels of mathematical actual performance.

The outcomes for the unit were initially defined by the content of the Western Australian curriculum for upper primary / lower secondary students and this provided clear justification for why pre-service teachers needed the skills and knowledge. The teaching support materials were based on what would be available in primary schools for the same reason and also because staff could then model good teaching strategies for the different types of content. A broad mix of individual, small group and whole class strategies was used in delivery, according to student need and the content topic. With only nine hours of contact time, resources also had to be made available for students to use when working independently outside class and a commercial online mathematics site provided a major proportion of these. The site had the advantage that a customised package of learning activities which matched the unit outcomes could be made available instead of the *one size fits all* pre-packaged courses offered by other on-line sources.

The unit involved students from both the Bachelor of Education (BEd) - Early Childhood Studies and the Bachelor of Education - Primary degrees giving a total enrolment of over 300 students each year. Apart from the logistical problems associated with managing large numbers of tutorials and keeping records of multiple assessment tasks for each student, the volume of data generated in the study enabled robust conclusions to be drawn when statistical significance was utilised.

In the development phase of the unit, staff believed that some areas in mathematics would cause more difficulties than others for students so details of performance in each individual question in the assessment tasks were collected and analysed to enable any trends and commonalities in skills and understanding across different topics to be identified. There was also a sense that students coming straight from high school would have different needs to those returning to study as mature age students, often after many years without formal study. Primary education courses have relatively low percentages of male students so there was some interest among staff in gender variations in performance and confidence. Students were enrolled in two different courses and anecdotal comments indicated that a number had chosen Early Childhood education because it would make fewer mathematical demands on the students. Differences in competence and confidence between the students in the two courses were therefore of interest.

As a result, the design of the unit was focused on addressing perceived student needs while the design of the research was based on determining the extent to which the low skill and confidence levels reported in the literature would be found amongst the cohorts and the effectiveness of the intervention in improving both competence and confidence. The data was collected as part of the unit delivery and provided feedback to staff and students as well as the researcher.

At the end of the unit, the effectiveness of the intervention was investigated by analysing scores in the exit assessments, which paralleled the entry tests, and then comparing them with both the required unit benchmarks and the original entry scores. Exit confidence levels were measured by asking students how they felt about their actual performance to correctly answer each question following the completion of the unit.

The research questions reflect the various facets described above and were based on the dual needs of providing both data for the research and feedback for staff to improve the effectiveness of their teaching.

1. How competent are first year pre-service primary teachers in primary school mathematics curriculum content?
2. How confident are pre-service primary teachers about their mathematical actual performance?
3. What are the particular areas of mathematical strength and weakness amongst pre-service primary teachers?
4. How effective is a specially designed intervention program in improving competence and confidence in mathematics amongst pre-service primary teachers?
5. Are there any gender, age or course differences in pre-service primary teachers' performance, confidence and self-efficacy before, during and after the intervention program?

By the end of their first semester at university, the goal of the unit, as expressed in the terms cited by Sobel and Maletsky (1975), was that pre-service teachers would know more *stuff* by being exposed to some artistic *stuffing* so that they could further develop the skills and understanding required to be effective teachers of mathematics in the rest of their course. This study reports on the extent to which the goal was achieved with two cohorts of students over a two year period in 2006 and 2007. The literature already published on the mathematical competence and confidence of pre-service teachers is examined against the background of political and community concerns about literacy and numeracy standards in schools. The context of the study is then described as part of a chapter outlining the methodology of the research. The quantitative data and its statistical analysis is presented in the Results chapter and the following chapter discusses the findings and their implications and relates the outcomes of the study to previous research. The concluding chapter summarises the study and identifies ongoing issues to be the subject of further research.

Chapter 2

Literature Review

This chapter addresses a number of issues associated with previous research in the area of the mathematical competence and confidence of pre-service primary teachers. After discussing the various terms used to define numeracy or mathematical literacy, the background and significance of the topic are addressed in terms of the importance of numeracy in education and amongst the general population, as well as the concerns associated with teacher numeracy standards. Further sections then discuss the literature as it relates to the five research questions: the levels of mathematics competence and confidence amongst pre-service teachers and whether there are problems with particular topics, what intervention strategies have been used elsewhere and whether gender and age variations have been identified.

Definitions

The topic of this research includes two terms that require clarification as they are not used according to their generally understood meanings. The terms are *mathematical literacy* and *multiliterate* and this section will consider how they are defined by other researchers as well as discussing alternatives which might have been used and clarifying the meaning of the terms as used in this context.

Mathematical literacy, numeracy and related terminology

The Crowther Report in the UK in 1959 first coined the term *numeracy* as a counterpart to literacy (cited in Kemp & Hogan, 2006, p. 4). Since then a range of interpretations of the term, and others like it, have been used to describe what it is about mathematics and its use that should be part of everyone's education.

In 1999 The Ministerial Council on Education, Employment, Training and Youth Affairs (MCEETYA) published *The Adelaide Declaration on National Goals for Schooling in the Twenty First Century*. The relevant goal for literacy and numeracy, was that “students should have attained the skills of numeracy and English literacy; such that, every student should be numerate, able to read, write, spell and communicate at an appropriate level” (Department of Education, Training and Youth Affairs, 2000, p. 6). While laudable, this statement gives little detail about what constitutes numeracy. Later in the same document, a definition developed by the Australian Association of Mathematics Teachers (AAMT) in 1997 is provided: “To be numerate is to use mathematics effectively to meet the general demands of life at home, in paid work and for participation in community and civic life” (Department of Education, Training and Youth Affairs, 2000, p. 14). Thus the emphasis in their definition of numeracy is not only on having basic skills, but also on being able to apply them in everyday life.

A number of researchers, particularly in the USA, have preferred to make the parallels with literacy more explicit by using the term *quantitative literacy* (Latiolais, Collins, Baloch, & Loewi, 2003; Watson & Moritz, 2002; Wilkins, 2000) but some see this as limited to arithmetic as in the definition used in National Adult Literacy Survey in 1993; “the knowledge and skill required to apply arithmetic operations, either alone or sequentially, using numbers embedded in printed material” (cited in Steen, 2001, p. 7). Others such as the International Life Skills Survey took a wider view defining quantitative literacy as “an aggregate of skills, knowledge, beliefs, dispositions, habits of mind, communication capabilities, and problem solving skills that people need in order to engage effectively in quantitative situations arising in life and work” (cited in Steen, 2001, p. 7).

Other terms which have been used in the same or similar texts include *computational fluency*, again focussing on numeracy as working with numbers (Flowers, Kline, & Rubenstein, 2003; Russell, 2000), and *financial literacy*, identified by the Australian Securities and Investments Commission (ASIC) in their 2003 discussion paper.

The Programme for International Student Assessment (PISA) adopted a similar definition to the AAMT version of numeracy and called it *mathematical literacy*: “an individual’s capacity to identify and understand the role that mathematics plays in the world, to make well-founded mathematical judgements and to engage in mathematics in ways that meet the needs of that individual's current and future life as a constructive, concerned and reflective citizen" (cited in Steen, 2001, p. 7}.

Mathematics has its own language and linguistic features so being mathematically literate includes the actual performance to use this language appropriately. In particular, reading mathematics is not limited to reading about mathematics and doing word problems but understanding the vocabulary and structure of the subject. Adams (2003) raised a number of issues including the use of formal and informal definitions and the confusion generated by homophones such as *plane* and *plain* or *symbol* and *cymbal*. In particular, terms are often used in mathematics which have different meanings in everyday life. For example, consider *base* as in baseball, the *base* of a triangle and *base* ten arithmetic. Adams (2003) also discussed the importance of understanding the structure of mathematics, the use of symbols and the different ways in which numbers are used including dates, telephone numbers and postcodes, as well as for counting and calculation.

It used to be the case in the USA that a person was defined to be literate and numerate if they had completed a grade four education (Steen, 1990). Expectations have risen since then. Steen went on to define various dimensions of numeracy:

- Practical numeracy
- Civic numeracy
- Professional numeracy
- Numeracy for leisure
- Cultural numeracy

In the context of this thesis, the term professional numeracy provides a potential basis for a required standard: primary teachers need to be able to demonstrate the mathematical skills required to carry out the requirements of their profession (Steen, 1990). This also reflects the view of Aldous (2006) who identified the conflict between the mathematical literacy required by a professional working in a mathematics or science field such as teaching compared to what an adult needs to know to be able to function as an informed citizen.

For the purposes of this study, the pre-service teachers were considered to be sufficiently mathematically literate if they were competent in the mathematical skills and understanding which would be expected of a student moving from primary school to high school in Western Australia, as this was the base level of content which the pre-service teachers needed to know to carry out their teaching role. By analysing the requirements for year seven students in the WA curriculum at the time the data was gathered, a list of outcomes was developed to form the basis of the teaching, learning and assessment within the intervention reported in this study. While it was acknowledged that a deep level of understanding of mathematics was required in order to teach it effectively (Ma, L., 1999), it was anticipated that this would be further developed over subsequent units of the course and that the focus at this early stage needed to be on basic personal skills, without which deeper understanding was unlikely to be achieved.

Multiliteracy

The title of the unit *Becoming Multiliterate* had already been decided before the unit was developed in detail and although it was retained, there was early recognition that the unit content was not going to reflect what the literature normally considered to be multiliteracy.

In the mid 1990s, researchers who became known as the New London Group coined the term *multiliteracies* during their discussions on how literacy pedagogy needed to change and expand to account for both the cultural and linguistic diversity within a globalised society, and for the huge variety of text forms associated with information and multimedia technologies (Cazden et al., 1996). Thus the term had a specific meaning linked to language and literacy development. This interpretation is now in widespread use and in Australia has been promoted by Kalantzis and Cope in particular, through programs and texts related to literacy education (Anstey, 2002; Kalantzis & Cope, 2008; Kalantzis, Cope, & Fehring, 2002).

Healy (2003) used the terms multiliteracies and *new literacies* in addressing the need to recognise that new technologies have meant that texts are no longer only available in a traditional print format, that all literacy has social and cultural implications and that educators need to consider the relationships among teacher, text and children (p.

153). Digital literacy can include sound, movement and hypertextual (non-linear) content, so students need to be able to use audio, graphic and verbal coding skills. She provided examples of relatively young children being able to use computers and complete tasks such as using CAD programs, games and digital information sources at home while appearing to have reading difficulties with print texts at school. Multiliteracy can be “understood conceptually to mean meaningful interaction with any text, irrespective of technology, media, form or structure” (Healy, 2003, p.166).

In attempting to develop the mathematical literacy of pre-service teachers, it was assumed that their general literacy skills were adequate. This was not a valid assumption, based on the pre-service teachers’ performance in the written literacy entry task in the unit, and this has also been identified as a problem in the literature. Conaway, Saxon and Woods (2003) used standardised reading tests with over 800 students in both elementary and secondary education courses at three universities. Previously analysed Scholastic Aptitude Test (SAT) data showed that students enrolled in teacher education had lower overall scores than those in other courses and students in elementary education had lower scores than their peers in secondary education. On the positive side, the National Adult Literacy Survey showed that teachers were no different to other adults in terms of the literacy needed for everyday life but, as noted earlier in this review, teachers needed professional levels of literacy if they were to effectively assist others to learn. Tests on vocabulary, reading comprehension and reading rate revealed widely varying levels of performance amongst the pre-service teachers, with gender differences in favour of females in all three areas. There were no consistent differences between the performance of those entering university and those in their senior year, indicating that it may be more important to attract able students to the profession in the first place than to try to address shortcomings during the course (Conaway, et al., 2003).

In the design of the intervention program based on the mathematics module of the *Becoming Multiliterate* unit, it was therefore considered an advantage that students’ written literacy and skills in the use of information and communication technology would also be targeted. This enabled the wider definition of multiliteracy to be appropriate in the unit title, even though performance in those areas did not form part of this research. In addition, support was provided to students with weak reading and writing skills in their other modules and it was hoped that this would assist in the development of their mathematical literacy.

Numeracy standards

Business and professional associations and governments both in Australia and overseas have identified the need for a numerate population, and made formal statements about how this might be achieved. These have included the definition of required numeracy standards in the school curriculum and in teacher education and a number of these are summarised in this section as part of the background and rationale for this study.

In Australia these have taken the form of a number of declarations from the Ministerial Council for Education, Early Childhood Development and Youth Affairs (MCEEDYA), a body comprising the State and Federal Ministers of Education and previously called the Ministerial Council on Education, Employment, Training and Youth Affairs (MCEETYA). In 1989 the *Hobart Declaration on Schooling* committed all states in Australia to a framework of national collaboration which included the definition of ten national goals for schooling (Ministerial Council on Education, Employment, Training and Youth Affairs, 1989). Goal 6b was “to develop in students skills of numeracy and other mathematical skills”.

A decade later, the *Adelaide Declaration on National Goals for Schooling in the Twenty First Century* (Ministerial Council on Education, Employment, Training and Youth Affairs, 1999), re-stated the goals and in particular noted in Goal 2.1 that students should have “attained high standards of knowledge, skills and understanding through a comprehensive and balanced curriculum in the compulsory years of schooling encompassing the agreed eight key learning areas” one of which was mathematics (Ministerial Council on Education, Employment, Training and Youth Affairs, 1999). In addition in Goal 2.2, “students should have attained the skills of numeracy and English literacy; such that every student should be numerate, able to read, write, spell and communicate at an appropriate level” (Ministerial Council on Education, Employment, Training and Youth Affairs, 1999).

Between these two declarations, in July 1996 the Ministers added a new goal, “that every child leaving primary school should be able to read, write, spell and communicate at an appropriate level” (Ministerial Council on Education, Employment,Training and Youth Affairs, 1998, p. ix), which was further amended in 1997 to read “that every child leaving primary school should be numerate, and be able to read, write and spell at an appropriate level” (Ministerial Council on Education, Employment,Training and Youth Affairs, 1998, p. 125). Their definition of *numerate* was not provided.

1997 also saw the agreement of all states in Australia, through MCEETYA, to a National Literacy and Numeracy Plan. This included a focus on early assessment of all students in the first years of schooling with timely intervention to address needs, the development of national numeracy benchmarks, assessment of all year 3 and year 5 students against those benchmarks and national reporting of results. The States would also provide professional development for teachers to support the implementation of the plan (Ministerial Council on Education, Employment,Training and Youth Affairs, 1998). Numeracy was at last defined, as “the effective use of mathematics to meet the general demands of life at school and at home, in paid work, and for participation in community and civic life” (Ministerial Council on Education, Employment,Training and Youth Affairs, 1998, p.130). This led to the *Numeracy Research and Development Initiative* which funded a number of projects over the next few years including:

- *Numeracy, a priority for all: Challenges for Australian Schools* (Department of Education, Training and Youth Affairs, 2000);
- *Teachers enhancing numeracy* (Education Queensland, 2004);
- *Primary Numeracy: a mapping, review and analysis of Australian research in numeracy learning at the primary school level* (Groves, Mousley, & Forgasz, 2006) and
- *Numeracy: demands and opportunities across the curriculum* (Department of Education and Training, 2004b).

A number of the project reports simply reviewed the situation while others made recommendations for change, but these recommendations were similar across the years and the issues did not appear to change significantly as time passed. In 2001 the Australian Council of Deans of Education produced a report entitled *New Learning: a charter for Australian education* in which they put forward a number of propositions about the shape of education into the future and provided data to support their argument that Australian education was not prepared to deal with ongoing changes and that politicians needed to match their rhetoric with action and increased funding (Australian Council of Deans of Education, 1998). On the other hand, in 2003 the Federal Minister for Education and Training published a pamphlet aimed at parents in which literacy and numeracy were identified as *signposts to success* and which included a positive summary of the progress made to date in implementing the National Literacy and Numeracy Plan (Department of Education, Science and Training, 2003).

In August 2006 MCEETYA approved the *Statements of Learning* for a number of learning areas including mathematics. The States are now required to incorporate these into their syllabus and curriculum documents and they define the agreed "opportunities to learn" (Ministerial Council on Education, Employment, Training and Youth Affairs, 2006, p. 1) for children in years three, five, seven and nine across Australia.

In December 2008 the *Melbourne Declaration on Educational Goals for Young Australians* noted that while "literacy and numeracy . . . remain the cornerstones of schooling for young Australians" (Ministerial Council on Education, Employment, Training and Youth Affairs, 2008, p. 5), a broader frame needed to be taken. The goals now state that:

1. Australian schooling promotes equity and excellence, and
2. All young Australians become successful learners, confident and creative individuals, and active and informed citizens. (p. 7)

Within Goal 2 there is a direct link to numeracy; "Successful learners have the essential skills in literacy and numeracy" (Ministerial Council on Education, Employment, Training and Youth Affairs, 2008, p. 8), and the *Commitment to Action* section includes the following specifics:

- The curriculum will include a strong focus on literacy and numeracy skills (p. 13)
- English and mathematics are of fundamental importance in all years of schooling and are the primary focus of learning in the early years. (p. 15)

One of the underlying influences referred to in the Declaration is the Programme for International Student Assessment (PISA) conducted by the Organisation for Economic Cooperation and Development (OECD) and in which "Australia should aspire to … become second to none amongst the world's best school systems" (Ministerial Council on Education, Employment, Training and Youth Affairs, 2008, p. 5).

Professional bodies such as the Australian Association of Mathematics Teachers (AAMT), the Australian Mathematical Sciences Institute (AMSI) and the Mathematics Education Research Group of Australasia (MERGA) have been active participants in the various forums associated with the development of the declarations and the National Literacy and Numeracy Plan, and their detailed submissions are included and recognised in the various reports listed above. As well as concerns about what was happening in schools, the Australian Academy of Science considered the implications for industry and research of falling numeracy standards and published its findings in *Mathematics and Statistics: critical skills for Australia's future* (Australian Academy of Science, 2006). Quotes from business and industry leaders included the following:

> Mathematics skills . . are very important because they appear in every facet of every job nowadays. Finance, research, statistics, money management, presenting information – maths is endemic. The sooner people acquire these skills, the better equipped for life they are. (p. 13)

Individual states have also conducted research in literacy and numeracy issues and in Western Australia a Literacy and Numeracy Review Taskforce chaired by Louden made a number of recommendations related to the early years of education and improved support for teachers as well as the development of targets for improvement. In particular the report recommended that the Department of Education and Training:

> ensures that it selects graduates for appointment in the early childhood and primary years who demonstrate
>
> - Strong personal literacy and numeracy skills
> - Understanding of the content of mathematics and English syllabuses, and
> - Practical skills in working with children who experience difficulties in literacy and numeracy. (Louden, 2006, p. 21)

Teachers not only need to be able to teach the current curriculum content but also to cope with the constant changes made by governments and their administrations. Recent decades saw a shift to outcomes based education beginning with *Everybody Counts - report to the nation on the future of mathematics education* (Mathematical Sciences Education Board, 1989) which led the National Council of Teachers of Mathematics in the USA to develop *Curriculum and Evaluation Standards for School Mathematics* (National Council of Teachers of Mathematics, 1989) and the *Professional Standards for Teaching Mathematics* in the USA (National Council of Teachers of Mathematics, 1991). These were paralleled by similar projects in the UK and Australia. At a national level *A National Statement on Mathematics for Australian Schools* (Australian Education Council, 1990) and *Mathematics - a curriculum profile for Australian schools* (Australian Education Council, 1994) formed the basis for state development of outcomes based approaches to education.

In Western Australia the *Curriculum Framework* (Curriculum Council, 1998), *Mathematics Student Outcome Statements* (Education Department of Western Australia, 1998) and *Progress Maps* (Curriculum Council, 2005b) provided a set of guidelines for teachers on the desired outcomes of mathematics education without prescribing in detail how they are to be attained. However, Western Australia recently published its K-10 Syllabus which includes scope and sequence statements for each learning area including mathematics and these provide a list of what teachers will teach rather than the outcomes based statements of what students will be able to do (Department of Education and Training, 2007). In 2010 the draft of an Australian Curriculum for mathematics has been produced by the Australian

Curriculum Assessment and Reporting Authority (Australian Curriculum Assessment and Reporting Authority, 2010) which has also taken a content based approach. Pre-service teachers need to become familiar with each set of relevant documents and then fully embrace the different curriculum philosophies. In order to do this they need a clear understanding of the concepts and skills that the children need to learn in all learning areas, not just mathematics.

If the high standards of numeracy required by the community are to be attained then the aforementioned report from the Australian Academy of Science needs to be heeded. It recommended that "all mathematics teachers in Australian schools have appropriate training in the disciplines of mathematics and statistics to the highest international levels" and that this include developing "national accreditation standards for teachers of mathematics at all levels of schooling . . . . .and . . . appropriate programs to ensure that future teachers meet these standards" (Australian Academy of Science, 2006, p. 15).

Teacher numeracy

Given that there is an expectation that teachers will be able to deliver a curriculum that will produce a numerate population, the identification of what research has to say about the extent to which teachers demonstrate the required knowledge and skills to do this effectively is relevant to the first question in this study vis *How competent are first year pre-service primary teachers in primary school mathematics curriculum content?*

The *Melbourne Declaration in Educational Goals for Young Australians* (Ministerial Council on Education, Employment, Training and Youth Affairs, 2008) noted that "the teachers . . who work in Australia's schools and educate young people are of fundamental importance to achieving these educational goals" (p. 11). Steffe (1990) further pointed out that in order to improve mathematical education in schools there needed to be improvements in the mathematical knowledge of teachers. It would therefore seem appropriate to consider what is needed to ensure that pre-service teacher education takes into account those conditions existing in schools and society in general which impact on a future teacher's preparation to teach the next generation.

Internationally there is wide agreement that for teachers to be effective in developing the numeracy levels of their students, they need to be mathematically literate themselves. Billstein, Libeskind and Lott (2004) deemed it essential that teachers know both the subject matter of mathematics as well as strategies for teaching. Turner-Bissett (1999) discussed the knowledge bases of the expert teacher and listed substantive and syntactic subject knowledge as priorities. Authorities in the United Kingdom now audit the mathematical subject knowledge of primary teacher trainees as part of the requirements of the National Curriculum for Initial Teacher Training (Goulding, Rowland, & Barber, 2002). Queensland Board of Teacher Education has stated that “graduate teachers will exhibit high levels of personal proficiency in oral and written language and numeracy” (Zevenbergen, 2005). The Australian House of Representatives Standing Committee on Education and Vocational Training (2005) announced an inquiry into teacher education with the terms of reference including an examination of the preparation of primary teaching graduates to teach literacy and numeracy. Researchers such as Betts & Frost (2000) and Kissane (2005) argue that teachers without adequate subject content knowledge may tend to rely on textbooks, emphasise procedural approaches rather than understanding, teach the way they were taught and have negative attitudes, none of which augur well for the required high standards of numeracy teaching into the future.

The problem is not new. In 1949, Glennon reported that “those preparing to teach mathematics in the elementary grades understand approximately 50% of the computational processes taught in grades one to six” (cited in Rech, Hartzell, & Stephens, 1993). The National Center for Research on Teacher Learning produced a series of research reports between 1988 and 1990 on the preparation of mathematics teachers (Ball, 1988a; 1988b; 1988c; 1989; 1990a; 1990b; Ball & Wilcox, 1989; Ball & Wilson, 1990) and a recurring theme was the importance of subject matter knowledge. American mathematician J. R. C. Leitzel stated in 1991 that “the mathematical preparation of elementary school teachers is perhaps the weakest link in our nation’s entire system of mathematics education”. Jonker (2002) noted that it cannot be assumed that pre-service teachers have taken high school mathematics and understood it, some may have actively avoided it. While Australian students may be required to study some mathematics up to year twelve, there is great variation in the level of mathematics required in different courses in each state and students may opt for those with less difficult content and still meet tertiary entrance requirements. As is described elsewhere, in Western Australia students do not actually have to pass any mathematics subjects to achieve secondary graduation (Curriculum Council, 2010).

In parallel with studies relating to numeracy standards, researchers and government bodies have examined the quality of the preparation of teachers to teach mathematics. In 1998 the UK Department for Education and Employment published Circular 4/98 Annex D which described in detail the initial teacher training (ITT) curriculum for primary mathematics. It was in three sections covering pedagogical knowledge and understanding, effective teaching and assessment methods and knowledge and understanding of mathematics. It was not meant to be an exhaustive list but ITT providers had to cover the specified content in courses which were "coherent, intellectually stimulating and professionally challenging" (Department for Education and Employment, 1998, section C, para. 5). Pre-service teachers were also required to have a minimum of a Grade C in GCSE mathematics although it was recognised that this would not guarantee either competence or confidence in the mathematics they would be teaching. Providers therefore were required to audit knowledge, understanding and skills and put support strategies in place to make sure everyone was competent before graduation (Department for Education and Employment, 1998). Since then the Training and Development Agency for Schools (TDA) in the UK has taken on the administration of Qualified Teacher Status (QTS) and this includes satisfactory completion of a numeracy skills test in addition to meeting the requirements of Initial Teacher Education institutions. This is "intended to ensure that everyone qualifying to teach has a good grounding in the use of numeracy in the wider context of their professional role as a teacher" (Training and Development Agency for Schools (TDA), 2007a, "Numeracy QTS skills test", para. 2), and requires trainees to show that they can "carry out mental strategies using . . . time, fractions, percentages, measurements and conversions" as well as interpret and use statistical information accurately and use and apply general arithmetic (Training and Development Agency for Schools (TDA), 2007b, "Test content").

In Australia, *Preparing a profession*, the report on the National Standards and Guidelines for Initial Teacher Education was commissioned by the Australian Council of Deans of Education (Australian Council of Deans of Education, 1998) and identified a number of attributes which graduates of teacher education programs should possess. Amongst these were statements about numeracy including the following:

> Graduates should be able to effectively contribute to their students' numeracy development. They should themselves be adequately and confidently numerate…They should appreciate numeracy as involving the actual performance to use a combination of
>
> - Underpinning mathematical concepts and skills . . ;
> - Mathematical thinking and strategies;
> - General thinking skills; and
> - Grounded appreciation of context. (Australian Council of Deans of Education, 1998, p. 14)

By early 2003 a number of papers were in circulation relating to the development of standards for teaching. The Australian College of Educators (ACE) published a document which represented the views of professional groups and considered the principles for guiding the establishment of standards, how they might be used and how issues such as assessment and certification, recognition and rewards might be addressed (Australian College of Educators, 2002). At the same time, MCEETYA circulated a consultation paper based on the thinking of education authorities and prepared by the Taskforce on Teacher Quality and Educational Leadership (Taskforce on Teacher Quality & Educational Leadership (TQELT), 2002). By November 2003, *A National Framework for Professional Standards for Teaching* (Ministerial Council on Education, Employment, Training and Youth Affairs, 2003) had been published. Like the work described previously on numeracy standards, this document arose from the Adelaide Declaration and focused on achieving a national approach to teacher education, both pre-service and in-service. It was based on a series of laudable principles including acknowledging the link between quality teaching and improved outcomes for students, and promoting, supporting, recognising and rewarding quality teaching. The Framework recognised the work that had already been done in each state on establishing boards of teacher registration and in particular, for the context of this study, the development of the Standards for Excellence in Teaching Mathematics in Australian Schools by the Australian Association of Mathematics Teachers (Australian Association of Mathematics Teachers, 2002). The standards are now used to define and recognise Highly Accomplished Teachers of Mathematics. More recently, AAMT has published a position paper on early childhood mathematics and recommended that teacher education institutions ensure that early childhood education programs allocate enough time for both mathematics content and pedagogy, and that they recognise their own students' need for support to build positive views of mathematics (Australian Association of Mathematics Teachers and Early Childhood Australia, 2006).

The Committee for the Review of Teaching and Teacher Education (2003a), reported on approaches to attract and retain teachers of science, technology and mathematics and, while the focus was on secondary specialist teachers, concern was expressed about the low priority afforded to science and technology in primary education courses. They described a negative cycle which needed to be broken:

> Arguably, too few well qualified, committed and innovative teachers of mathematics, science and technology in schools has led to too few well prepared, confident and interested students entering higher education. Amongst those who do commence, retention is not high. This has obvious consequences for the number of graduates available to take up teaching. This has led to too few well qualified, committed and innovative teachers and so on. (p. 3)

They also note the importance of developing children's interest in science and mathematics from an early age in primary schools.

In Western Australia the Department of Education (DETWA) has developed a Competency Framework for Teachers that is used within the university in this study as the basis for the assessment criteria for practicum placements. Applicants for employment and promotion with the Department also use the framework in compiling professional portfolios of their qualifications and experience. The framework addresses attributes, knowledge and practice and develops these over three phases, and the underpinning professional knowledge includes a requirement for teachers to “know the key concepts, content and processes of inquiry that are central to relevant learning areas” (Department of Education and Training, 2004a, p. 7).

A number of the reports into numeracy standards include addressing teacher skills, knowledge and competence in teaching mathematics. *Teachers enhancing numeracy* (Education Queensland, 2004) identified that teachers had insufficient knowledge of crucial concepts, structures and abstractions; that planning was piecemeal and relied on textbooks rather than using active learning and that, while they wanted to improve, teachers had insufficient support through professional development and time for collaborative planning. The research team identified teacher mathematical knowledge as one of the factors that influenced students’ numeracy outcomes and developed a professional development program which addressed this and other issues with positive outcomes for teachers and children (Education Queensland, 2004). Also in Queensland, the Numeracy in Pre-service Teacher Education Working Party report to the Board of Teacher Registration (2005) noted that studies elsewhere, which have shown that pre-service teachers often demonstrate errors and misconceptions in mathematics, were likely to apply to Australian students, given the similar diversity of age, mathematical backgrounds, and attitudes towards mathematics. They went on to define numeracy standards for graduates of pre-service teacher education programs based on the AAMT standards referred to earlier. Of note is the fact that they include standards for all teachers, not just those who teach mathematics: numeracy for teachers is seen as essential across the curriculum.

The need for agreement on national standards for teacher numeracy becomes clear when the mathematics entry requirements of the various BEd primary courses are compared. Of 31 courses analysed by the Australian Mathematical Sciences Institute (AMSI) in 2006 only 4 required year 12 mathematics for entry and 5 required year 11. The rest either did not specify a requirement or explicitly stated that there was none. Twelve of the courses only included units on mathematics education while 15 explicitly included units with mathematics content. AMSI recommended that entry requirements for primary education degrees be implemented which required at least some year 12 mathematics, that candidates for teacher education courses should be carefully selected and that a national exit test should be set which requires potential graduates to demonstrate competence appropriate to teaching primary school mathematics (Australian Mathematical Sciences Institute, 2006).

Groves, Mousley and Forgasz (2006) also considered pre-service teacher education in their review and commented that:

> Pre-service teachers' beliefs, levels of self confidence, and lack of suitable past experiences, act as constraints on their actual performance to support high level mathematics learning. Many pre-service teachers feel insufficiently prepared in mathematics content knowledge and pedagogical content knowledge. (Executive Summary, "Gaps identified", para.16)

In *Prepared to teach: An investigation into the preparation of teachers to teach literacy and numeracy,* Louden and his team (2005) surveyed beginning teachers, senior staff in the schools where they worked, and teacher educators. Of the new teachers surveyed, 95% felt their personal numeracy skills were adequate for their work as a teacher although only 69% of the senior staff agreed and teacher educators specifically commented on weaknesses in numeracy. In most of the tertiary institutions involved in the study, students completed some kind of basic competence test at the start of their course with resources such as CD ROMs and voluntary tutorials available to address weaknesses. With most mathematics education units incorporating both subject and pedagogical content knowledge, there was some feeling that needing to upgrade skills detracted from work on pedagogy and wider numeracy education issues and time spent helping those who are struggling caused frustration for more able students (Louden et al., 2005).

The Australian Institute for Teaching and School Leadership (AITSL) (formerly Teaching Australia) has been mandated by the federal Minister of Education to take responsibility for the development of a new standards-based *National Teaching Professional Framework* to be used in the implementation of national accreditation for teachers (Gillard, 2009). Teaching is one of the last professions in Australia to establish such accreditation and state laws and teacher registration requirements vary. For example, three states have formal processes for approving teacher education courses, while others rely on the fact that individual graduates have to meet registration requirements as their means of quality control of teacher education institutions. This creates difficulties with an increasingly mobile population if states present barriers for teachers who have qualified in other jurisdictions (Teaching Australia, 2006).

It would seem from the research that, although much work has been done to define required standards and some structures are being put in place to ensure these standards are met, there are still many teachers entering or continuing in the profession whose mathematical literacy is insufficient to be as effective in their role as the curriculum and society demand.

Mathematical subject content knowledge and deep understanding

There is a large body of research on the scope and type of knowledge needed by teachers and this was considered when designing the content of the unit in this study.

In 1986 Shulman defined three categories of teacher knowledge:

- Subject content knowledge (SCK)
- Pedagogical content knowledge (PCK)
- Curricular knowledge

He noted that the identification of pedagogical knowledge as separate from subject content knowledge was a relatively new phenomenon. He examined the California State Board examination for elementary school teachers in 1875 and noted that they had to complete tests worth a total of 1000 points, and only 50 points were about the theory and practice of teaching; the rest were all about knowing the content they were to teach. By 1980 the pendulum in most states of America had swung to the extent that content knowledge might be assessed on entry but not on graduation or as part of accreditation or registration as a qualified teacher (Shulman, 1986). In an appendix to *Man and Superman*, George Bernard Shaw wrote, “He who can, does. He who cannot, teaches,” (Shaw, cited in Shulman, 1986), and Shulman expressed concern that there was a risk of this becoming fact if all three categories of teacher knowledge were not addressed in teacher education. However, simply knowing the subject content of the syllabus or curriculum is not enough. Shulman (1986) broke each area down into three further aspects:

- Propositional knowledge – the principles, maxims and norms
- Case knowledge – specific events, examples and ideas which in turn illustrate general approaches and strategies
- Strategic knowledge – what to do when, choosing appropriate knowledge and pedagogy

and suggested modifying Shaw's cynical statement to "Those who can, do. Those who understand, teach" (p. 14).

Subsequent researchers have further refined Shulman's model. Turner Bisset (1999) identified three components of SCK: substantive subject knowledge, syntactic subject knowledge and beliefs about the subject. Teachers not only need to know the facts, concepts and organising frameworks of the subject area but they also need to know the syntax or how the knowledge has been constructed. In addition their beliefs about the subject will influence what and how they will teach. This is particularly true in mathematics where affective factors can have a significant impact, as will be discussed later in this chapter.

The term *instrumental understanding* (Mellin-Olsen, cited in Skemp, 1976) has been used to define being able to follow rules and apply them, possibly blindly. Some would argue that this is not understanding at all but for many students and teachers this is what they mean when they say they understand mathematics. Skemp then went on to refer to *relational understanding* as knowing both what to do and why. While, in an ideal world, it would be desirable for everyone to have relational understanding of mathematics concepts, many texts and teachers are content to settle for an instrumental understanding for their students. Skemp identified a number of potential issues with this approach. What about the child who is happy to understand instrumentally being taught by a teacher whose goal is relational understanding? If the system defines success as being able to pass assessments which only require instrumental understanding, why put in the extra effort that may be required to achieve the deeper relational understanding? Skemp himself included a section headed Devil's Advocate where he presented the advantages of teaching for

instrumental understanding (p. 8). However, he also noted that in order to make a reasoned choice between teaching for the different understandings, the teacher must have relational understanding of the mathematics involved. Hence while there may be an argument for instrumental understanding to be sufficient for the population in general to be considered numerate or mathematically literate, the mathematically literate teacher must have deeper, relational understanding (Edge, 2001).
L. Ma (1999) compared the preparedness of elementary teachers in China and the USA to teach mathematics and concluded that effective teachers require profound understanding of fundamental mathematics (PUFM). This idea of *deep understanding* mirrors Skemp's relational understanding and has received wide recognition as being a highly desirable goal in pre-service teacher education, albeit one which is proving difficult to attain.

Manouchehri (1997) noted the close links between SCK and PCK and suggested that both were best developed by providing pre-service teachers with opportunities to work with children. She recognised that effective mathematics teaching called for knowledge beyond recall of facts and algorithms and that teacher educators could not assume that their students had the deep subject knowledge they need. The mathematics they had done at school was likely to have been largely instrumental and college mathematics content courses were often designed for non-education students so they did not stress conceptual understanding. As a result many students reverted to teaching the way they were taught, despite methods courses emphasising teaching for relational understanding.

Ball (1988a; 2000) also linked SCK and PCK and the importance of seeing the implications of not having deep understanding when in a real classroom. She identified the beliefs of pre-service teachers about mathematics as another related factor. Those who depended on the answers in the teacher's guide developed a sense that there was always one correct answer and that it came from an external source. The types of questions used sent messages about what was important, usually speed and accuracy rather than clear thinking and investigation. Ball (1988a) listed three stages in the development of understanding: partial and inexplicit understanding, tacit understanding and explicit understanding, but noted that understanding alone, deep or otherwise, did not guarantee the actual performance to teach effectively; "subject knowledge is one term of the pedagogical equation" (p. 36).

An example of the aspects of understanding needed by the teacher was provided by Ball (2000). She considered the following problem. "Write down a string of 8s. Insert some plus signs at various places so that the resulting sum is 1000" (p. 242). While there might be an answer in the teacher's guide, a good teacher needed to know:

- how to solve it
- other ways to solve it
- generalised solutions
- whether it is suitable for a particular group of students
- how to adapt it to suit the needs of the class
- how to analyse children's solutions and use them to diagnose teaching needs
- how to present the problem to the students, the scaffolding they will need and the prompt questions that could be asked.

All of these require mathematical insight and understanding. Producing explanations for children required the "capacity to unpack one's own knowledge, because an explanation works only if it is at a sufficient level of granularity . . . to make sense for a particular learner" (Ball, 2000, p. 245).

Australia has recently seen the increasing use of middle schools across all states and the development of a teaching approach referred to as "middle schooling". Such schools often have teachers working in teams with a mix of secondary trained subject specialists and primary trained generalists, although the shortage of secondary mathematics teachers has led some to migrate to "senior" schools and colleges where they can teach pre-tertiary and other post-compulsory courses (Kissane, 2005). This has left mathematics in some middle schools being taught by teachers who are secondary trained with mathematics as a minor, or are primary trained with an interest (hopefully) in mathematics. The Quality Mathematics in the Middle Years Conference discussed the implications of these issues and proposed strategies to address them (Morony & Stocks, 2005). These included the development of university courses specifically for teachers intending to teach in middle schools and recommended that such courses place a heavy emphasis on deep mathematical knowledge. Subsequently, the Australian Department of Education, Science and Training (DEST) commissioned the Australian Association of Mathematics Teachers to bring together research evidence supporting the teaching and learning of mathematics in the middle years of schooling (Doig, 2005). While the resultant document identifies good practice and includes pointers to research, recommendations about ensuring quality teachers are appointed to teach this age group do not go on to suggest ways in which this might be done.

In terms of this study, while developing deep understanding was considered to be a desirable goal, it was recognised that a single first year unit would not be able to achieve the required standard, given the calibre of the students entering the course. Staff agreed that it was preferable to focus on a relatively instrumental understanding at this stage and to incorporate the development of relational understanding into subsequent mathematics pedagogy units when a firmer foundation had been established.

Dispositions towards mathematics and its teaching

The second research question in this study concerns the confidence levels of pre-service teachers in their mathematics ability on entry to their course. If pre-service teachers come into a teacher education course with negative dispositions towards mathematics, addressing deficiencies in mathematical content knowledge will be more difficult as they are unlikely to be motivated to put in the time and effort required to improve their skills.

> Elementary teachers who don't know much mathematics, who have little interest in what it means to do mathematics, and who are afraid of mathematics, are not likely to engender positive attitudes towards mathematics in their students. (Hungerford, 1994, p.16)

Galbraith (1984) surveyed Australian students entering undergraduate mathematics courses and post-graduate teacher training and concluded that dispositions towards mathematics were more negative at tertiary level than at secondary. He expressed concern about the impact this could have for both attraction to teaching mathematics and the quality of that teaching when students are working in schools.

Perceptions about mathematics do not have to be true to have an impact. Frank (1990) listed 12 myths about mathematics which were identified by Kogelman and Warren (1978), and reported on the extent to which pre-service elementary school teachers agreed with them. Not only did a large percentage of the students agree with myths such as “Some people have a math mind and some don’t” and “Maths requires logic, not intuition” (Frank, 1990, p. 11), but the myths had contributed to mathematics anxiety and avoidance. Simply discussing the myths in class contributed to changes in beliefs as students realised that others shared their perceptions and that it was possible to debunk some of them and identify teaching strategies to overcome misperceptions.

Barlow and Reddish (2006) surveyed pre-service elementary teachers about the same myths and compared the results with Frank’s findings. The four myths with the highest levels of agreement were the same in both surveys meaning that 16 years later students entering teacher education courses still felt the same about mathematics despite the efforts made in schools to improve attitudes and perceptions. There were three themes in their results:

- If students believed that you were either good at mathematics or not, those that felt they did not have a “math mind” lacked confidence in themselves and were unlikely to challenge students in their classrooms whom they perceived to be weak at mathematics as it would be a waste of time.
- If mathematics was seen as set rules and needed to be memorised, they were likely to teach procedurally rather than for understanding.
- Ignoring the importance of intuitive thinking, particularly when problem solving but also in the use of idiosyncratic methods for calculations, meant teachers could discourage students from using alternative approaches in favour of clearly defined algorithms.

Of particular concern is that pre-service primary teachers have been found to have more negative attitudes towards mathematics than the general college (population) (Rech, et al., 1993) and their competence scores were also lower. However, the authors’ recommendation that more university mathematics courses would improve both competence and attitude was in contrast to the views expressed by Hungerford (1994) who noted that those with weak skills and high anxiety did not want to study more or harder mathematics and that having reluctant conscripts in such courses was counterproductive. Norwood (1994) did find that students with high anxiety preferred courses which took a more structured algorithmic approach but even these were not likely to engender positive changes in disposition towards mathematics. As Klein (2000) wrote, “If teachers are to think differently about teaching mathematics then they will need to think differently about mathematics itself” (p. 23).

More recent research indicates that many of the concerns of the 1980s and 1990s have persisted into the 21st century. Hannula, Kaasila, Laine and Pehkonen (2005) surveyed Finnish pre-service primary teachers and identified three key elements of their core view of mathematics: belief in their own talent, beliefs about the difficulty of mathematics and how much they liked mathematics. While female students perceived themselves to be more hardworking and diligent than male students, this could have an adverse effect, as their negative views (such as needing a *mathematical* mind) would be reinforced if they worked hard and subsequently failed.

Southwell, White, Way and Perry (2005) observed that confidence in one’s mathematical ability was not a good predictor of actual competence. While some quite weak students had high (but misplaced) levels of confidence, relatively able students underestimated their own ability. On the other hand, confidence in one’s ability to teach mathematics was a better predictor of achievement. In general they found higher confidence levels in ability than previous research but unfortunately this was not linked to a commensurate increase in mathematical ability which might indicate that level of confidence is persistent despite evidence to the contrary.

In the USA the National Council for Accreditation of Teacher Education (NCATE) has defined six standards, and these include frequent references to “knowledge, skills, and professional dispositions”, placing an obligation on teacher education institutions to address affective issues (National Council for Accreditation of Teacher Education, 2008, p. 12). Unfortunately, when commenting an earlier version of the standards, Hillman, Rothermel and Scarano (2006) noted that institutions were tending to hope that those with negative dispositions would fail or drop out of courses rather than taking active steps to improve attitudes and perceptions towards mathematics and other learning areas. An instrument (The University of New England Professional Performance Student Self Assessment and Review or PPSSR) has been developed to allow dispositions to be assessed so that pre-service teachers can work to improve problem aspects and institutions can identify those who may need intervention and support (Hillman et al., 2006).

One of the key approaches to teaching examined in teacher education courses is constructivism whereby planning for learning begins by finding out what children already know. Yet few courses implement this approach in finding out what preconceptions their students bring with them about teaching (Ball, 1988c). Pre-service teachers have already spent many years in schools and have developed ideas and attitudes about the role of the teacher, what strategies are used for teaching mathematics in general and specific skills in particular. Ball (1988c) suggested they have to *unlearn* to teach mathematics and cited an example of a course called Exploring Teaching where students were given the opportunity to think critically about preparing to teach mathematics themselves.

Klein (1998) noted in her journal during her work with pre-service teachers in Queensland that:

> A general feeling is that students in the course are enjoying it, are learning a lot and may be accepting (that) mathematics doesn't have to be as they experienced it at school. BUT . . .it is clear that they still think there is one way to teach mathematics, that I know it, and that I should tell them. Learning, for them, is equated with being told.
> (Klein, 1998, p. 81)

Scott (2005) surveyed and interviewed beginning and graduating pre-service teachers in Australia about their beliefs concerning mathematics teaching and learning. It was encouraging to find that as the course progressed, experiences in schools and at university changed a number of beliefs. For example, students valued strategies such as discussion in mathematics classes even though they were unlikely to have experienced this as learners in school. They also laid great store by advice from those staff at the university who practised what they preached and modelled effective classroom strategies, even when their observations in schools seemed to contradict what they had learned at university (Scott, 2005).

In a study by Perry, Way, Southwell, White and Pattison (2005), first year pre-service primary teachers in NSW completed three surveys designed to determine:

- their competence in the mathematics they would be expected to teach
- their beliefs about mathematics, mathematics teaching and mathematics learning, and
- their attitudes towards mathematics.

The surveys were administered at the end of a mathematics methods course and showed some variation from the consensus of research in that the beliefs about mathematics teaching based on previous experiences had been modified by the course to a more constructivist view. Student results in the achievement test were poor (reflecting other research) with students who held strong beliefs about the importance of computation skills and correct answers generally performing less well than their peers (Perry, et al., 2005).

Mathematics anxiety has been defined as “an irrational dread of mathematics that interferes with manipulating numbers and solving mathematical problems within a variety of everyday life and academic situations” (Buckley & Ribordy, 1982, cited in Furner & Berman, 2003). Numerous potential causes have been identified including parental influences, socio-economic status, poor instruction, teacher attitudes, textbooks, persistent myths, test anxiety and pressure to succeed (Furner & Berman, 2003), so reducing anxiety becomes problematic when the reasons behind it are so diverse. Ma and Xu (2004) grouped these factors into three main areas: environmental (including experiences at home and at school); intellectual (including the perceived innate characteristics of mathematics); and personal (related to factors such as self esteem, preferred learning style and physical and psychological well being).

While mathematics is often seen as impersonal and logical, it can engender highly emotional responses in learners. Ingelton and O'Regan (1998) asked pre-service teachers and university staff to recount their mathematical experiences as a way to increase their awareness of their own learning of mathematics and to hopefully improve their teaching.

Kazelskis (1998) identified six particular dimensions of mathematics anxiety. These included:

- Mathematics test anxiety
- Mathematics course anxiety
- Worry (the extent to which participants worried about having to do mathematics or about how well they were doing in it compared to other subjects)
- Negative affect towards mathematics (the extent to which participants experienced adverse physical and psychological responses associated with mathematics)

The design of the assessment tasks in this study took particular note of the stresses associated with text anxiety.

Various strategies have been put forward for addressing high mathematics anxiety levels. Furner and Berman (2003) suggested many which were simply good teaching practice in any learning area and included:

- working in groups
- use of manipulatives
- discussion
- asking students to justify their thinking
- relating content to real life
- basing assessment on multiple information sources
- making cross curriculum links

They also referred to the effect of teacher anxiety on students and emphasised the need for a strong knowledge base and familiarity with best practice.

There is evidence that anxiety levels amongst pre-service teachers can be reduced through effective methods or pedagogy courses, not just by teaching more mathematics content. Tooke and Lindstrom (1998) reported that by presenting mathematics content as, ”This is how children learn this”, rather than “This is what you must learn” (p. 138), students were able to accept that it is common to have difficulties with mathematical principles and this seemed to reduce their emotional response.

Confidence and self-efficacy are the positive counterpoints to anxiety and a number of researchers have examined the extent to which these are evident amongst pre-service teachers of mathematics. Bandura (1994) defined perceived self-efficacy as “people’s beliefs about their capabilities to produce designated levels of performance that exercise influence over events that affect their lives” (p. 1). Those with high self-efficacy see a difficult task as a challenge rather than something to be avoided, bounce back after setbacks and experience less stress. Bandura cited four main sources of influence on self-efficacy:

- Mastery experiences (they have already been successful)
- Observations of social models (they see someone like themselves succeeding)
- Social persuasion (others tell them they can do it), and
- Emotional state (how they deal with stress).

Nielsen and Moore (2003) developed an instrument for measuring the mathematics self-efficacy of high school students in which they were asked to rate themselves according to how confident they felt about being able to perform particular mathematics tasks. The instrument was administered twice, once where students were asked how confident they would be in a classroom context and again where they rated their confidence to perform the task under test conditions. In neither case were they required to actually perform the tasks so the instrument only measured perceived competence. Scores in both contexts were highly correlated but significantly lower for the test context, as might have been expected, and the difference between the scores for the two contexts was greater for students with low efficacy.

Judgements about one’s ability to solve mathematics problems are indicative of actual performance according to work done by Pajares and Miller (1994). They noted that as self efficacy is a mediator and predictor of achievement, it is important for teachers to consider student beliefs as well as actual prior knowledge when planning for learning. They also emphasised that the measures of self efficacy must be specific to the performance tasks so simply asking students how good they are at mathematics is not sufficient. They need to be asked how confident they feel about performing those tasks under consideration (Pajares & Miller, 1995). This is the approach that was taken in this study where students indicated their confidence in being able to correctly answer specific questions in the tasks.

Because high self-efficacy is linked to a tendency to persevere when problems are encountered it may be argued that strong positive beliefs can overcome some weaknesses in actual ability. Mwamwenda (1999) stressed the importance of identifying low levels of self-efficacy as early as possible so they can be modified before they develop into mathematics anxiety and avoidance.

Unfortunately, given the low confidence levels of many pre-service teachers about their mathematical subject content knowledge, testing them to see what they can or cannot do has the potential to increase anxiety. A number of researchers, especially in the UK, have investigated the impact of the currently mandated audit process on student attitudes. Sanders and Morris (2000) linked data collected as part of an audit of SCK in mathematics with students’ previous study of mathematics, confidence in their knowledge and their beliefs about mathematics. Initially students marked their own tests but, as they were enrolled in a post-graduate certificate course, their intensive workload meant that few of them made time for optional classes or other avenues for improving their own performance. A more directive approach was needed so the Moriarty Test (Moriarty, 1995) was used together with Likert scale measurements of confidence in tackling certain types of questions through surveys before the original test and at resit sessions. Students could attend classes, use study guides or CDROM materials or access a combination of means of support.

There were different impacts on confidence for different topics. Students who did poorly on questions they thought would be straightforward showed adverse effects on confidence: “I can’t believe I got the long division question wrong. I feel really worried now about what else I don’t know” (Sanders & Morris, 2000, p. 403). Others recognised errors in some questions were because they had forgotten mathematical terminology or specialised knowledge and confidence increased once they reviewed and updated their knowledge. Further investigation led Sanders and Morris (2000) to classify students into three groups based on how they reacted to having their poor performance identified. *Ostriches* (32%) either refused to believe they had a problem or avoided doing anything that would provide more evidence of their weaknesses. *Mananas* (28%) acknowledged their difficulties but did little to actively correct them, often only working on a topic when they found themselves having to teach it during school placements. *Nettle graspers* (40%) both acknowledged their problems and tried to resolve them. They attended classes regularly, did extra practice and generally improved their scores during resit assessments (Morris, 2001; Sanders & Morris, 2000).

Pre-service primary teachers were found to have different views of the value of the audit in research conducted by Murphy (2003). Post-graduate certificate students were surveyed about the impact of the audit process on their teaching of mathematics and the results indicated that students fell into one of two groups. One group were already relatively confident and saw little benefit in the audit except that it was part of a “jumping hoops” (Murphy, 2003, p. 89) process because it was a requirement for gaining their qualification. Others, generally those who were initially less confident, saw the value of the audit as part of their whole course in “filling gaps” (p. 89) and not only acknowledged increased confidence but saw its relevance to their teaching.

A possible explanation for the varying reactions of students was considered by Bibby (2002). She linked the emotional responses to feelings of shame and investigated her ideas by interviewing teachers about their experiences of mathematics both at school and later as adults. The interview involved giving participants ten mathematics problems and asking them to rank them according to perceived difficulty. One question identified as easy, one hard question and one from the middle of the range were then selected and the participant asked to have a go at solving them. They were given assistance if it was requested or if they seemed to be becoming distressed.

Their solutions, their verbalisations as they worked and their non-verbal behaviours were recorded and a number of key issues identified. Bibby noted discomfort associated with having to expose their work to judgement – students mentioned being okay to do things on their own but that having someone watching inhibited recall and performance. Committing ideas to paper was difficult even though verbalisations clearly indicated they had the correct solution or understanding. On the other hand others lacked the appropriate vocabulary and tended to say nothing rather than say something which was incorrect. Participants had developed a number of coping mechanisms during their education including distancing themselves by shutting off or even physically removing themselves from the situation which required the use of mathematics which Bibby labelled as *absconding* (p. 715). Others disguised their lack of knowledge or skill by putting up their hand even if they did not know an answer, or writing anything on the page to make it look as if they were writing a solution. As most teachers have found, creating a diversion by misbehaviour is also a common strategy. Even when discovered to be in deficit there was a tendency to hide behind self-denigration - there seems to be little social stigma to admitting to being innumerate although illiteracy receives a different reaction. Unfortunately, pre-service primary teachers can no longer distance themselves from mathematics so their problems have to be confronted. Hence the design of this study included a determination of the entry levels of mathematical confidence among the cohort so that the unit could manage this potential confrontation without placing further stresses on pre-service teachers whose dispositions towards mathematics might already be at a low level.

Specific areas of weakness in mathematical content knowledge

While there is concern about, and hence research into, the overall mathematics subject content knowledge (SCK) of pre-service teachers, some researchers have looked at specific aspects of mathematics. This was also of interest in this study as it was felt that there might be some variation across different topics in students' levels of competence and confidence so the third research question *What are the particular areas of mathematical strength and weakness amongst pre-service primary teachers?* considers this issue.

Number topics

Chick, Pham and Baker (2006) assessed pre-service teachers' understanding of whole number subtraction by having them explain how they would assist a child whose work sample was provided. This linking of subject content knowledge (SCK) to pedagogical content knowledge (PCK) is used in a number of studies, perhaps as the work is often done in the context of mathematics methods units within the degree course. The work sample provided showed three and four digit subtraction calculations set out vertically. The child had made the common error of subtracting the smaller number from the larger within the calculation, regardless of whether it was in the top or bottom line, and hence avoided the need to regroup. The pre-service teachers' responses focussed on correct application of the standard algorithm, and they then recommended the children do more revision and practice with some mentioning supporting this with the use of base ten blocks. What was clear was that they lacked the profound understanding of fundamental mathematics (PUFM) described by Ma (1999) as being essential for effective mathematics teaching.

Flowers, Kline and Rubinstein (2003) also looked at subtraction but presented a question written horizontally where mental strategies were more appropriate than the standard algorithm. Students were asked to find the answer and discuss the merits of alternate methods vis à vis the standard written approach. The range of alternatives they suggested was limited and when asked to look at samples of how children carried out the calculation, the students found it difficult to interpret the methods and explain why they worked. This skill is essential if teachers are to diagnose misconceptions, and then support or remediate for improvement.

Deep understanding of multiplication was investigated by Chinnanppan (2005) by asking pre-service teachers to show how they would teach single and two digit multiplication using a computer program which allowed on-screen manipulation of base ten blocks. When analysing their approaches it was found that while they understood place value and the concept of multiplication as repeated addition, and used these appropriately, the pre-service teachers did not consider using the distributive and commutative properties of multiplication to explain the algorithms or simplify calculations, nor the illustration of multiplication using a rectangular array, nor the connection between multiplication and division.

Division appears to present a number of difficulties for the mathematics learner and several studies have examined this and the issues are not limited to pre-service teachers. A group of undergraduate psychology students were asked to respond orally to division facts displayed on a screen and to explain the strategy they had used to obtain the answer (Robinson, Arbuthnott, & Gibbons, 2002). Analysis of the time taken to respond showed that easy questions (up to a dividend of about 25) took less time and were generally answered using retrieval methods (recall of the division fact previously learned without conscious thought). Questions with larger dividends took longer and, as well as retrieval, participants used recasting methods such as recalling multiplication facts and reversing them. Of interest was that older students tended to be faster and to use retrieval more often, and it was suggested that there were links to their having been at school when the rote teaching of multiplication tables was the norm, something that is of relevance when the needs of mature age students are considered.

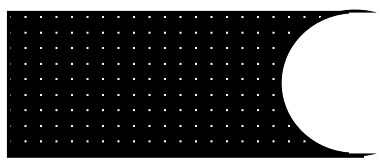
Teachers have to be prepared for issues to arise in the classroom which may be outside the normal range of the curriculum so developing mathematical understanding should be an ongoing process. Crespo and Nicol (2006) used division by zero as an example of responding to children's questions and possible misconceptions, while at the same time helping the pre-service teachers to question their own ideas. Students were required to investigate and reflect upon the topic and in the process developed both content and pedagogical knowledge. They noted that the quality of what was learned depended on the disposition of the students and their attitude towards mathematical inquiry, so it was important to address affective issues as well as knowledge and understanding of concepts.

Ordering whole numbers presents few problems for most adult students but ordering decimals is often fraught with misconceptions. As well as those whose answers indicate that they believe that "longer is larger" ($0.63 > 0.8$ as $63 > 8$) or "shorter is larger" ($0.6 > 0.83$ as any number of tenths is bigger than any number of hundredths), many students can answer questions correctly by applying rules that they do not understand. By designing a suitable diagnostic task, Steinle and Stacey (1998) were able to identify who had which misconception and hence target remedial assistance. In particular, when they analysed their data by year groups, they noticed that while the proportion of students answering correctly improved up to year seven, there was minimal further improvement from years seven to ten. It seemed that if children did not have the appropriate understanding by the end of primary school, they were unlikely to gain it in high school. When using their instrument with pre-service teachers they identified misconceptions linking decimals to fractions and negative numbers which had not been evident amongst children. For example, these adults made statements such as, "0.3 > 0.4 as $^{1}/_{3}$ is bigger than $^{1}/_{4}$" or "0.3 > 0.4 as -3 is bigger than -4" (Steinle & Stacey, 1998, p. 1).

Tsao (2005) looked at number sense rather than specific computational issues but his results were no more encouraging. Broadly speaking number sense was considered to include understanding numbers, understanding operations, calculating fluently and estimating. Pre-service teachers were given a number sense task designed for year six to eight children and, as well as the information from the task itself, twelve students were interviewed, six from the top 10% of the cohort and six from the bottom 10%. The task involved the use of the four basic operations and in general students performed better on questions involving whole numbers and decimals than they did with fractions. During the interview students were asked how they had obtained their answers and it was found that the lower achieving students relied on rule based methods whereas more able students successfully used number sense and alternate strategies up to twice as often as their weaker peers.

Measurement and Space

Pre-service teachers' understanding of the Measurement topics of area and perimeter has been investigated and results indicate that, using Skemp's terminology, while they have an instrumental understanding, they lack relational understanding (Skemp, 1976). Reinke (1997 p. 75) asked students to explain how they would find the area and perimeter of a shape comprising a rectangle with a semicircle removed from one end



Only 12% could explain how to find the perimeter correctly although 53% could find the area. 22% used the same method for both which was to find the area by subtracting the area of the semicircle from the area of the rectangle and then do the perimeter the same way. 25% answered that the perimeter was just the perimeter of the rectangle and 21% said the same for the area. The evidence seemed to indicate a reliance on procedural methods which might be recalled incorrectly, if at all, rather than on underlying concepts (Reinke, 1997).

Menon (1998) also investigated pre-service teachers' understanding of perimeter and area. Students were first asked to write a question for children which would assess whether they understood the meaning of perimeter. They then considered three area and perimeter problems related to shapes made from rectangles and triangles and had to decide whether there was sufficient information provided to answer them, and if not, what additional information was needed (p. 367). In the first task over 40% of the students wrote a question which assessed only a low level of understanding and was generally procedural in nature such as finding the perimeter of a shape in which all side lengths were given. Only 11% wrote something which assessed conceptual understanding and 5% wrote totally inappropriate questions such as, "If the perimeter of an isosceles triangle is 60 cm, what is the length of its side?" (p. 368). While over 70% of the students answered two of the other three tasks correctly, 85% got the final task wrong which was a concern given that all of them had successfully completed at least Ordinary Level (General Certificate of Secondary Education, GCSE) mathematics.

Number sense, the metric system and understanding of volume were all addressed in a study by Zevenbergen (2005). Students were presented with the following question:

> What amount of concrete would be needed to fill a barbecue area 8.5 m long, 3.2 m wide and 30 cm deep? Express your answer in the way you would if you were to phone the concrete company to place the order. (p. 8)

Using this example in several years of teaching, she found that between 40% and 50% of students were able to provide an appropriate answer. Others gave inappropriate levels of accuracy (too many decimal places for a real order) or used units incorrectly (errors in converting cm to m and using litres or even kilograms). Follow up interviews provided further insights into student thinking and a major concern was that although mathematics methods units had addressed some issues, such as the actual size of 1 m^3, misconceptions persisted. One possible explanation was that student observations of teachers in classrooms during practicum placements reinforced their experiences in schools as learners and not the experiences they had at university. Hence they dismissed on-campus learning as being irrelevant in *real* classrooms (Zevenbergen, 2005).

Data/Statistics

In the study described in this thesis, the display and interpretation of data in tables and graphs, as required in the Chance and Data Outcomes of the WA Outcomes and Standards Framework, was actually covered in the scientific literacy component of the unit to avoid duplication. Similarly, some of the research on pre-service teachers' use of statistics and data practices has looked at the use of the skills and concepts in science. Lewis, Alacaci, O'Brien and Zhonghong (2002) analysed how students in a science education project used mathematics. The project reports were analysed according to what mathematical strategies could have been used and compared the results to how many students actually used them. While about two thirds of the students had information for which a table would have been appropriate, only half of them actually used tables to display data. Conversely, 61% used a bar graph when it was actually appropriate in only 17% of projects. Of the fifteen possible applications of suitable mathematics available, including percentages, averages, and different types of graphs, eight had not been used at all and four had been used by less than 10% of the students. They noted that students who did not have suitable mathematical skills were limited in the type of scientific investigations they could carry out and recommended developing close links between science and mathematics education specialists for their mutual benefit.

Bowen and Roth (2005) looked explicitly at the data and graph interpretation practices of pre-service teachers in science education units. One issue they identified was that while real data rarely fits a straight line graph, students found this hard to explain, believing they had made recording or measuring errors. Concepts such as recognising that other variables were affecting variation, or that the data was subject to random errors, did not fit with their experience of questions in mathematics classes where data fitted nicely along smooth curves or straight lines. The approach taken in the science module of the *Becoming Multiliterate* unit addressed this concern as students designed, conducted and reported on a number of experiments, including presenting and interpreting real data they had collected themselves.

Other topics

Houssart (2000) investigated teachers' views on pattern and noted that the term was used widely but not always appropriately. Identifying and using number patterns, for example, could include topics such as multiplication tables, sequences and investigations and there were many examples of patterns involving shapes and other Space topics. Some teachers in her study felt that "pattern spotting" was an activity only for more able students which is a concern for the Western Australian context as Outcome PA 18.1 states that: "The student recognises patterns in his or her daily life: copies, continues and makes repeating and counting patterns with various forms and when prompted, copies and continues a pattern represented in one form, with a different form, including number", meaning this is an expectation in junior primary classes (Curriculum Council, 2005a, p. 116).

While the content of the mathematics module in *Becoming Multiliterate* was primarily based on the curriculum the pre-service teachers would be expected to teach in schools, the literature on performance in a range of mathematical topics helped to justify the inclusion of a variety of skills and concepts into the unit and to identify appropriate ways to assist students who might exhibit the same misconceptions.

Intervention programs

As well as identifying the current levels of competence and confidence in mathematics amongst pre-service primary teachers, researchers have also developed, implemented and evaluated a number of strategies to improve skills and attitudes. Their findings provide a basis for comparison with the data collected in attempting to answer the fourth question in this study about the effectiveness of the mathematics module in the *Becoming Multiliterate* unit.

The SKIMA (Subject Knowledge in Mathematics) and then the MKiT (Mathematical Knowledge in Teaching) groups in the UK have worked across one year Post-Graduate Certificate in Education courses in a number of institutions offering Initial Teacher Education (ITE) in the UK since the late 1990s. With the advent of a skills audit requirement to be implemented by the institutions as part of teacher registration/accreditation, they were concerned about the effect this would have on their students and whether it would act as an incentive to develop skills or simply exacerbate negative attitudes towards mathematics. There was potential for an audit to be used as a filter in selection processes for teacher trainees or as a tool to identify weaknesses so appropriate support could be provided. Given teacher shortages it seemed likely that the latter would occur with the subsequent onus on the training institutions to address shortcomings. They also raised concerns about how the list of required content for the audit had been decided as it went beyond the normal primary curriculum. As required by the Teacher Development Agency, they based their own audit on a number of principles including an emphasis on links between the subject knowledge and teaching mathematics in a classroom and a developmental approach throughout the course. Student performances varied across questions and between institutions but significant weaknesses were identified and strategies implemented to address these including pre-audit teaching, working with peers and the provision of support materials. They also compared students' performance in the audit with their assessment when teaching numeracy during school placement, and found an association between poor subject matter knowledge and weaknesses in planning and teaching primary mathematics. They concluded that most graduates would require ongoing professional development to further develop their skills so meeting audit requirements as part of ITE was not sufficient (Goulding, et al., 2002).

In a later article in 2003 Goulding reported on one approach where students self audited on a number of items in their own time and were allowed to consult support materials. As they answered each question they rated themselves against a Likert scale on their ability to answer it correctly. Responses ranged from 0 (I could not attempt this question without help) to 4 (I am completely secure in my response).

These responses were then compared with the results of the external audit to identify students with appropriate or inappropriate self perceptions and to form suitable peer support groups. Again she noted that developing skills and confidence is likely to take longer than the one year available in the course and will need to be continued once graduates start teaching (Goulding, 2003). Further updates of her research findings published in 2007 reported that while the compulsory audit of skills against a defined list of content had been abandoned, graduates were still required to have “a secure knowledge and understanding of the subjects (they) are trained to teach” (Goulding, 2007, p. 2). It was left to institutions to decide how to make sure this is the case.

In Australia a number of approaches have been used to improve skill levels. Mays (2005) developed a diagnostic test at the University of New England based on TIMSS (Trends in International Mathematics and Science Study) questions for year eight students without the multiple choice options being provided. This replaced a previous online multiple choice assessment which students completed and then self-remediated using textbooks. The new version addressed concerns such as catering for different learning styles, providing more information for staff on misconceptions and removing the potential for cheating. Of the student intake, 25% scored less than 50% on entry with an overall mean score of 60%. Mathematics methods classes then incorporated activities which addressed identified misconceptions and students were re-tested with more difficult questions. If they still failed to meet the 80% benchmark they were referred to a unit entitled “Common Misconceptions in Mathematics K-6” (Mays, 2005). Researchers also applied the approach with pre-service teachers in Samoa and obtained similar results (Afamasaga-Fuata'i, Meyer, Falo, & Sufia, 2006).

Other studies have focused on addressing anxiety issues through skill improvement. Norwood (1994) applied the ideas of instrumental and relational understanding (Skemp, 1976) to two groups of college students. He measured their anxiety and confidence levels about mathematics as part of a pre-test and then taught them in a arithmetic course. One group was taught using an instrumental approach which emphasised rules and formulae. The other was taught using a relational approach with an emphasis on underlying concepts. Both groups improved similarly in the post-test in terms of performance but when surveyed the students with higher anxiety levels much preferred the instrumental approach. Skemp himself (1976) argued that relational understanding reduced anxiety as it relied less on learned rules, but these adult learners wanted the security of being told exactly what to do. These results were based in an arithmetic course where success could be achieved using rules and the students were familiar with an algorithmic approach from their own schooling, but few of them showed any interest in even discussing why particular rules worked.

Hill (1997) had more success with a group of pre-service teachers when she based a mathematics methods course in a primary school. Students attended a mathematics methods class taught by their tutor at the school and then taught mathematics to small groups of children. This activity was followed by group discussion and reflection before planning for the following week. Hill deliberately applied a model for conceptual change based on helping her students to see how instrumental understanding was inadequate when it came to explaining ideas to children (dissatisfaction), by enabling them to develop their own relational understanding (intelligibility) and by providing opportunities for them to apply their new understandings (plausibility) and to see the rewards in positive outcomes for children (fruitfulness).

Jonker (2002) used a similar approach but asked his pre-service teachers to conduct enrichment activities in schools. While the content was still at elementary school level, the requirement to provide enrichment within the curriculum resulted in the students developing some of the deeper understanding required of classroom teachers.

Anderson and Piazza (1996) picked up the barriers to reforming mathematics teaching that exist because pre-service teachers are products of the systems they are trying to change. They noted that while teacher education courses encouraged a constructivist approach, this was harder to learn and implement and required teachers to have deep content knowledge and an understanding of connections. As a result there was a tendency for pre-service teachers to teach the way they were taught with a heavy reliance on textbooks, and a *one right answer* approach. They believed that this was compounded by systems which evaluated teacher performance based on student results in standardised tests and which encouraged conformity. However, they did achieve positive outcomes for their students by teaching mathematics content using the same strategies they wanted the pre-service teachers to use in classrooms, including the use of manipulatives, small group work and lots of discussion. This was found to reduce anxiety and also to increase student willingness to use constructivist approaches themselves in schools. This approach was also used successfully by Steele and Widman (1997) who found that pre-service teachers changed from thinking about mathematics as simply learning how to compute to recognising the importance of knowing how and why procedures worked and they began using manipulatives and diagrams to model thinking when problem solving. However Steels and Widman (1997) noted that further research would be needed to determine if the change continued into the classroom teaching of the students in their study.

Others have used similar approaches at university only to find that much of their hard work was undone when pre-service teachers faced the reality of the classroom (Brown, McNamara, Hanley, & Jones, 1999). Students wanted clear, specific directions about what to do and how to teach each topic and were unable to take the general pedagogical ideas and apply them in different contexts with children of different ages and abilities. Given the time constraints of a university primary education degree, it was not possible to teach students how to teach every single subject to every age group they were likely to encounter but this was actually what pre-service teachers seemed to expect (Brown, et al., 1999). Members of the same team later looked more closely at the transition from being a “learner of mathematics” to becoming a “teacher of mathematics” and the impact the need for this change of identity had for four students. The students did not think “you can suddenly become a mathematical sort of person” (p. 7) but did use their experiences as learners to inform the way they were intending to teach mathematics (Jones, Brown, Hanley, & McNamara, 2000).

Levine (1998) collected data on anxiety levels and anticipated teaching styles before and after a mathematics methods course for elementary teachers. The course emphasised a problem solving approach based on the use of manipulatives, different representations for abstract concepts and teaching for understanding. The pre-service teachers reported an appreciation of issues such as recognition of multiple solutions, the developmental needs of children and the role of the teacher as a facilitator of learning and valued the teaching ideas that were shared. As a result, anxiety levels decreased and teaching styles shifted from teacher centred to student centred. Witt and Mansergh (2008) found similar effects and noted the importance of tutors being approachable and patient and presenting mathematics teaching as very different from the dry and humourless subject many pre-service teachers perceived it to be at the start of their course.

Hawera (2004) monitored the effectiveness of an optional mathematics course focussing on content knowledge which was designed to address the needs of mathematically anxious first year pre-service teachers. Key factors in its success were the use of a social constructivist approach with lots of student interaction with each other and with staff, use of manipulatives and the creation of a safe learning environment. It would seem that good teaching practice modelled by tutors who engage students in their own learning works as well with pre-service teachers as it does with children in schools.

Some institutions have established learning support mechanisms specifically for students who need assistance with mathematics including the Centre for Academic Writing and Numeracy Skills (CAWNS) at the University of Gloucestershire (Huntley, 2009) and the Loughborough University Mathematics Learning Support Centre who have published a guide to setting up similar centres in universities elsewhere (Croft, 2000; Croft, Harrison, & Robinson, 2009). A number of staff from these and other centres in the UK have established a free online resource called MathTutor for staff and students wishing to improve their skills (Educational Broadcasting Services Trust (EBST), 2009). However, the activities tend to target students enrolled in courses where competency in mathematics and statistics skills is the priority rather than the understanding of mathematical concepts, and the focus is on rote learning and drill and practice following the reading of worked examples.

When developing this study, consideration was given to concurrent research within the same university into the written literacy skills of pre-service teachers. A discussion paper produced by a working party led by Rivalland (2005) identified essential learnings for pre-service teachers in literacy and language. These included theories of language and literacy learning, language diversity, assessment and planning for teaching of literacy, children's literature and technology and literature. They also considered personal literacies and recommended the use of a diagnostic test on entry, the implementation of a *Literacy for Teachers* unit and the explicit development and assessment of student skills in writing for professional purposes across all units in the education degrees. The introduction of the *Becoming Multiliterate* unit addressed a number of their concerns and the effectiveness of the written literacy component was analysed by Thwaite (2005) following the first semester of delivery in the pilot year. While the majority of students (86%) eventually passed the module, most needed several attempts and the benchmark was lowered late in the semester. If the original benchmark had been retained, only 64% would have passed. As part of the support system within the course, students had also been asked if they thought they would need help with academic writing skills. Of those surveyed, 77% said they would not need help but 54% of those failed the writing test. These results parallelled the mathematics data on the confidence and competence of the students, with entry confidence levels being inflated compared to performance. The results from Thwaite's work were used to evaluate the 2005 program as part of the pilot study for this research.

It would seem that successful intervention programs for pre-service teachers have a number of key characteristics which were incorporated into the design of the mathematics module in *Becoming Multiliterate.* These included:

- Consideration of anxiety and other affective factors;
- Clear statements of requirements and justification for the inclusion of particular topics;
- Use of teaching strategies which model effective classroom teaching in primary schools such as the use of manipulatives and group work;
- Individualisation of materials so students recognise what they need to do and are provided with support to address their weaknesses and
- Supportive tutors who create a safe learning environment.

Age and gender effects

The pre-service teachers involved in this research came into university via a number of different pathways and a large proportion of them were mature age students. In addition, males are generally under-represented in primary teacher education. Hence the fifth research question aims to identify the extent to which there was variation in performance and disposition across age and gender as well as across the Early Childhood and Primary degree courses. This section considers some of the literature which has focused on students of different ages and genders, as well as some strategies which might be applied to meet particular needs of the different groups.

The changing demographics of students entering university include increased numbers of adult learners returning to study. With many courses designed for the traditional undergraduate who has just left year 12 with a tertiary entrance qualification, the needs of this group of students present specific challenges for teacher educators. On the positive side, mature age students also bring experiences that can enrich the learning of the classes in which they participate. They have made clear decisions to make teaching their career, they know the local community and have established networks and they are prepared to ask questions when they need information. However, they also tend to be more anxious, have financial or family issues to deal with and may find it hard to interact with younger students (Eifler & Potthoff, 1998).

Those working with adult learners may need to consider specific approaches to address their issues and these can include (Ehrlich, 2000):

- Letting them know why something is important to learn
- Showing them how to find out things for themselves
- Relating learning to their previous experiences
- Ensuring they are ready and motivated to learn
- Supporting them to overcome inhibitions or change beliefs and behaviours

Strategies might therefore include mentoring, use of cohort groups, connecting theory with practice and screening to identify particular issues for individual students

(Eifler & Potthoff, 1998) and a number of these were incorporated into the design of the *Becoming Multiliterate* unit.

Miglietti and Carney Strange (1998) also suggested some effective strategies, especially for students returning to study after a long break or with minimal formal qualifications. She assessed the teaching styles of staff against the Principles of Adult Learning Scale (PALS) and then analysed student responses to questionnaires for their classes. In general, learner centred classes “were related to higher grades, a greater sense of accomplishment and greater overall satisfaction” (p. 7) and she recommended a focus on personalised instruction where student experiences and needs were identified and they were encouraged to be active participants in their own learning. Along with other strategies discussed in this section, this approach was reflected in the design of *Becoming Multiliterate* where mature age students from a range of backgrounds formed a significant proportion of the cohort.

Malinsky, Ross, Pannells and McJunkin (2006) measured anxiety levels amongst pre-service teachers and identified significantly higher levels of anxiety amongst females compared to males. While there was some positive correlation between age and anxiety, the oldest students did not have the highest anxiety levels so the trend was not linear.

This finding reflects the results of research conducted by Bowd and Brady (2003) who also found significant gender differences in anxiety even though the students had similar levels of formal mathematics education and reported similar time lapses since taking a formal mathematics course. They then investigated perceptions of school mathematics experiences and beliefs about mathematics for the same students and noted that females tended to start having more negative perceptions about mathematics once they left elementary school. They commented that this could be attributable to the predominance of male role models in high school mathematics (Bowd & Brady, 2003).

X. Ma (1999) examined 26 studies on the relationship between mathematics anxiety and achievement. While there was some variation in the degree of correlation according to whether standardised tests or teacher grades are used to measure achievement, there was overall correlation between anxiety and achievement. The implications of the link varied with the type of student; for example high anxiety could be a motivating factor for competitive high achievers but have a negative impact for those who were already struggling to achieve.

In a later study, Ma and Xu (2004) investigated the potential links between mathematics anxiety and mathematics achievement by analysing data from the Longitudinal Study of American Youth (LSAY) for over 3000 students as they moved from Grade 7 to Grade 12. They identified causal ordering between prior low achievement and later mathematics anxiety, particularly amongst boys, but for girls this effect was only obvious at critical transition points such as when moving from elementary school to high school. They noted that the expected gender differences in anxiety levels across the year groups were less pronounced than in previous studies and that anxiety levels were generally stable from one year to the next for girls. They suggested that a focus on improving performance may be one way to decrease anxiety amongst males but that early intervention to prevent anxiety developing in girls would be more effective in reducing later levels for them. While these studies focused on school students, many of the attitudes identified would be established strongly enough to persist into tertiary education and hence would impact on the confidence of first year students. With a majority of female students, their higher levels of anxiety needed to be explicitly addressed in the design of the intervention program described in this study.

Conclusion

Curriculum standards internationally place a strong emphasis on the place of literacy and numeracy in school education, and in primary schools in particular the importance of children being taught to read, write and do arithmetic is undeniable. The need for wider mathematics study in the years prior to secondary school is probably more open to debate, although few would deny the relevance of measurement skills and spatial awareness. Various terms are used to define what is important including numeracy, mathematical literacy and quantitative literacy, and mathematics is also seen as one aspect of being multiliterate.

Unfortunately reports of falling standards of both literacy and numeracy continue to be published and those looking to allocate blame find teachers an easy target. This has led to auditing of teacher mathematical competence both for research purposes and, more recently, as part of accreditation requirements, and the data is not encouraging. Even for primary teaching, pre-service teacher competence in mathematics can be lower than that of the children whom they will be expected to teach. Various approaches to improve skills have been considered and implemented with varying degrees of success both in Australia and overseas. An associated issue has been that as well as poor skill levels, pre-service teachers exhibit low levels of confidence and self efficacy in both their ability to do mathematics and their ability to teach it to others. This may even manifest itself as mathematics anxiety and the implications for future generations of having teachers who have negative attitudes to the subject they are teaching cannot be underestimated. The imminent introduction of audit tests to verify that pre-service teachers' literacy and numeracy standards meet registration requirements provides an added incentive to develop and evaluate strategies such as the *Becoming Multiliterate* unit which may be able to improve skill deficits and negative attitudes.

Chapter 3

Research Context and Methodology

In this chapter the context in which the research was conducted will be established in parallel with a description of the development and implementation of the methodology.

The structure of the chapter will reflect the realities of most educational research in that it was impacted at all stages by the circumstances in which it was conducted. A number of the factors which needed to be considered are therefore described along with their effect on the research design and implementation. Following an overview of the study and the research questions, the context in which the study was conducted is presented in some detail. The development and implementation of the intervention program is then described followed by information on the data collection and analysis.

Research overview

Mathematics education staff at the university had recognised from student performance in class and in skills assessments linked to semester examinations that many pre-service primary teachers in the course lacked the mathematical skills and knowledge needed to teach the content of the primary school curriculum and that, in addition, their confidence about their ability in mathematics and its teaching was often low. The literature identified this as being more than a recent and local problem (Ball, 1990b; Louden et al., 2005; Rech et al., 1993; Southwell et al., 2005). As a result, the approaches taken in mathematics pedagogy units used activities which combined the modelling of appropriate teaching strategies with thinly disguised opportunities for students to develop their own skills and understanding. While this had some success it was agreed that as similar problems had been identified in student literacy levels, a more direct approach was needed and a new core unit, *Becoming Multiliterate*, was added to the course structure. The mathematics component of the unit provided an opportunity to explicitly measure student competence and confidence levels and to investigate the efficacy of the unit in improving them.

Data for the research was collected as part of the unit delivery as students completed diagnostic entry tasks in order to enable staff to customise the modules to suit their individual needs, and students later completed exit tasks to demonstrate whether they had achieved the required benchmarks. By adding a Likert scale to each question for students to record the extent to which they believed they had answered the question correctly, data was obtained on entry and exit confidence levels. The unit was first run in 2005 and this was considered as a pilot project, with full data for this study collected during 2006 and 2007. Demographic data, including course enrolment, gender and age for each student, was obtained (with permission) from university record systems and linked to student performance and confidence records before de-identification. The data was then analysed against the research questions and appropriate conclusions drawn.

Research questions

The research questions were designed to take advantage of the fact that the data would be collected as part of the normal delivery of the unit. One aim of the study was to determine the extent to which the students entering the university demonstrated the low levels of mathematical competence and confidence described in the literature (Goulding, et al., 2002; Hillman, et al., 2006; Mays, 2005; Norwood, 1994). In particular it was of interest as to whether similar levels of skill were evident across all areas of mathematics or if some aspects, as identified by researchers such as Houssart (2000) and Zevenbergen (2005), caused more difficulties than others. Having determined base levels, exit data enabled the efficacy of the unit in addressing any identified weaknesses to be determined. In addition, any variations amongst student performance based on differences in age, gender and intended teaching role (primary or early childhood education) would serve to support conclusions about the usefulness of the approach in a range of contexts.

The research questions are below:

1. How competent are first year pre-service primary teachers in primary school mathematics curriculum content?
2. How confident are pre-service primary teachers about their mathematical ability?
3. What are the particular areas of mathematical strength and weakness amongst pre-service primary teachers?
4. How effective is a specially designed intervention program in improving competence and confidence in mathematics amongst pre-service primary teachers?
5. Are there any significant gender, age or course differences in pre-service primary teachers' performance and confidence before, during and after the intervention program?

Research context

While the lack of mathematical skills and knowledge amongst pre-service primary teachers was already an area of personal interest and some investigation, new course development and the introduction of the *Becoming Multiliterate* unit provided an opportunity to put a number of ideas into practice and evaluate their effectiveness as a formal research project.

As a result, the methodology used was subject to a number of constraints which conversely became useful defining characteristics in the design of the research. The university structures and rules and the requirements of the research study both conflicted with and complemented each other in designing and delivering a unit where the primary purpose was to meet the needs of the students.

If the intervention unit had been designed as part of a stand alone research study, the process of its development might well have been different. The requirements to meet university guidelines and to develop a unit which was part of the first year of a four year degree course while working with a number of other staff with interests in related areas and fitting in with timetable restraints, meant that sometimes practical considerations took precedence over research design issues.

The university requires a process for course and unit development which is both long and complex. The BEd Primary and Early Childhood Studies degrees had been subject to a period of review and redevelopment throughout 2003 and this had been adversely affected by a number of issues including the politics associated with teaching staff working in different learning areas of the school curriculum all wanting more time for their subjects than was available in the timetable. With a change in senior staff at the start of 2004, executive decisions were made and course structures with associated unit outlines were produced in a relatively short period by a small group of staff. This was presented as a fait accompli and all staff members were then asked to nominate to complete the development of the units ready for implementation of the courses with the first year intake in 2005. At this point *Becoming Multiliterate* was identified as being linked to my area of interest and I was appointed as unit coordinator.

The unit was specifically aimed at ensuring first year students had appropriate levels of literacy and numeracy. The unit outline, which had been approved as part of the course development, defined outcomes in personal literacy in written and oral communication, mathematics, science and information and communications technology. The oral communication aspect was dropped early in the development process with the intention that it would be covered in other units including drama and literacy pedagogy. Students enrolled full time in the degree courses were completing three other units in the same semester. As well *Becoming Multiliterate*, students were enrolled in *Becoming a professional teacher* and *Social influences on learning*. Primary students were also enrolled in *Becoming more effective learners* while Early Childhood students did *Drama education in early childhood settings*. These were all considered foundation units.

The unit outline format is clearly defined by the university and retained within the Course Management System. Changes can only be made by authorised staff and anything other than a minor variation requires approval from School and Faculty committees. In 2004 the unit outline to be implemented in 2005 was already defined when I became involved so the unit description, learning outcomes, teaching processes and texts were already in place (see Appendix A). Unit coordinators are then required to develop unit plans which build on the “skeleton” of the unit outline.

Given the nature of the unit in covering a number of learning areas and the intention to take an innovative approach, a team of staff, which ultimately included 18 other people besides myself, worked on the unit plan for most of the second half of 2004. Once agreement had been reached on the overall philosophy and approach, sub-groups separately developed the four literacy areas to meet agreed common criteria. This team approach proved valuable in giving ownership of the decisions back to staff and most of them continued their involvement in the unit over the following years. As a researcher, my ability to control the development of the instruments and intervention was occasionally subject to negotiation but the opportunity to use the resources and ideas of colleagues compensated for this.

The implementation of the unit was subject to constraints of timetables, calendars, resources and staffing. The unit, like all others, was taught over a 12 week period with three hours of contact per week which was not a lot of time to address four areas of literacy (writing, science, mathematics and ICT). As the unit was to be part of both the Primary and Early Childhood studies degrees, the potential first year cohort was over 300 students. However, university admission procedures meant that final numbers would not be available till week one of semester so the number of classes could not be confirmed till then. While most staff involved in teaching the unit were part of its development throughout 2004, workload requirements resulted in others being brought in just before the unit started in 2005, a number of them being sessional (casual) tutors. The unit as a whole was designed to make use of on-campus computing facilities so all tutorials had to be timetabled into laboratories which restricted class sizes to 22 students (the number of computers in each room). While it was an advantage to have such a relatively small number of students in each group, the consequence was that a large number of tutorials were needed which caused timetabling problems.

These practical constraints were addressed by adopting a rotational approach across concurrent tutorials as described later in this chapter. Each student was assessed in writing, science and mathematics in week one, spent two weeks working on ICT tasks in weeks two and three and then rotated through three modules of three weeks each for the other three areas. Therefore, each student had nine hours of contact time to cover the requirements of the mathematics module as well as access to online and paper resources outside the classroom. The rotation approach also meant that in 2006 and 2007 all mathematics classes were taught by full time and sessional staff with a background which included primary and secondary school classroom teaching of mathematics as well as experience in teaching in mathematics education units in the rest of the courses.

Although the principal research focus in this thesis was on the mathematical literacy of the students, the approach taken was consistent across the unit as a whole and reflected a shared philosophy amongst staff. This was based on ensuring students were enabled to develop the skills and confidence needed to be successful in their degree course and to graduate as effective teachers of literacy, numeracy and science in primary schools.

While the opportunity to use the development and implementation of Becoming Multiliterate as the basis for doctoral research was identified early in the process, it was important that the needs of the research did not compromise the quality of what was being delivered to the students. Fortunately my role as unit coordinator from almost the start of the process was a significant advantage. I was able to define and develop the mathematics module within the constraints of the university requirements and student needs, to treat the 2005 version of the unit as a pilot and to collect data from the 2006 and 2007 cohorts with ethics approval from the university. The only major changes that would have been made if other restrictions had been removed would have been to have much longer than three weeks to work on skills and to then develop a greater skill set and level of competence so as to set a higher exit standard. However, the advantage of having to meet the constraints was that the project was embedded in a practical context and the results are consequently of relevance to others working in similar university circumstances.

The remaining sections of this chapter describe how the intervention program was developed and implemented and then how the data needed to answer each of the research questions was obtained. The final section addresses the analysis of that data and issues of validity and reliability.

Intervention program

As the data for this study was collected as an integral part of the delivery of the unit, the overall design of the unit and how content was presented to the students is covered first. The unit philosophy is discussed and then the processes involved in its development and implementation are described before covering the content and delivery of the mathematics module in detail.

Unit philosophy

An initial point of agreement amongst the staff was that the *Becoming Multiliterate* unit would take a competency based approach.

> Competency-based training (CBT) is an approach to vocational education and training that places emphasis on what a person can do in the workplace as a result of completing a program of training. Competency-based training programs are often comprised of modules broken into segments called learning outcomes, which are based on standards set by industry, and assessment is designed to ensure each student has achieved all the outcomes (skills and knowledge) required by each module.
>
> Ideally, progress within a competency-based training program is not based on time. As soon as students have achieved or demonstrated the outcomes required in a module, they can move to the next module. In this way, students may be able to complete a program of study much faster. (Queensland Department of Education, Training and the Arts, 2008, p. 1)

In applying this to a university rather than a training context, it was determined the unit would define the skills which students needed in each area of literacy and then develop learning activities and provide assessment tasks for students to demonstrate what they could do. Students would have multiple opportunities to demonstrate their skills, and recognition would be given for pre-existing competencies as well as those gained during the semester.

In order to recognise students' existing skills and knowledge, a means of assessing current levels of competence was required and it was agreed by all staff planning the unit that simply giving exemptions on the basis of prior qualifications would not be appropriate. As well as the risks associated with the deterioration in skills over time for students who were not recent school leavers, the content knowledge required for teaching in primary schools is not the same as that required to pass tertiary entrance subjects. For those students whose previous experiences meant that they were already competent, an entry assessment task would provide the required confirmation, and for those who had gaps in their knowledge the task would identify the areas in which support was needed.

Throughout the development of the unit, staff expressed concern about how information on student needs could be obtained through diagnostic assessment tasks without having a deleterious effect on their potentially fragile confidence levels. A model used by the Toastmasters organisation (Gray, 2008) was identified as a possible strategy.

The *CRC* approach – Commend, Recommend, Commend – is used by Toastmasters when giving feedback to members on their public speaking skills. Its history is somewhat blurred with both New Zealand and Australian sites claiming ownership and it has been used in a number of other organisations as well. One website is quoted below:

> Australian Toastmasters have developed a very effective structure for evaluations. It is a sandwich of Commend | Recommend | Commend - the CRC. Recommendations for improvement are wrapped between Commendations for existing skills.
>
> This style is based on educational research which has established that negative feedback is a very ineffective way of changing human behaviour. Clear explanations and demonstrations of proposed changes followed by praise for improvement, no matter how slight, and encouragement to keep trying, is the most effective style to facilitate change in behaviour. (Toastmasters Australia, n/d)

There are a number of similar models including PIP (Praise, Improvement, Praise) and the *feedback sandwich* which are used in a number of fields such as the training of doctors. The key is to include well targeted constructive criticism between two specific praises. This approach identifies clearly to the recipient which behaviours need to be retained and what to do to improve others which might be less than satisfactory and has the advantage of making the negative feedback more palatable (Dohrenwend, 2002).

This model reflected closely the approach which was needed for the unit, especially in mathematics, so the ongoing development used CRC as a foundation. For example, rather than presenting the results of the entry task in terms of what still needed to be done, students were commended on the skills they had already demonstrated and relevant outcomes signed off on checklists. Recommendations for improvement included specific direction to resources and the provision of individualised support by patient tutors. Following the exit tasks, further commendation on what had been achieved was linked to celebration of success where appropriate, or recommendations for ongoing development when benchmarks had not yet been reached. This approach was intended to ensure that concerns in other research about the impact of having weaknesses identified (Bibby, 2002; Morris, 2001; Sanders & Morris, 2000) would be minimised. Addressing this nexus between competence and confidence is what is unique about this research.

Unit development

Beginning with the unit name *Becoming Multiliterate* and the brief unit outline, a number of staff from different curriculum areas worked together throughout the second half of 2004 to provide the detail of the unit content and delivery.

The term multiliteracies has a specific meaning amongst literacy and language educators and refers to the literacy required for life long learning, particularly in a world of increasing cultural and linguistic diversity and expanding communication technologies (Cazden et al., 1996). In the unit, being multiliterate has been taken to refer to the need for teachers to be able to communicate and understand the processes involved in four areas; writing, mathematics, science, and information and communication technology (ICT). Mathematical literacy (Aldous, 2006; Steen,

2001) has been used by some researchers as an alternative term for numeracy when the intent has been to consider content beyond number manipulation. There is wide research on scientific literacy (Rennie & Sheffield, 2005) where the emphasis is on the ability to read and communicate effectively about scientific ideas as well as to use scientific method. Computer literacy requires the ability to use a variety of electronic tools for communication and data and information processing.

Because of the unit title, the term mathematical literacy was used by the original developers without a consideration of how their intent reflected its understanding in the broader context of mathematics education. As a result, while the term was used throughout the development and implementation of both the unit and this study, there is no pretence that the content of the module and the outcomes which students need to demonstrate represent mathematical literacy in its broadest sense. The unit was simply designed to provide beginning pre-service teachers with skills and knowledge in mathematics (as well as writing, science and ICT) sufficient to ensure that they would be able to cope with the content of the degree course and the delivery of the curriculum content currently being taught in Western Australian primary schools.

Education staff with expertise in each area developed specific intended learning outcomes. In deciding on the level of competence required, the Western Australian Outcomes and Standards Framework (Curriculum Council, 2005a) was used to identify the outcomes at Level 4 in mathematics (Table 3.2) and science as these provided the benchmark for year nine students in the state and could be expected to define much of the content taught at year seven level (the final year of primary school in Western Australia at the time of the study). In writing and ICT, the outcomes were based on the skills needed by the students to succeed in their university studies and covered academic writing skills (including spelling, grammar and punctuation), use of word processing software and critical research in the library and on the internet.

Checklists of competencies formed part of the expanded unit plan so students enrolling in the unit knew exactly what was required of them. These lists provided the basis for the development of learning activities and materials, and assessment tasks comprised questions and tasks linked to specified outcomes.

Unit structure and delivery

It was recognised that presenting students with a series of tests in their first week of university would be threatening and possibly counterproductive. However, it was also felt that even weak students needed to be able to demonstrate what they could already do so they could have those competencies “signed off” on their checklist. Finding a way to recognise existing skills without intimidation was a difficult path to tread but a number of strategies were applied as the part of the beginning of the CRC process. The university conducted orientation sessions for all new students and a majority of the students attended the presentations organised for beginning primary and early childhood education students. Part of the presentation included information about the *Becoming Multiliterate* and students were given a flyer (Appendix B) which outlined the requirements, as well as a copy of the mathematics checklist (Appendix C). The words “test”, “pass” and “fail” were banned so reference was made to “assessment tasks” and “meeting benchmarks”, and it was emphasised that the purpose was to find out what students could already do so it could be ticked off their list and leave them less work to do during the semester. Their justifiable trepidation was recognised and a light hearted approach taken to the presentation. The format of the unit was explained, including the fact that there would be multiple opportunities to demonstrate the outcomes. Students still arrived in their first class feeling nervous and worried but at least any fear of the unknown was reduced.

The 12 week semester was broken into four modules each of three weeks duration. The first week of the first module was used for entry assessment tasks and was followed by two weeks for ICT work (and time for staff to mark entry assessments). The rest of semester then comprised three modules for the other areas of literacy. Staff with expertise in each area were used as tutors and, as they were also involved in the methods units later in the course, they had a clear sense of the skills and knowledge required to teach effectively in that area. They were also able to help students make links between the various units in their course and to look at their longer term development beyond the first semester.

Each module comprised 9 hours of classroom contact (three hours per week for three weeks) in a computer laboratory, with a maximum of 22 students per class (the number of computers in each room). Virtually all of the materials in mathematics and writing were available electronically or as hard copy handouts, so students could access them outside class time and were encouraged to practise their skills between sessions. The science module took a practical approach with students working in small groups to complete three simple experiments, the first under tutor direction, the second with some tutor support and the third independently. The focus was on scientific method and modelling the way the students would teach science in a primary classroom. The ICT tasks had online instructions and could be completed in class or anywhere with computer and internet access.

The first week of each three week module included time for the tutor to talk to individual students about their performance in the entry assessment tasks and the weaknesses they had to address. Personalised checklists were provided with demonstrated competencies signed off and focus areas for further development identified.

The last hour of the third week of each module was used for students to complete an exit assessment. These tasks paralleled the entry tasks so students knew what was expected of them. However, it should be noted that students who had scored 75% of the available marks for a given question in the entry mathematics task were considered competent in that question. Even if they had to do the task again because their overall mark was below the required benchmark, they did not have to answer that question the next time they attempted the task. Similarly, students who had passed the spelling and word usage sections in the writing task on entry but had not met the requirements for punctuation and the essay, would only resit the punctuation and essay sections in the exit assessment. In science, marks accumulation was not possible as each task was complete in itself, consisting as it did of a sequence of questions related to a particular experimental investigation.

Students who met the benchmark in each area on entry or by the end of the module were considered to have passed the unit. Others needed more time so two further opportunities to demonstrate competence were provided. One was at the end of semester, once other unit examinations had been completed. This allowed students more time to practise ongoing areas of weakness and the tasks were again parallel to the ones they had attempted previously. For those who needed even longer, a second and final resit session was held in the first week of the following semester. The three or four weeks over the mid-year break enabled weak students to put in some focused practice on their remaining weaknesses and many benefited from this. Those who failed to meet all the benchmarks after this final opportunity were given a fail grade for the unit and had to enrol to repeat the unit in summer school or first semester the following year. They also had to start the whole unit from scratch, even if the fail had only been in one area and, while this caused some dissent, it was felt that it was important to ensure that the skills they had developed in their first attempt had been retained.

Mathematics module

In week 4 students attended the first class of the first rotation and in mathematics they were interviewed individually. They were shown the spreadsheet of their results in each question in the entry task with shaded cells indicating questions they had *passed* i.e. where their score was at least 75% of the available marks and staff marked off the completed outcomes on their personal checklist. They were directed to the targeted learning materials and over the next three sessions worked individually, in small groups or as a whole class on the skills and knowledge they still had to demonstrate.

Having identified areas where students were already competent, and commended them on their existing skills, the second important aspect of the CRC model was the development and provision of a range of learning materials and resources which they could be recommended to use to improve their skills in areas of weakness. These needed to be targeted to the outcomes, suitable for use in class and at home and able to cater for a range of learning styles. One option was an electronic resource known as Mathletics (3P Learning, 2009). This had been designed in Australia for use in primary and secondary schools and in 2005 was available in the form of a CDROM with exercises aimed at a particular stage of schooling. Students in the pilot year were provided with in-class access to the upper primary material by loading the software onto the computers in the laboratory and they could purchase the CDs through the bookshop for personal use at home. While much of the material provided useful practice, it was not specific enough to the identified outcomes and many students needed to develop earlier skills before they could tackle the exercises for the selected year group. The activities were motivating and engaging and provided one strategy which suited a good proportion of the students, but substantial supplementary materials were also needed.

In 2006 the Mathletics materials were expanded and made available through a website, and their usefulness increased significantly. It was now possible for staff to create a “course” from a bank of activities at different levels and to make this available online to any computer with internet access via a user name and password. Suitable activities were identified, some at a level below that which would be needed, so weak students had somewhere to start and others could build their confidence. Extension activities were also included as options for stronger students and as a goal for others. The system generated a different set of random questions each time the activity was selected so students could practise the same skills repeatedly. In addition, once a student answered several consecutive questions correctly the next question was taken from a slightly higher level so there was continuous challenge. If the student answered these harder questions incorrectly, the level dropped back till they were ready to move up again. There were Help buttons on each page where a hint would be given or a similar example demonstrated. Records of performance were maintained on each student’s personal site so they could see what they had done, and if required a printout of each exercise was available with appropriate solutions provided for incorrect answers. Because students had personalised access it was possible for staff to download records of what they had been doing and how well they had performed and this enabled progress to be monitored and students to be encouraged to put in more effort if appropriate. Students were provided with free access using generic passwords in the computer lab and at a minimal cost at home using individual codes.

In 2007 the publishers provided access to the website free of charge from any computer, with the intent that students would mention the program when on teaching practice and hence promote its use to schools. A number of students also purchased full access for their own families, an indication of their perceived usefulness of the resource.

There was concern initially that the students would resent being asked to work with materials which had been developed for primary school children. In the pilot year this was monitored and staff actually observed the opposite. Students felt less threatened by activities which were not presented in an adult format and engaged with the cartoon characters and various sound effects in much the same way as children in a classroom. The atmosphere in the laboratories was relaxed and even fun so when the improved version was made available in 2006 staff were keen to use it. The approach supported the emphasis on building confidence by making the learning materials user-friendly and individualised. Students had twelve months of access so those who needed to repeat the unit, or had mathematics education units in semester two, could continue to develop their skills through ongoing practice.

To complement the online activities and to cater for content which was not included on the Mathletics site at an appropriate level, a number of hard copy worksheets, some based on classroom texts and others developed by staff, were collated into a workbook which students could use at home or in class. In class, activities in small groups or as a whole class were conducted by staff with an emphasis on how the same content might be taught in a primary classroom so students could start to consider some teaching strategies. For example, activities on estimating weight used double pan balances and non-standard units such as blocks, and students would be asked to estimate how many blocks were equivalent in weight to the given item before moving on to standard units. Students were introduced to base ten blocks to assist with developing their skills in place value and arithmetic with whole numbers and decimals. Dice and spinners were used to illustrate concepts associated with chance processes as well as to generate data for processing to display and interpret. Multifix cubes served a dual purpose for drawing different views of shapes made from cubes and discussing surface area and volume. Some of these materials were also made available in the assessment tasks for students who found them helpful.

The other resources, including the worksheets and hands on activities which were made available, led to a pattern arising in classes where students would spend some time on computers and some time in groups discussing particular outcomes, with flexible movement between the two as the topics changed. Staff also circulated around the room throughout the sessions to deal with queries and provide extra individual support for those who needed it.

Just before the exit assessment in the last of the three sessions, staff checked that students were clear about what they had to do and had the required materials. Students received individualised papers with the questions they still had to answer highlighted. Apart from the incentive of being able to omit a number of questions as they worked, it was intended that students felt that they were being treated as individual learners rather than being part of a one size fits all approach.

When marks for the exit assessment were recorded a copy of the entry assessments spreadsheet was used and individual question scores were replaced by exit marks if they had improved. Hence every student's mark was higher after the exit assessment. By seeing an improvement over the three weeks it was hoped this would provide an incentive for continued effort even if the benchmark had not been reached. This was part of the final C - Commend where students had their improvement recognised. A further boost to confidence was that students had fewer questions to answer in the exit assessment and this reduced the stress caused by running out of time to complete the test and meant they had more time to focus on areas of previous weakness. Parallel questions meant they had some idea of the format of the paper and the level of difficulty. As a result, the exit assessment was designed to be less intimidating than the entry task and students were hopefully more confident about their ability to succeed.

Multiple assessments of individual questions had significant consequences for record keeping but it was felt that it was a worthwhile effort if the CRC model was to work effectively. A separate worksheet was used for each task with links to previous results in the same workbook. Summary sheets including the sequence of marks were then generated so students could see progress. As well as personal interviews where individual performance was discussed, copies of the spreadsheets with students listed by their student identification number were emailed after each module so they could check their performance and get a sense of how they rated against other students who were anonymous. Weak students would be able to see that others were in the same position and others who had performed well but were lacking in confidence would see how high they were ranked. This open communication was designed to create the feeling that staff and students were working together to improve their competence.

Three weeks was recognised as a relatively short time to address some deep seated problems, so students were able to continue working on their skills after the module had finished and to return at the end of semester for another attempt at the exit task. They were also allowed one more opportunity to sit the task at the start of second semester.

Completing the unit

Table 3.1 shows how three students might have progressed through the unit and its three modules during the semester.

Table 3.1 Examples of the Semester Programs for Typical Students

Week	Student A	Student B	Student C	Comments
1	Entry assessment tasks in writing, mathematics and science			
2	ICT task completion			Staff mark entry tasks and meet to discuss moderation, marks recording and allocation of students to rotations
3	ICT task completion			
4	Mathematics	Science	Writing	• First session of each module includes individual discussion identifying strengths and weaknesses • Second session focuses on building skill levels • Final session is revision and the last hour is used for the exit assessment
5	Mathematics	Science	Writing	
6	Mathematics	Science	Writing	
7	Writing	Mathematics	Science	
8	Writing	Mathematics	Science	
9	Writing	Mathematics	Science	
10	Science	Writing		
11	Science	Writing		
12	Science	Writing		
14	-	Exit task resit 1 (writing and science)	Exit task resit 1 (writing)	Held in examination weeks after other unit commitments are completed
Sem 2	-	Exit task resit 2 (writing)		Held at the end of the first week of semester 2

Student A did not meet the benchmark in any of the three areas in the entry tasks but was able to do so in the exit tasks at the end of each module. He received a Pass grade for the unit at the end of semester one.

Student B did not meet any of the benchmarks in the entry tasks and only achieved the benchmark in Mathematics in the exit assessments at the end of the modules. She achieved the benchmark in science in the first resit sessions at the end of semester one and resat writing again at the start of semester 2 when she was able to reach the standard required.

Student C met the benchmark in Mathematics in the entry assessment so was not required to attend that module which was arranged to be her final rotation. She passed science in the exit assessment at the end of the module but needed to resit at least one component of the writing task in order to complete the unit requirements.

Students who were unsuccessful in *Becoming Multiliterate* were allowed to continue with other units in semester two, but as the unit was a pre-requisite for the first literacy education unit in second year, they were counselled by student support staff and given an amended pathway to complete their degree. This caused some concerns amongst staff as students who had non-standard enrolments tended to create problems as they moved through the course, but it was agreed that if their literacy skills were weak, they were at risk of failing other units and this would also require a personal pathway. According to the university rules, students who failed the unit three times were excluded from the course, as was the case for a core unit of any degree.

Measuring mathematical competence on entry and exit

This section, and the ones which follow, covers how the data to answer the research questions was generated and collected. Only the mathematics module will be considered as this was the focus of the research study. However, a parallel process was followed in writing and science in designing the module, the learning activities and the assessment tasks. Interactions with students focused on the positive - what they could already do, how well they were progressing, how much they had improved – rather than pointing out areas of weakness and how much more needed to be done. In reality, students tended to be negative already without staff reinforcing their perceptions, so the Commend-Recommend-Commend approach was emphasised with all staff. It should be noted that most staff behaviour was not labelled as CRC until later although my personal knowledge and use of the approach in other fields meant that the mathematics module development was using it implicitly from the start.

Mathematics module content

While it would have been preferable to set the benchmarks for the unit at a higher level than was chosen, the literature and staff experience with similar cohorts of students indicated that their mathematical skills and confidence would be weak. In line with the CRC approach it was agreed that the aim would be to ensure that all students entering the mathematics education units later in the courses were competent in the material they were likely to teach in primary schools. In Western Australia the Department of Education and Training has identified Standards which provide benchmarks for students at various stages of schooling. These Standards are incorporated into the Outcomes and Standards Framework: Mathematics (Curriculum Council, 2005a) and there are similar benchmarks for English, Science and Society and Environment. The mathematics assessment tasks were based on Level Four outcomes and represented the benchmark for year nine students in government schools in the state at the time of the study. As such, 75% of year nine students were expected to be able to demonstrate all of the outcomes. In order to achieve this, schools needed to teach the relevant content and skills in earlier years, so it was considered likely that primary teachers could be required to teach this material in a year six or seven class. As well as providing an appropriate level at which to aim the teaching and learning materials, staff were able to justify the content to reluctant students whose catch cry, like many before them, was, "When am I ever going to use this stuff?" There was some added resistance from the early childhood cohort who intended to work in pre-primary centres and junior primary classes. However, it was pointed out that a number of graduates of their program had found themselves working in a school where upper primary teachers were in short supply and they had been required to teach up to year six or seven.

A further incentive to achieve at the required level was provided by political discussions at state and federal level indicating that, as in the UK, graduate teachers may soon be required to demonstrate their personal literacy and numeracy skills before they can be registered with the appropriate professional body and be eligible to teach (Gillard, 2009; Teaching Australia, 2006).

The Mathematics Curriculum in WA was based on nineteen outcomes grouped into seven clusters. With the exception of Appreciating Mathematics, each outcome had a descriptor for each of eight levels covering the school years from Kindergarten to year 12. The descriptors for each outcome at Level 4 are provided in Appendix D (Curriculum Council, 2005a). Using these as a basis, outcomes were developed for the mathematics module which staff agreed reflected the core skills and knowledge required by pre-service primary teachers. While one would hope that teachers would be significantly more competent than the students they intend to teach, Level 4 was chosen as a compromise between what was desirable and what was a realistic goal. Given the time restrictions and the anticipated ability of the incoming students, the outcomes had to be specific and achievable by the majority of students. Staff concerns were ameliorated somewhat by a mutual agreement to include mathematics subject content knowledge (Shulman, 1986) within the mathematics education units later in the course which would normally have focused only on pedagogical content knowledge.

The list of outcomes is shown in Table 3.2. In addition, the approach to the unit using the CRC model specifically addressed the Appreciating Mathematics Outcome AM 1 Confidence in Mathematics but is not listed here. The list was provided to students to use as a checklist before and during the unit (Appendix C).

Outcome WM1 *Check all answers carefully using methods such as estimation and checking reasonableness* was not assessed directly but students were encouraged to develop checking strategies and to apply them in each task. This may have been explicit, for example by reminding students to check their work before handing it in or when discussing individual performance in previous tasks, but was also implicit in all the teaching and learning activities. Outcome C3 *Answer questions about data presented in the form of tables and graphs* was addressed in the science module and

Table 3.2 Outcomes for Mathematics Module and Related Question Numbers

Working Mathematically: Students use mathematical thinking processes and skills in interpreting and dealing with mathematical and non-mathematical situations	**Question Number**
WM1 Check all answers carefully using methods such as estimation and checking reasonableness.	N/A
Number: Students use numbers and operations and the relationships between them efficiently and flexibly.	**Question Number**
N1 Write large and small numbers in figures and words	1
N2 Put fractions and decimals in increasing or decreasing order	2
N3 Locate fractions and decimals on number lines and scales	3
N4 Explain which will be the correct operations to use when presented with word problems	4
N5 Add, subtract, multiply and divide whole numbers and decimals using mental arithmetic and pen and paper methods	5
N6 Perform calculations involving money using the four operations	6
Measurement: Students use direct and indirect measurement and estimation skills to describe, compare, evaluate, plan and construct.	**Question Number**
M1 Measure the length of line segments	14
M2 Convert among units within the metric system e.g. cm to m, kg to g	7
M3 Determine the perimeter, area or volume of shapes which can be decomposed into squares or cubes	8
M4 Find lengths, areas and volumes of shapes which have been enlarged or reduced by a simple scale factor e.g. on maps or scale models	9
M5 Provide estimates of the size or mass of objects within the room	10
Chance and Data: Students use their knowledge of chance and data handling processes in dealing with data and with situations in which uncertainty is involved.	**Question Number**
C1 Estimate the probability of simple events e.g. a particular outcome when rolling a die	11
C2 Summarise a data set e.g. finds mean, maximum, range, relative frequency of a given value.	12
C3 Answer questions about data presented in the form of tables and graphs.	N/A
Space: Students describe and analyse mathematically the spatial features of objects, environments and movements.	**Question Number**
S1 Draw representations of simple three dimensional shapes e.g. plan and elevation, perspective view	13
S2 Interpret maps in terms of the direction and distance between points.	14
S3 Identify the symmetry properties of figures in two and three dimensions	15
S4 Sketch the image of 2D shapes after reflection or rotation	16
S5 Identify properties of shapes such as parallel and perpendicular lines, congruent and similar figures, acute and obtuse angles	17
Pre-algebra and Algebra: Students use algebraic symbols, diagrams and graphs to understand and to reason.	**Question Number**
A1 Write a simple story explaining the changes in a quantity represented on a graph e.g. mood changes during the day, traffic flow data	18
A2 Continue simple sequences of numbers or shapes, explaining how they obtained their answer	19
A3 Solve “find the missing number” problems	20

assessment tasks and, as the mathematics tasks were already quite demanding in the time allowed to complete them, it was felt that there was no need to assess the outcome twice.

Table 3.2 also links the outcomes to the 20 questions in the assessment tasks. These explicit connections enabled student performance in a given question to be linked directly to an outcome as well as to the appropriate teaching and learning materials for that outcome. For example, Question 2 in the assessment task was specifically directed to assessing the students' ability to demonstrate N2 *Put fractions and decimals in increasing or decreasing order* and by using the same code, students could access targeted activities using websites, worksheets and manipulative materials if they wished to improve their skills in ordering fractions and decimals. The booklet given to students to help them to identify relevant Mathletics activities is provided as Appendix E.

Assessment task design and implementation

Once the outcomes had been defined, an assessment task was created by the staff with one question addressing each outcome, with one exception. Outcomes M1 *Measure the length of line segments* and S2 *Interpret maps in terms of the direction and distance between points* were assessed in a single question which required students to measure distances on the map as part of describing a route. A bank of several versions of each question was then developed using a similar format so that as students sat repeated assessments tasks the expectations were consistent but it was not possible to "learn the answers". As there was a need to compare performance across several papers and two years, the questions on a given outcome had limited variation, for example the shapes were changed in the Space questions and the numbers changed in calculation questions. In subsequent years it was possible to have more variety in the questions and extra content was added. Another factor in question design was that students were being tested on their competence in an explicit skill so there was no attempt made to introduce an element of problem solving or to include lengthy word questions. Each question required them to carry out a task and this was quite explicit. A sample paper is provided in Appendix F.

The entry assessment task format required students to answer in the spaces provided on the paper and no other paper for working was permitted, although isometric graph paper was supplied for drawing three dimensional objects if the students wished to use it. Tutors were then able to consider the steps the student had taken to answer each question and award part marks for correct methods even if the final answer was incomplete or incorrect. A conscious decision was made to use short answer questions rather than a multiple choice format despite the extra marking load that this created. The CRC approach meant that students needed to be commended for the skills they could demonstrate and being able to achieve part marks for a question provided much needed encouragement to weaker students. It also allowed students who had made a minor error in an otherwise correct answer to be credited with having demonstrated the required outcome.

From a validity viewpoint, using short answer questions meant that students could not just guess the correct answer from a number of options. As they had to work out the solution to each question for themselves, those who knew little but might have made lucky guesses could be distinguished from those who had at least some idea of how to respond. The extra detail provided about student performance also enabled specific errors and misconceptions which were demonstrated by a number of students to be identified and addressed during class and to be considered when designing subsequent questions. For example, the wording of some questions was clarified and amended when it became apparent that some students had misunderstood the instructions or had failed to answer the question in full. It would not have been possible to do this in a multiple choice question environment.

The questions were designed by staff with experience of the primary curriculum and therefore a sense of the key understandings associated with each outcome. While it would have been better to have several questions for each outcome and to vary them as students repeated each task, part of the CRC approach was to minimise the stress caused to students. Having a sense of the sort of content for each question relieved the anxiety which would have been created by having a completely different set of questions each time. Tutors did not “teach to the question” and the resources focused on developing a wider understanding of the outcome content even if only one aspect was assessed. Anecdotally, the overall performance of the 2005 cohort as they moved into the mathematics pedagogy units indicated that those who had achieved well in the tasks had a reasonable understanding of the mathematics they were learning to teach and were able to develop their pedagogical content knowledge. However, those who had underperformed in *Becoming Multiliterate,* and in some cases were going to repeat the unit, had difficulties with both subject content knowledge and pedagogical content knowledge.

An example of the format for the questions is provided below. Question 7 related to Outcome M2 *Convert among units in the metric system*. The first column gives the question number and the total number of marks available for the question. The second column indicates the outcome to which the question is linked. The third column contains the question and space for the student answer. The fourth column (only provided in the entry task) was for students to indicate the extent to which they were confident they had answered the question correctly. This was designed to provide baseline data on confidence levels and did not take time away from the task as all students had to do was circle a number according to a Likert scale.

The exit tasks followed a similar format but did not include the confidence column as students were not answering every question and exit confidence data would therefore have been incomplete.

7 (3)	**M2**	A craft class teacher needs to buy supplies for the students. One week she has to buy ribbon – all the same colour and width – and wants to find out how much she needs to get. She has notes with her students' orders with the following measurements on them: 30 cm, 450 mm, 1.2 m and 1 m 25 cm. How much ribbon does she need to buy altogether?	**1 2 3 4**

The entry tasks for writing, mathematics and science had 55 minutes allocated for each task and a five minute break between them. Students who finished a task in less time were allowed to leave the room and were asked to return in time for the next task. This was to avoid disturbing those who needed to take longer to complete their answers.

Detailed marking templates were provided for staff and they only marked papers in their area of expertise. This enabled consistency across all groups to be maintained. All staff worked with others in their area to moderate the student work and borderline students were discussed at some length. In 2005 and 2006, an overall benchmark of 70% was set as representing a realistic expectation of students at this stage of their university studies. This was increased to 75% in 2007 after the performance of students in methods units indicated that competence levels needed to be further improved. While this may seem a minimal change, if it had been imposed in 2006 a further 60 students (21.5% of those completing the exit task) would not have passed the mathematics module as there was a strong tendency to do only as much work as was required to meet the benchmark.

While students worked on their ICT tasks in weeks two and three, staff marked their papers. In mathematics, Excel spreadsheets were set up to record the marks for each individual question for each student. With a benchmark of 75% (70% in 2006), students who scored a total mark of 60 out of the 80 marks available were considered to have passed the module, even though there were still some questions which they had answered incorrectly. Marks for individual questions were recorded on the spreadsheet and when the 75% criterion had been met for the question the relevant cell was shaded to assist with providing feedback to students and subsequent data entry and analysis. Later, when the exit test was marked, the new marks for the repeated questions were inserted into a new version of the spreadsheet and replaced the entry scores for those questions, provided the mark had improved. For example, consider two students who scored three out of five marks for a given question on entry. If one then scored four out of five marks on exit, the three was replaced by four. However, if the other student only scored two out of five on exit, they retained the higher score of three out of five.

The entry tasks enabled students to demonstrate existing knowledge as well as to identify areas where they needed to work on skill improvement. Staff used the information to support students in this ongoing development at both a class and individual level. The exit tasks provided the opportunity for students to show their increased skill levels and to make sure there were no further areas which needed attention. At the same time, the tasks provided the study with the data needed to answer the first question about mathematical competence levels, the third question about areas of weakness and to measure the efficacy of the intervention program.

Measuring mathematical confidence on entry and exit

The assessment tools, which were designed to address the need for skills recognition at the start and end of the unit, also provided information in a form which could be used to address the research questions. In addition to demonstrating their mathematical competence on entry to the unit, students indicated the extent to which they felt confident about the correctness of their answers to each question. This assisted tutors in identifying students who might need particular support in the module, as well as providing base data for the research. Further data on confidence levels was obtained from primary students at the start of their first mathematics methods unit in semester two and this provided comparison data on the efficacy of the unit in maintaining or improving confidence levels. In addition, the university Unit and Teaching Effectiveness Instrument was used to provide information on students' affective responses to the unit as positive attitudes would indicate that confidence levels had not been adversely affected.

Confidence data collection

As they completed each question in the mathematics entry assessment, students were asked to respond on a Likert scale according to how confident they felt that they had answered the question correctly. The responses were as follows:

1 Not at all confident
2 A little confident
3 Reasonably confident
4 Very confident

This gave a maximum score of 80 over the twenty questions. Total scores were converted to a percentage although allowance was made for students who did not complete all the questions by calculating the percentage based on the maximum score for the number of questions they had answered. Staff used the data to identify individual students who had particularly low levels of confidence to ensure they were supported appropriately. They were also able to identify students where there was a discrepancy between competence and confidence levels and to help them to be more realistic about their performance. In some cases this meant providing encouragement to students whose level of achievement was greater than their self-belief and for others it required a tactful reminder that success in high school mathematics with a graphics calculator and algebraic techniques was not always going to help them to understand and teach primary school mathematics.

Because students did not answer every question on exit, it was not possible to collect complete confidence scores as part of the assessment task. It was decided to survey the primary students at the start of their mathematics education unit in semester two. Unfortunately, it was not possible to collect exit confidence data from the early childhood students but it was felt that surveying them at the beginning of the following year when their course timetabled their mathematics education unit was too late to be of use for this purpose. This was unfortunate as course comparisons would have been of interest but it was important that students were not asked to do anything for the research which was beyond or irrelevant to what they were doing as the normal requirements of their studies. The exit confidence data was used in ensuring needs were met within the mathematics education unit so it would not have been appropriate to collect it from students who were not enrolled in such a unit at that time.

In week one of semester two, in their first class for the mathematics education unit, primary students were provided with a copy of the *Becoming Multiliterate* mathematics assessment task and asked to complete a questionnaire indicating, for each question, how confident they now felt they would be able to answer it correctly (performance confidence) and how confident they felt about being able to teach the content in a primary classroom (teaching confidence). The same scale as the entry assessment was used so comparisons could be made. The information from the questionnaire was used as part of the unit evaluation and report for the EDF1103 *Becoming Multiliterate* unit and also enabled the tutors in the mathematics methods unit to identify areas where students' confidence levels were still of concern and where particular focus needed to be placed when discussing teaching and learning strategies for the classroom.

Additional information on the impact of the unit on affective issues was obtained from an analysis of the data generated by the university Unit and Teaching Effectiveness Instrument (UTEI). This is normally administered to all students in the last two weeks of each semester and includes three sections. At the time of this study, the first section was an evaluation of the unit as a whole and contained 21 statements about the unit and its delivery as follows:

- Questions 1 – 5 related to Unit Organisation, for example:
    - ‘The content of the unit was well organised.’
- Questions 6 – 10 related to Learning Scope, for example:
    - ‘The unit enhanced my knowledge and skills in the subject.’
- Questions 11 – 15 related to Evaluation of Learning, for example:
    - ‘I had a clear idea of what had to be completed and the level of work that was expected.’
- Questions 16 – 20 related to Resources and Contexts, for example:
    - ‘The activities in the unit supported my learning.’
- Question 21 related to Overall Satisfaction
    - ‘Overall, I was satisfied with this unit’.

The second and third sections covered issues related to the performance of the Lecturer and Tutor respectively. Given the nature of this unit whereby student contact with staff was in a three hour workshop setting, some aspects of each instrument were more relevant than others as the survey was based on the normal delivery pattern of a one hour lecture and a separate two hour tutorial.

In the Lecturer and Tutor Evaluations there were 11 questions divided into three areas:

- Questions 1 – 5 related to Learning Support, for example:
    - ‘The lecturer encouraged me to take responsibility for my own learning.’
    - ‘The tutor encouraged and supported my learning.’
- Questions 6 – 10 related to learning Guidance, for example:
    - ‘The lecturer catered for my individual needs in this unit.’
    - ‘The tutor made clear what I was expected to do and learn.’
- Question 11 related to Overall Satisfaction:
    - ‘Overall, I was satisfied with the performance of this lecturer.’
    - ‘Overall, I was satisfied with the teaching of this tutor.’

The scores for individual tutors enabled comments specifically related to the mathematics module to be extracted for those two surveys, but the Unit comments were based on all three modules so it was more difficult to identify mathematics specific comments unless students made reference to issues such as the Mathletics website or mathematics activities or named the tutor.

While the UTEI surveys provided useful data for 2006 and 2007, there were problems with their administration. Students were asked to evaluate tutors at the end of each module so they completed three Lecturer and three Tutor surveys over the course of the semester. The unit evaluation was done once at the end of semester and comments tended to be based on whatever module students had most recently completed.

In 2006 paper based surveys were used and response rates were approximately 72% although they varied across different tutors. In 2007 the university introduced online surveys and the response rates fell to about 17% meaning that any conclusions drawn from them lack some reliability. In 2006, the paper surveys were conducted in class with tutors explaining what had to be done and then leaving the room before other staff or reliable students collected the forms, sealed them in an envelope and handed them in to administration. Hence all students who attended on the day, which was the majority of those needing to do an exit assessment, completed a survey. This had the disadvantage that those students who passed a module on entry did not participate. However, this was not considered a major issue as these students had not attended classes after the first week of the module and the data was being used to determine the effectiveness of the intervention. The online surveys in 2007, as well as being new and therefore unfamiliar to students, had a number of teething problems which made access difficult, so many students tried once and then gave up and their views were not recorded. Despite these limitations, the surveys included space for student to write in comments and these provided interesting insights into student reactions to the unit which were used to examine the effect on confidence levels.

Student responses in the UTEI were scored as follows:

-100	Strongly disagree
-50	Disagree

0 Neither agree nor disagree

+50 Agree

+100 Strongly agree

Hence scores above zero indicated more agreement than disagreement. Scores below zero indicated more students disagreed with the statement than agreed. There were no reversed statements (negative statements where students were expected to disagree), so there was a tendency for students to record the same score for each statement which in some cases might have indicated they had not read them all.

After coding and processing the responses the results were published online for staff access. As well as being able to read their own results, staff coordinating units could see all the data for staff teaching in that unit. For each statement the number of responses received was provided together with the percentage of students giving each response, the mean score and the total percentage of students who agreed or strongly agreed. Table 3.3 shows some examples.

Table 3.3 Sample Extract from UTEI Report

	n	Responses %					Mean	% Agree
		SD	D	N	A	SA		
Tutor survey – statement 1								
The tutor assisted in developing my understanding of the subject matter	67	0	0	3	43	54	75	97
Lecturer Survey – statement 5								
The lecturer helped make the content interesting and engaging	48	2	2	15	58	23	49	81
Unit Survey – statement 9								
The unit was engaging and interesting	48	0	15	10	52	23	42	75

The written responses were transcribed and analysed for repeated themes and areas of particularly positive or negative feedback. The statement scores were used to gain a sense of overall feelings about the unit as these would indicate the extent to which students were demonstrating positive attitudes towards mathematics and its teaching as well as the success of the unit in meeting their needs.

Identifying areas of mathematical strength and weakness

By recording individual student marks for each question it was possible to analyse the data for particular outcomes. Staff used the information in teaching the unit to identify areas where students needed particular support because their performance was poor and/or because confidence levels were low or unrealistic. These results also enabled staff to implement the CRC approach by identifying questions where students had been successful in reaching the benchmarks and Commending students for their progress. At the same time they could Recommend targeted support for outcomes where more work was needed to achieve the required standard.

While a question by question analysis of performance and confidence has been carried out, the level of detail is too great for the purposes of this study. Because of the design of the unit content in terms of outcomes grouped according to the curriculum strand, the performance and confidence scores across the groups of questions relating to each strand were available for analysis and these were used to answer the third research question vis *What are the particular areas of mathematical strength and weakness amongst pre-service primary teachers?*

Total entry and exit performance scores for the questions relating to a given strand were calculated for each student and converted to a percentage based on the maximum points available for that strand. This enabled scores across the strands to be compared for students entering the unit and again in the exit assessments.

Total entry and exit confidence scores for each strand were calculated for each student and converted to a percentage based on the number of questions for which a confidence level response was available for that particular student.

The comparison of the entry and exit data for each strand enabled any variation in the efficacy of the intervention program to be determined.

Course, gender and age group variations

This study was conducted at one of the metropolitan campuses of a university in Western Australia. As the largest provider of pre-service teacher education in the state, the university offered a number of courses in early childhood, primary and secondary education at undergraduate and post-graduate levels.

The students who were involved in the research were enrolled in the first year of one of two courses, both requiring four years of full time study:

- Bachelor of Education (Primary), qualifying them to teach children in school years 1 to 7 (ages 6-12 years)
- Bachelor of Education (Early Childhood Studies), qualifying them to teach children from kindergarten to year 3 (ages 4-8 years) as well as to work with younger children in child care environments

Students came from a variety of backgrounds including recent school leavers with Tertiary Entrance Rankings sufficiently high to meet university requirements, students with TAFE qualifications at Certificate IV and Diploma level, mature age students who had sat the Special Tertiary Admissions Test (STAT) and recent school leavers who had been accepted for direct entry based on school recommendations, interviews and portfolios. Hence there was the potential for their literacy and numeracy levels to vary considerably and the unit needed to be designed with a high degree of flexibility. It was also recognised that not only did students vary in their competence, but in their attitude to studying at university and the confidence they had in their ability to meet the course requirements. Some lacked confidence because of the time lag since their last experience of formal education. Others had no personal or family experience of university and had no idea about what the expectations would be. The approach taken by staff and the structuring of the unit needed to take these affective issues into account as well as the academic needs of the students.

The participants

This section provides background data on the characteristics of the cohort of students involved in the study over the two year period. Because the subsequent data analysis separates the results for 2006 and 2007, the demographics of the two year groups are presented separately.

Table 3.4 shows the distribution of the students by course. The percentages of students in each course were similar for both years although the total number of students enrolling in the unit increased.

Table 3.4 Enrolments by Course

Course	Number of students			
	2006		2007	
	n	%	n	%
Early Childhood	121	37.8	132	38.4
Primary	199	62.2	212	61.6
All students	320	100	344	100

Table 3.5 shows the gender distribution of the enrolled students in 2006 and 2007. As might be expected, given that these students intended to teach in primary schools, males were under-represented in the courses.

Table 3.5 Enrolments by Gender

Gender	Number of students			
	2006		2007	
	n	%	n	%
Female	264	82.5	292	84.9
Male	56	17.5	52	15.1
All students	320	100	344	100

When the data is broken down by course (Tables 3.6a and 3.6b), the gender distributions across the two courses were significantly different (c^2 =33.8, p=0.000 in 2006 and c^2 =24.4, p=0.000) with very few males opting for Early Childhood Studies (ECS). Gender comparisons for Early Childhood students were not conducted for this reason.

Table 3.6a Enrolments by Gender and by Course: 2006

Gender	Number of students					
	Early Childhood		Primary		Total	
	n	%	n	%	n	%
Female	119	98.3	145	72.9	264	82.5
Male	2	1.7	54	27.1	56	17.5
All students	121	100	199	100	320	100

Table 3.6b Enrolments by Gender and by Course: 2007

Gender	Number of students					
	Early Childhood		Primary		Total	
	n	%	n	%	n	%
Female	128	97.0	164	77.4	292	84.9
Male	4	3.0	48	22.6	52	15.1
All students	132	100	212	100	344	100

At the time of the study, the university accepted students via a number of different pathways for entry to its courses. These included:

- school leavers with a Tertiary Entrance Ranking (TER) based on their performance in Year 12 subjects
- school leavers who did not meet the TER requirements but who had successfully completed a one semester University Preparation Course (UPC) conducted by the university
- mature age students who had successfully completed the Special Tertiary Admission Test (STAT)
- school leavers and mature age students who had used a direct entry pathway based on a portfolio application
- students who held Vocational Education and Training (VET) qualifications at Certificate IV or above

As a result, students were from a range of age groups and backgrounds. Information about entry pathways was not available for all students so this factor was not considered in the analysis in this study. However, as part of the course review, it has been useful to evaluate the relative success in this and other units for students using different entry pathways, and this has formed the basis of other research.

Table 3.7 shows the distribution of students across age groups. The overall mean age in 2006 was 22.2 years compared to 22.7 years in 2007. The distributions were similar for both years with the highest percentages of students in the younger age groups. Just over one third of students could be considered to be school leavers, i.e. were within approximately one year of the school leaving age for the end of year 12.

Table 3.7 Enrolments by Age Group

Age group	Number of students			
	2006		2007	
	n	%	n	%
18 and under	112	35.0	130	37.8
19-21	89	27.8	80	23.3
22-25	56	17.5	47	13.7
26-35	45	14.1	59	17.2
36-50	15	4.7	25	7.3
Over 50	1	0.3	1	0.3
Not available	2	0.6	2	0.6
All students	320	100	344	100

The Not Available category in Table 3.7 corresponds to a small number of students who completed the entry assessments in week one but withdrew from the course before the census date and hence had no records in the database. As a number of other students also withdrew from the unit, and in some cases the course, during the semester, all their data has been included in the discussion of issues related to the entry test. The size of the cohort decreased throughout the semester so exit test and comparative data will only include students who completed all tests. One of the students was in his early sixties when he enrolled in the unit and was therefore unlikely to be employed as a teacher once he graduated. He had a history of ongoing academic studies for much of his adult life and was enrolled on a part time basis. The other student in this age group was in her early fifties and she withdrew from the unit late in the semester but before completing the mathematics exit assessment. She then changed courses to another campus of the same university and enrolled in a BEd course which did not include a unit requiring the demonstration of specific literacy and numeracy standards.

Tables 3.8a and 3.8b show the comparison between the age distributions for students from the two courses. The proportion of students in the youngest age group was higher for ECS students but the differences in the overall distributions for the two courses were not statistically significant. The mean ages in 2006 were 22.4 years and 22.1 years for ECS and Primary students respectively. The corresponding figures for 2007 were 22.6 years and 22.7 years, i.e. there were only minimal differences between the two year groups.

Table 3.8a Enrolments by Age Group and by Course: 2006

Age group	Number of students					
	Early Childhood		Primary		Total	
	n	%	n	%	n	%
18 and under	48	39.7	64	32.2	112	35.0
19-21	27	22.3	62	31.2	89	27.8
22-25	18	14.9	38	19.1	56	17.5
26-35	20	16.5	25	12.6	45	14.1
36-50	6	5.0	9	4.5	15	4.7
Over 50	0	0.0	1	0.5	1	0.3
Not available	2	1.7	0	0.0	2	0.6
All students	121	100	199	100	320	100

Table 3.8b Enrolments by Age Group and by Course: 2007

Age group	Number of students					
	Early Childhood		Primary		Total	
	n	%	n	%	n	%
18 and under	55	41.7	75	35.4	130	37.8
19-21	29	22.0	51	24.1	80	23.3
22-25	15	11.4	32	15.1	47	13.7
26-35	19	14.4	40	18.9	59	17.2
36-50	13	9.8	12	5.7	25	7.3
Over 50	0	0.0	1	0.5	1	0.3
Not available	1	0.8	1	0.5	2	0.6
All students	132	100	212	100	344	100

Tables 3.9a and 3.9b show the distribution of students across the various age groups for males and females separately for 2006 and 2007. There were no significant differences between the distributions across the two years but there are gender differences in the age distributions within each year (χ^2 = 14.6, p=0.012 for 2006 and χ^2 = 17.4, p=0.004 for 2007).

Table 3.9a Enrolments by Age Group and by Gender: 2006

2006	Number of students					
	Female		Male		Total	
	n	%	n	%	n	%
18 and under	101	38.3	11	19.6	112	35.0
19-21	71	26.9	18	32.1	89	27.8
22-25	40	15.2	16	28.6	56	17.5
26-35	37	14.0	8	14.3	45	14.1
36-50	13	4.9	2	3.6	15	4.7
Over 50	0	0.0	1	1.8	1	0.3
Not available	2	0.8	0	0.0	2	0.6
All students	264	100	56	100	320	100

Table 3.9b Enrolments by Age Group and Gender: 2007

2007	Number of students					
	Female		Male		Total	
	n	%	n	%	n	%
18 and under	120	41.1	10	19.2	130	37.8
19-21	68	23.3	12	23.1	80	23.2
22-25	38	13.0	9	17.3	47	13.7
26-35	41	14.0	18	34.6	59	17.2
36-50	22	7.5	3	5.8	25	7.3
Over 50	1	0.3	0	0	1	0.2
Not available	2	0.6	0	0.0	2	0.6
All students	292	100	52	100	344	100

In 2006 the mean age of the female students was 22.0 years compared to 23.3 years for the males. The corresponding data for 2007 produced means of 22.3 and 24.9 respectively. The difference in means (as determined by Student's t test for independent samples) was marginally significant in 2007 ($t=-2.47$, $df=340$, $p=0.014$) but not in 2006 ($t=-1.46$, $df=316$, $p=0.146$). The distributions indicate that, while the largest percentage of females entering teacher education was in the 18 years and under age group, males tended to be older and in 2007 the largest percentage of males were aged between 26 and 35 years. The implications of this variation for this study are considered during the analysis of performance and confidence.

Anecdotal evidence from tutors indicated a perception that older students in general had lower skill levels in mathematics than other students and demonstrated lower confidence levels during conversations inside and outside the classroom. The extent to which this was confirmed by the data forms part of the analysis, as does an examination of the extent to which their skills and confidence did or did not improve and whether there were variations in any trends according to gender or course.

Other issues of research design and methodology

The opportunity to use the development and implementation of the unit as the basis for doctoral research was recognised early in the process, but the needs of the students and the university were of primary importance. The design of the unit, including the assessment tasks and the intervention strategies, was based on meeting the needs of the university and the students but also helped to provide a framework for the research design. As described in the previous sections, data collection was simply part of the administration of the unit. This was acknowledged by the university when granting ethics approval. This section looks at what was learned from the pilot year of the intervention program and summarises the data collection and analysis.

Pilot year

Becoming Multiliterate was conducted for the first time in 2005 with a cohort of 336 students. A number of issues arose during the initial implementation of the unit which led to changes being made in subsequent years. Students were allowed to continue to work towards achieving the benchmarks until the end of semester two and tutorials were conducted on a voluntary basis for those who still needed assistance. As only a handful of students made use of this opportunity, and their marks did not improve significantly with the extra time for study, the deadline for unit completion for 2006 and 2007 was moved back to the beginning of semester two. Marks recording was streamlined after trialling a number of approaches with greater use made of links between multiple worksheets in the same Excel workbook.

The assessment task was modified for 2006 onwards so that there was a more direct match between the outcomes and the questions. In 2005 there were 22 questions and in some cases one outcome was assessed over two questions while in others a single question addressed three outcomes. This made it difficult to give credit for successful achievement of an outcome and to identify specific weaknesses needing further practice and support which were identified as key elements of the intervention design.

Timetabling problems meant that in some time slots there were fewer than three concurrent classes so staff were required to teach outside their usual learning area. While most were happy to do this and were quite capable of covering the material with the resources provided, in 2006 onwards the timetable was structured to have three concurrent classes in all sessions. Three staff then worked in rotation with the same groups of students, one specialist for each of mathematics, writing and science. Overall the improvements made to the unit after the pilot year were relatively minor and the methodology from a research perspective was simply refined without being significantly changed.

Data sources

University records provided data such as age, gender and course enrolment for all students but much of the data needed for the research was collected during the routine management of the unit, including overall and individual question scores in the entry and exit assessments. Copies of completed tests were retained for analysis but students were given access to their previous work when planning their activities in week one of each module. These papers were kept in secure storage for the duration of the unit as students revisited them (under supervision) later in the semester when preparing for resit sessions. Once the unit was complete they were retained in secure storage as research data. Because student records needed to be linked from one task to the next, information could not be de-identified till after the unit was complete but this was done as soon as practical and the databases used for analysis listed codes rather than names.

Data collected for each student included:

- Information from university records:
    - Age (recorded as defined age groups).
    - Gender.
    - Year of studying the unit (2006 and/or 2007).
    - Course (primary or early childhood studies).
    - Whether the student was repeating the unit.
- Information from mathematics entry tasks:
    - Total performance score on mathematics entry task as a percentage.
    - Total confidence score on mathematics entry task as a percentage.

- Scores for individual questions in mathematics entry task.
    - Confidence scores for each individual question on entry.
- Information from mathematics exit tasks:
    - Highest total score achieved on mathematics exit tasks.
    - Number of attempts at mathematics assessment tasks.
    - Highest scores for individual questions in mathematics exit tasks.
- Information from confidence level questionnaires given to primary education students:
    - Total performance confidence score on exit from the unit as a percentage.
    - Total teaching confidence scores on exit from the unit as a percentage.
    - Performance confidence scores for each individual question on exit.

Data analysis

The data was entered into SPSS and, once complete, was de-identified. Analysis then included determination of summary statistics including measures of centre and spread and graphical display. Comparisons between year groups, genders and courses used Student's t test and Pearson correlation coefficients. Age group comparisons were investigated using analysis of variance.

One issue which arose and led to a variation in the planned analysis was that the 2006 and 2007 data could not be combined into a single data set. This was due to a number of factors. Firstly, the entry scores for the two year groups had significantly different distributions indicating that the students were starting from a different base point. This was confirmed using a Kolmogorov-Smirnov two sample test. Secondly, the benchmark for successful completion was changed from 70% in 2006 to 75% in 2007. The change was made because it was felt by staff that 70% was not a sufficiently high standard for students to cope well with the subsequent mathematics education units. Also, there were increasing indications that teaching graduates would be required to demonstrate that their personal literacy and numeracy skills were up to a required standard before they could be registered as teachers with the WA College of Teaching (WACOT) and the standards were likely to be higher than required for the *Becoming Multiliterate* unit. However, the higher standards meant that students exited the 2006 unit earlier, with lower scores than their 2007 peers, and exit scores were not comparable. Comparisons were therefore made between the year groups and within the year groups but the data sets were kept separate.

The design of the assessment tasks and resources to explicitly address the outcomes contributed to ensuring the tasks were valid instruments and the marking schemes for each task were detailed and specific to the level of half mark allocations. Because staff taught the module at least three times in the semester (most staff had several tutorial sessions each week) and marked parallel assessments each time, they became very familiar with the marking and this maintained consistency. In addition sample papers were cross marked by different staff as part of the unit moderation processes.

Item reliability was investigated for the entry assessment task although this was complicated by the fact that many students did not attempt all the questions. Cronbach’s alpha was 0.818 in 2006 and 0.876 in 2007. Split half analysis yielded values for the correlation between forms of 0.624 and 0.742 for 2006 and 2007 respectively. Guttman’s lambda 6 was 0.880 for 2006 and 0.915 for 2007 (this was used because it allowed for the fact that each question was assessing a different outcome with limited overlap between questions). All these measures indicate high levels of item reliability.

Conclusion

A number of synergies emerged when combining research design and data collection with the realities of conducting the unit which formed the intervention program. Meeting university requirements for course and unit design provided a clear framework in which to situate the program, and collecting detailed performance and confidence data for the research provided information for tutors to support and encourage the students to develop their self efficacy and competence. As a result all parties benefited from the exercise. The staff involved in the unit had ownership of the content and delivery and were therefore motivated to implement it effectively, the students received individual feedback and support to maximise their performance and as a researcher I was able to access the expertise of colleagues and experience a rare opportunity to combine the research and teaching aspects of my academic role.

Chapter 4

Results

The results in this chapter are organised according to the five research questions and cover student competence and confidence on entry to the course, including areas of strength and weakness, competence and confidence after participation in the program, and variations in the above by course enrolment, gender and age. Results are mainly presented in the form of tables. Appropriate tests of significance have been used and relevant test values are quoted together with their level of significance. A more detailed discussion of the results and their implications against the research questions is considered in the next chapter.

Mathematical competence levels of pre-service teachers

The level of mathematical competence demonstrated by the pre-service teachers on entry to the university was measured in several ways. Their overall score in the first mathematics test was calculated and class level measures of central tendency and spread were determined. A second issue was their ability to complete the test in the allotted time as this was a potential indication of fluency, so data was collected on the number of questions they actually attempted, regardless of score.

Mathematical competence based on overall mathematics entry test score

Students completed an entry assessment test in mathematics as part of the first week's tutorial. There were twenty questions based on defined outcomes and students had been informed about these outcomes and the assessment requirements at orientation and via the university online student interface which used the Blackboard environment. They were allowed 55 minutes to complete the test and no calculators were allowed. Total scores for the paper were converted to percentages and scores for individual questions were also recorded so students could be credited with the skills they could already demonstrate.

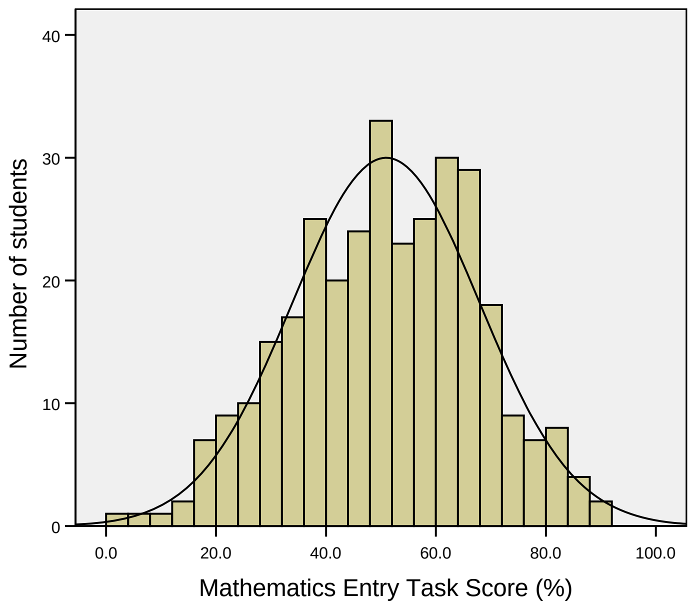


Figure 4.1a. *Mathematics entry test scores 2006*

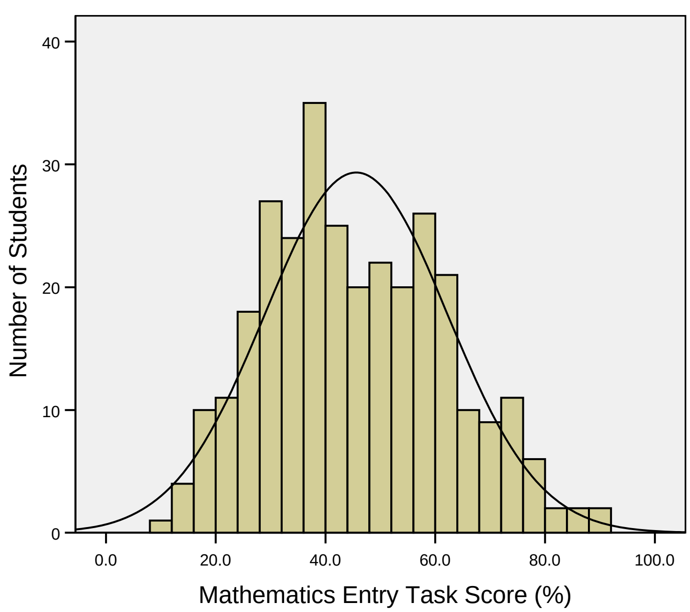


Figure 4.1b. *Mathematics entry test scores 2007*

Table 4.1 shows some summary statistics for the mathematics entry assessment tests from 2006 and 2007 and Figures 4.1a and 4.1b show the distributions of scores as histograms. As discussed in Chapter 3, there was a significant difference between the means for 2006 and 2007 and the entry scores for the two year groups had significantly different distributions indicating that the students were starting from a different base point. When considered together with the change in the benchmark from 70% to 75%, a decision was made to treat the data from the two years separately in subsequent analysis.

Table 4.1. *Summary Statistics for Mathematics Entry Assessment Tests by Year*

	2006	2007
Number of students completing entry test	320	306
Mean percentage score	50.9	45.6
Standard deviation	17.0	16.6
Minimum percentage score	3.1	10.0
Maximum percentage score	91.9	90.9
Lower quartile	38.1	33.0
Median	51.2	43.8
Upper quartile	63.8	57.7

Visual comparisons of the distributions with the normal curve indicate a reasonable fit and this is confirmed by the Kolmogorov-Smirnov (K-S) test where the skewness and kurtosis of the distributions cannot be concluded to be different to those of a normal distribution (Z = .839 in 2006 and 1.230 in 2007; scores less than 2 support this conclusion). This enables statistical tests which rely on the assumed normality of a distribution to be used with some confidence.

Students who failed the unit were required to repeat the following year if they wished to continue in the course. Hence the 2007 classes included a number of students who had previously attempted the unit in 2006. They were not permitted to carry forward their marks from 2006 and hence started the unit from scratch. It might be expected that they would have performed relatively well in the entry test as they had prior knowledge of the structure of the paper and the type of questions for each outcome. The results for this group compared to those for newly enrolled students are shown in Table 4.2. Contrary to expectations, their mean scores are significantly lower than those of students attempting the test for the first time (t = 2.03, df = 304, p = .043).

Table 4.2. Mathematics Entry Test Scores out of 100: Comparison of first enrolment and repeating students for 2007

Status	n	%	Mean	Standard deviation
First enrolment in unit	287	93.8	46.1	16.8
Repeating unit	19	6.2	38.1	14.7
All students	306	100	45.6	16.6

Performance based on entry test completion

One factor which impacted on student performance in the entry test was the time they took to answer the questions. In developing the assessment test it was acknowledged that the time allowed would not be sufficient for many of the students to attempt all the questions but it was agreed that if the students were competent they would be able to achieve the 75% benchmark even if they did not manage to answer every question. As a result, competence was defined in a way that included knowledge of content and speed of recall and test completion. The rationale for this included the recognition that teachers in front of a class have to be able to answer queries from children quickly and accurately.

Table 4.3 shows the overall performance of students in terms of the number of questions attempted. Students were considered to have attempted a question if they had written anything in the space provided for their answer, or if they had indicated their level of confidence with their ability to answer the question correctly, as this implied they had read the question and at least thought about how to answer it. In recording scores for the entry test, questions which had not been attempted were left blank in the database, whereas questions which had been attempted but earned no marks were recorded as a zero score. This allowed for some differentiation between students who had run out of time and those who did not have the required knowledge or skill. Although performance scores were significantly different for 2006 and 2007, the number of questions attempted was almost the same across the two years. In both years at least 75% of the students answered 15 or more questions and at least 60 students in each year attempted all 20 questions, approximately 20% of those sitting the test. This indicates that, while time was a factor in success, 55 minutes was not an unreasonable time allowance. One of the Proficiency strands in the Australian Curriculum: Mathematics is Fluency which is described as follows:

> Students develop skills in choosing appropriate procedures, carrying

> out procedures flexibly, accurately, efficiently and appropriately, and recalling factual knowledge and concepts readily. Students are fluent when they calculate answers efficiently, when they recognise robust ways of answering questions, when they choose appropriate methods and approximations, when they recall definitions and regularly use facts, and when they can manipulate expressions and equations to find solutions (Australian Curriculum Assessment and Reporting Authority, 2011, p 3).

In demonstrating that they could answer the questions correctly in a time frame which was apparently quite short for most of them, students were encouraged to develop improved fluency and hence serve as appropriate models in their future classrooms.

Table 4.3 Summary Statistics for Number of Questions (out of 20) answered in Mathematics Entry Test by Year

	2006	2007
Number of students completing entry test	320	306
Number of questions attempted:		
Mean	16.9	16.8
Median	17	17
Standard Deviation	2.6	2.8
Minimum	4	0
Maximum	20	20
Lower quartile	15	15
Upper quartile	19	19

The data presented in this section indicates that concerns about low levels of mathematical literacy amongst pre-service teachers are well founded, at least for these two groups of students. Not only were the scores on upper primary mathematics content less than 50% for many of the students, 80% of them could not complete the task in the allotted time.

Student confidence levels at start of unit

In order to ensure that the intervention program did not have a deleterious effect on student confidence a base level was required for comparison. For each question students answered in the entry test, they also indicated the extent to which they were confident that their answer was correct according to the following Likert scale.

1 Not at all confident

2 A little confident

3 Reasonably confident

4 Very confident

Hence lower scores indicated lower levels of confidence. Scores for each question were added to give a score out of 80 which was then converted to a percentage. As the confidence level data was based on the students' perceptions of how correct their answers were, the percentage score was calculated from the number of questions to which they had responded. For example if a student had a total confidence score of 40 but had only answered 15 questions their percentage score was recorded as 66.7 (40 out of a possible total of 60 converted to a percentage). Table 4.4 shows some of the summary statistics for the total confidence score for 2006 and 2007.

Table 4.4 Summary Statistics for Self Reported Student Confidence Levels in Mathematics Entry Assessment Tests by Year

	2006	2007
Number of students completing confidence level ratings	222	296
Mean percentage confidence total	71.5	65.3
Standard deviation	17.1	16.4
Minimum percentage score	25	25
Maximum percentage score	100	100
Lower quartile	60.3	54.2
Median	73.5	66.5
Upper quartile	84.3	76.8

As with the entry test performance scores, there was a significant difference between the two year groups in mean confidence levels (independent samples *t*-test, $t = 4.178$, $df = 516$, $p < .001$). The 2006 cohort not only performed better than their 2007 counterparts, they were more confident about their ability to answer the questions correctly.

Relationship between performance and confidence in entry test

With similar trends in the data for performance and confidence levels becoming evident over the two year groups, the data was analysed to look for relationships between the actual ability of students to answer the questions in the mathematics entry test and their confidence in their ability to do so.

Although total entry score and overall confidence level scores use different scales, they correlate significantly in both 2006 and 2007 across all students (Table 4.5). In general students with high competence levels were also highly confident and vice versa. However, the scores indicate that while students rated themselves as "reasonably confident" about the correctness of their work, they still performed poorly in actually answering the questions.

Table 4.5 Relationship Between Mathematics Entry Test Performance and Confidence Levels for 2006 and 2007

	n		Mean score (%)		Pearson correlation	
	2006	2007	2006	2007	2006	2007
Entry test performance score	222	296	52.5	46.0	.50 [a]	.40 [a]
Entry test confidence score			71.5	65.4		

[a] Correlation coefficients significant at $p < .001$

Unfortunately, a number of students did not record their confidence levels and supervising staff did not always pick this up when the tests were collected. The total number of students in Tables 4.4 and 4.5 is therefore less than the number who completed the entry tests in each year. There was potential for this incomplete data to skew the results; for example weaker students may have had less time to consider confidence ratings or may have been stressed by the test completion and missed a number of responses. To investigate this, the mean performance scores for students who had recorded confidence levels were compared with those who had not noted their confidence levels for each year. In 2006 almost a third of the students did not record their confidence and their mean test score was 47.4% compared to 52.5% for the rest of the students. The difference is significant (t = 2.48, df = 317, p = .014) and this seems to support the concern. However, in 2007 only 5.5% of the students who sat the entry test failed to record their confidence levels, so although their mean was 39.9% compared to 45.9% for the rest of the students, the difference for that year is not significant (t = 1.464, df = 304, p = .144).

The data indicates that students had reasonably high levels of confidence in their mathematical ability which may be unfounded given their relatively low test scores. In addressing student needs in the intervention modules which followed the entry tests, staff needed to be careful to help students become more realistic about their skills without causing them to lose all their confidence. This is where the Commend, Recommend, Commend (CRC) approach was of particular importance.

Areas of strength and weakness in mathematical competence and confidence

During the course of the unit, entry results were collated for each question so that scores for individual questions could be provided to students for diagnostic and study purposes. In addition, class results for each question helped staff to identify content aspects needing particular support and intervention. However, for the purposes of this study, questions were grouped according to their curriculum strand to identify variations in performance and confidence across questions related to similar topics. This analysis was designed to answer the third research question about identifying broader areas of strength and weakness rather than focussing on specific skills related to single questions.

Performance across different strands in entry test

The data was analysed according to the strands used in the Western Australian Curriculum documents (Number, Measurement, Space, Chance and Data and Algebra) as the outcomes to be achieved had already been labelled against these areas (see Table 3.2). To avoid confusion in question 14, the majority of the marks were for interpreting a map rather than for measuring line segments so this was classified as a Space outcome for the purposes of analysis. The total mark for the questions in each strand was converted to a percentage to enable comparisons to be made. Table 4.6 compares student performance in each strand for 2006 and 2007 based on the mean scores together with the *t* and p values for an independent samples t test.

Table 4.6 Entry Test Scores (out of 100) for each Strand: 2006 and 2007

	Number		Measurement		Chance and Data		Space		Algebra	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
Mean	67.7	63.5	44.2	34.8	57.1	48.5	47.6	42.2	31.0	31.6
Standard deviation	19.3	19.7	20.7	20.9	29.6	29.7	22.7	20.8	40.0	27.6
t value	2.68		5.66		3.63		3.10		-0.25	
p value	.007		< .001		< .001		.002		.806	

The high values for the standard deviation indicate the wide variation in the scores within a given strand. The *t* test results indicate that the scores were significantly higher in 2006 than in 2007 (p < .01) for all strands, except Algebra where the scores were almost the same in both years.

A comparison of scores for each student across the different strands, using a *t* test for paired samples, provides evidence of significant differences in performance as shown in the Tables 4.7 and 4.8.

Table 4.7 Entry Test Scores Cross Strand Comparison: 2006 and 2007: t and p Values from Independent Samples t test.

	Measurement	Chance & Data	Space	Algebra
Number	t = 24.1 p < .001	t = 7.78 p < .001	t = 15.2 p < .001	t = 19.5 P < .001
Measurement	-	t=-8.94 p<.001	t = -2.74 p = .006	t = 6.94 p < .001
Chance & Data	-	-	t = 5.82 p < .001	t = 12.0 p <. 001
Space	-	-	-	t = 10.3 p < .001

Table 4.8 Strands Ranked by Mean Score: Comparison for 2006 and 2007

Strand	Mean [a]	
	2006	2007
Number	67.7	63.5
Chance and Data	57.1	48.5
Space	47.6	42.2
Measurement	44.2	34.8
Algebra	31.0	31.6

[a] Means for 2006 and 2007 are significantly different for all strands ($p < .001$).

The ranking of the strands according to the mean scores is the same for both years so students consistently performed best in questions related to Number topics and worst in questions related to Algebra.

Confidence across different strands in entry test

The confidence data was analysed for each strand to determine whether there were differences in confidence for particular areas of mathematics. The results of this are shown in Table 4.9. The higher levels of confidence evident in the overall scores of 2006 students compared to 2007 are consistent across all the strands with Measurement showing the lowest scores in both years. Confidence was highest in the questions related to the Number strand although Algebra scores were also high, unlike the actual performance results.

Table 4.9 Mean Entry Self-reported Confidence Scores (out of 100) for each Strand: 2006 and 2007

	Number		Measurement		Chance and Data		Space		Algebra	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
Mean score	74.1	68.6	68.2	63.4	72.8	63.4	70.5	63.9	73.6	67.3
Standard deviation	17.8	17.6	18.9	23.0	22.2	23.0	19.9	19.7	25.2	20.4
t value	3.48		2.49		4.45		3.60		2.41	
p value	.001		.013		< .001		< .001		.017	

The disparity between confidence and competence scores in Algebra is of note. Students performed worst in these questions but their confidence ranks close to Number and above the other strands where they performed better.

Effectiveness of the intervention

This section addresses the question of how effective the unit was in addressing student levels of competence and confidence. Results in the exit tests are examined as well as self-reported confidence levels at the start of the following semester. Relationships between competence and confidence are investigated and entry and exit levels compared.

Performance based on highest achieved score in exit tests

At the end of the three week mathematics module students sat an exit assessment test made up of parallel items to the entry test, with further opportunities to meet the benchmarks available at the end of semester one and in semester two using similar parallel tests. In some cases only the numbers or shapes in the questions were changed, in others the same mathematics was embedded in a different context. Students were only required to answer those questions for which they had not scored at least three quarters of the available marks in the entry tests or previous attempts at the exit test.

Because most students had multiple attempts to meet the 75% benchmark for the overall assessment test score, record keeping had to be detailed. The results presented in this section are based on the highest score achieved by each student, regardless of the number of attempts. Students who withdrew from the course after only completing the entry assessment have been excluded.

As can be seen in Table 4.10, the differences between the year groups in the exit scores are not significant (t = 1.564, df = 565, p = .118) even though the 2007 cohort had weaker results on entry. One factor impacting on this was that students in 2006 only had to achieve 70% to meet the benchmark whereas in 2007 the required score was 75%. In 2006, students exited the module with scores between 70 and 75, whereas in 2007 they continued and improved their scores on further attempts. There was a greater degree of spread in the 2007 scores compared to 2006 as indicated by the standard deviation and the range.

Table 4.10 Summary Statistics for Highest Achieved Exit Scores in Mathematics Assessment Tests by Year

		2006	2007
Number of students completing at least one test		279	288
Mean percentage score		78.4	76.9
Standard deviation		9.78	12.8
Minimum percentage score		26.9	16.3
Maximum percentage score		95.6	97.5
Quartiles	25	73.1	75.0
	50	79.4	79.1
	75	85.0	84.4

Although repeating students in 2007 performed less well in the entry assessment than those who were attempting the unit for the first time, it was hoped that the extra experience and intervention time would enable them to achieve success. Table 4.11 compares the exit test performance of first enrolment and repeating students in 2007. The difference between the mean scores for the two groups is significant ($t = 4.09$, $df = 286$, $p < .001$) with first enrolment students continuing to perform better than their repeating peers.

Table 4.11 Mean Exit Scores in Mathematics Tests: Comparison of First Enrolment and Repeating Students for 2007

Status	n	%	Mean exit score (%)	Standard deviation
First enrolment in unit	270	93.8	77.7	12.0
Repeating unit	18	6.2	65.2	18.6
All students	288	100	76.9	12.8

Performance based on number of attempts to pass tests

Although the final exit test scores have been used to generate the performance data discussed so far, of additional interest was the number of attempts the students had taken to achieve these “best” scores. Table 4.12 shows the distribution of the number of times students attempted to pass the mathematics tests. It should be noted that not all students were successful even after multiple attempts and the number who had only one attempt includes those who passed on entry as well as those who missed the entry test but passed the first time they tried the exit test. Also included in the distribution are those students who did not withdraw from the unit but failed to attend for subsequent tests despite not meeting the benchmark at their first attempt.

Approximately twice as many students had three or four attempts in 2007 compared to 2006, again reflecting the weaker performance of this year group.

Table 4.12 Number of Times Students Attempted to Meet Benchmark by Year

Number of attempts	Number of students			
	2006 [a]		2007[a]	
	n	%	n	%
1	78	24.4	59	17.2
2	189	59.1	147	42.7
3	35	10.9	82	23.8
4	17	5.3	27	7.8
5	1	0.3		
All students	320	100	315	100

[a] This is the number of attempts in the given year and does not include attempts in previous years for repeating students

As well as examining the number of attempts per se, the data was analysed according to how many students were successful after each attempt and the results of this analysis are shown in Tables 4.13a and 4.13b. The students listed as withdrawing from the unit did so after failing to meet the benchmark, so in total 70 students failed the mathematics module in 2006 and 94 in 2007. Based on this data, 78% of students who attempted the mathematics tests in 2006, eventually passed by the end of semester, compared to 70% in 2007. In 2006, 11.6% passed at their first attempt, compared to 5.7% in 2007. As the pass mark was increased in 2007, and the 2007 cohort were weaker on entry to the unit, the two years are showing similar trends.

Table 4.13a Outcome for each Test Attempt: 2006

2006	Withdrew from unit	Did not meet benchmark	Met benchmark	Total
1 attempt	31	10	37	78
2 attempts	3	9	177	189
3 attempts	-	8	28	36
4 attempts	-	8	8	16
5 attempts	-	1	-	-
Total	34	36	250	320

Table 4.13b Outcome for each Test Attempt: 2007

2007	Withdrew from unit	Did not meet benchmark	Met benchmark	Total
1 attempt	30	11	18	59
2 attempts	2	16	129	147
3 attempts	-	20	62	82
4 attempts	-	15	12	27
Total	32	62	221	315

Performance across different strands in exit test

Student performance in the exit tests was analysed for each strand with a view to identifying whether the trends in overall improvement were reflected consistently across different areas. Table 4.14 shows the strand means for the total enrolment in each year.

Table 4.14 Highest Achieved Scores in Mathematics Tests: Comparison for Each Strand for 2006 and 2007

	Number		Measurement		Chance and Data		Space		Algebra	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
Mean score	78.8	83.9	62.3	67.9	72.4	77.5	69.1	72.5	66.4	79.1
Standard deviation	17.1	12.9	21.2	19.6	25.7	21.7	21.3	16.0	31.0	22.1
t score	-4.16		-3.35		-2.66		-2.22		-5.77	
p value	< .001		.001		.008		.027		< .001	

It would seem that, with few exceptions, the trends in the overall performance are mirrored within individual strands. The improvements are therefore across the board, not limited to one area of mathematics, with differences (of varying significance) in favour of the 2007 cohort in all strands. When the overall mean scores for each strand are ranked, Number is still the area with best results, but Algebra is no longer the weakest area. In 2006 it was third, after Number and Chance and Data, but was second only to Number in 2007. Measurement was the weakest area in both years.

Student confidence levels at end of unit

Because students did not answer all the questions in the exit assessments, complete data on confidence levels could not be collected during the assessment tests. Instead, Primary students were surveyed at the start of the following semester when they were taking the first of two mathematics methods units. They provided feedback on how confident they felt about being able to answer each question following the unit (Performance Confidence) and, in addition, how confident they felt about being able to teach the skills and concepts exemplified by each question (Teaching Confidence). It was not possible to carry this out for the Early Childhood Students as they did not have their mathematics methods unit till the following year and the time lag was too great for comparisons with their primary peers. Table 4.15 shows the summary statistics of the total scores for exit confidence for 2006 and 2007. Students in 2006 were significantly more confident than their counterparts in 2007 about both their ability to correctly answer the questions ($t = 4.28$, $df = 224$, $p < .001$) and their ability to teach the content ($t = 1.72$, $df = 222$, $p = .087$). In both years their overall performance confidence was greater than their teaching confidence ($t = 10.6$, $df = 119$, $p < .001$ in 2006; $t = 8.67$, $df = 103$, $p < .001$ in 2007). There was a greater degree of spread (higher standard deviation and range) in the teaching confidence scores. It would seem that the students recognised that there was more to teaching or explaining mathematics than just having the skills and knowledge to do it yourself. However, for the remainder of this section, only the performance confidence scores will be considered as these were the primary focus of the design of the intervention unit.

Table 4.15 Summary Statistics for Student Confidence Levels on Exit from Unit by Year

		Performance confidence		Teaching confidence	
		2006	2007	2006	2007
Number of students completing confidence level ratings		121	105	120	104
Mean percentage confidence		85.1	79.2	74.2	71.4
Standard deviation		9.80	11.0	12.7	11.8
Minimum percentage score		41.3	40.0	38.8	30.0
Maximum percentage score		100	100	100	96.3
Quartiles	25	80.0	72.5	66.6	64.1
	50	87.5	80.0	75.0	72.5
	75	91.3	88.1	83.8	79.7

The confidence levels of students who had different numbers of attempts to meet the required benchmark were also analysed (Table 4.16) and, as might be expected, those who took more attempts had lower levels of confidence.

Table 4.16 Student Performance Confidence on Exit from Unit: Comparison by Number of Attempts to Meet Benchmark for 2006 and 2007

Number of Attempts	Number of students		Mean confidence level (%)		Standard deviation (%)	
	2006	2007	2006	2007	2006	2007
1	17	7	91.3	88.5	7.28	4.89
2	82	56	85.7	81.8	9.72	9.08
3	15	32	78.8	73.5	8.93	12.3
4	6	10	77.6	76.6	5.62	10.7
All students	120	105	85.2	79.2	9.78	11.0

Applying ANOVA to the data indicates that there is a relationship between the number of attempts the student has to meet the benchmark and their confidence in their ability to answer the questions at the end of the unit ($F(3,116) = 6.41$, p < .001 in 2006; $F(3,101) = 6.83$, $p < .001$ in 2007) i.e. the students who took more attempts to pass reported lower performance confidence levels.

When performance confidence data is analysed for the different strands, 2006 students were more confident about their performance than their 2007 peers across all strands (Table 4.17). As they were more confident at the start of the unit, this is to be expected.

Table 4.17 Student Performance Confidence on Exit from Unit: Comparison for Each Strand for 2006 and 2007

	Number		Measurement		Chance and Data		Space		Algebra	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
All students	86.0	82.7	82.0	75.8	89.6	82.2	84.7	76.5	84.9	79.7
t score	2.14		4.03		3.77		4.43		2.58	
p value	.033		< .001		< .001		< .001		.011	

Only two students who completed the confidence survey had repeated the unit so comparisons between first time enrollees and repeaters were not possible.

Relationship between performance and confidence on exit from the unit

As the links between competence and confidence were a major focus of this study, the exit data was analysed to test relationships among exit test performance and performance confidence. The results for overall scores are shown in Table 4.18.

There are significant correlations between actual performance and performance confidence for both year groups. That is, students who performed well on the exit test had high levels of performance confidence and vice versa. However the values of the correlation coefficient are lower than they were on entry to the unit (Table 4.5) so there has been some disruption to the relationship during the course of the unit.

Table 4.18 Relationships between Mathematics Exit Test Performance and Confidence Levels for 2006 and 2007(Primary students only)

	n		Mean score (%)		Pearson correlation	
	2006	2007	2006	2007	2006	2007
Exit test score	119	105	79.0	79.8	0.23[b]	0.37[a]
Exit performance confidence			85.2	79.2		

[a] Correlation coefficient significant for $p < .001$
[b] Correlation coefficient significant at $p = .013$

Comparison of entry and exit data

Table 4.19 shows the overall "before and after" scores for competence and confidence for both years of the study. The means are based on paired data so only students who had results on both entry and exit from the unit have been included. It should be noted that the design of the tests was such that all students had to improve their scores, but the magnitude of the improvement in competence is substantial.

Table 4.19 Comparison of Entry and Exit Competence and Confidence: Mean Scores 2006 and 2007

	2006			2007		
	Entry mean	Exit mean	n	Entry mean	Exit mean	n
Competence (test score)	51.7	78.4	279	46.4	77.1	278
Mean performance confidence	72.1	85.3	99	66.1	79.3	100

Scores in the entry and exit tests are highly correlated ($r = .53$, $p < .001$ in 2006 and $r = .51$, $p < .001$ in 2007). Similarly, confidence scores at the beginning and end of the unit are significantly correlated with $r = .56$ ($p < .001$) in 2006 and $r = .47$ ($p < .001$) in 2007.

The differences in the entry and exit means for competence and confidence were analysed using a *t* test on results paired by individual students (Table 4.20). Negative scores indicate exit results were significantly higher than entry results

Table 4.20 Comparison of Entry and Exit Competence and Confidence: t Values 2006 and 2007

	2006			2007		
	t value	df	*p* value	*t* value	df	*p* value
Pre- and post-competence	-30.4	278	< .001	-33.5	277	< .001
Pre- and post-confidence	-9.40	98	< .001	-8.45	99	< .001

In summary, the data indicates that while student competence and confidence improved significantly during the unit, those with low levels of skill and confidence on entry were still performing less successfully than their peers and had less confidence in their ability to perform the required mathematical tasks. On the other hand, those who were initially more confident continued to maintain or even improve their positive attitude.

Comparisons across course, gender and age groups

So far the data has been analysed with a view to answering the research questions for the total student cohort. The following sections report the analysis of the comparison of performance and confidence levels for various subgroups of students. For example, were ECS students weaker at mathematics than their primary course peers? Did males outperform females or have higher confidence levels? Given tutor comments about the neediness of mature age students, were there real differences in their performance and confidence levels relative to the recent school leavers? There are three aspects to the analysis based on course, gender and age comparisons.

Course comparison

The students in the unit were enrolled in two different courses, BEd (Primary) and BEd (Early Childhood Studies (ECS)) and anecdotal comments indicated that course choice had in some cases been predicated on the mathematics expectations. It was therefore considered important to analyse the data by course enrolment to identify whether the two cohorts were inherently different in their performance and confidence levels and whether the intervention was equally effective with both groups.

Entry test performance

The entry test mean scores were compared by course for each of the two years and the results are shown in Table 4.21. The differences between the mean scores for the students in the two courses were significant for both years (t = -3.13, df = 318, p = .002 for 2006 and t = -4.28, df = 304, p < .001 for 2007) with the primary degree students performing better overall than the ECS students. There was a greater variation in the ECS scores in 2006, as evidenced by the standard deviations, but this difference between the cohorts was reduced in 2007.

Table 4.21 Mathematics Entry Test Scores out of 100: Course Comparison for 2006 and 2007

Course	Mean		Standard deviation	
	2006	2007	2006	2007
Early Childhood	47.2	40.6	18.2	16.4
Primary	53.2	48.7	15.9	16.0
All students	50.9	45.6	17.0	16.6

Table 4.22 shows the comparison between the course groups based on the number of questions they attempted in the entry test and Table 4.23 compares their performances in the different strands.

Table 4.22 Mean Number of Questions Attempted in Mathematics Entry Test: Course Comparison for 2006 and 2007

Course	Mean Number of questions attempted (out of 20)	
	2006	2007
Early Childhood	16.8	16.8
Primary	17.0	16.9
All students	16.9	16.8

The minimal differences between the scores indicate that the rate at which students were able to attempt the questions was relatively independent of their course choice. While their overall performance scores were different, the students completed the questions at similar rates.

In Number, Measurement and Chance and Data, the Primary students significantly outperformed the ECS students ($p < .005$) (Table 4.23). The same was true for the Space strand but for larger p values of .09 and .08. However, the differences in means for the Algebra strand were not significant. Curiously, ECS students performed slightly better in Algebra than those enrolled in primary education in 2006 but not in 2007.

Table 4.23 Mean Entry Test Scores (out of 100) for each Strand: Course Comparison for 2006 and 2007

Course	Number		Measurement		Chance and Data		Space		Algebra	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
Early Childhood	63.6	57.4	38.3	27.5	50.7	40.6	44.8	39.5	32.6	30.1
Primary	70.2	67.3	47.8	39.4	61.0	53.4	49.3	43.8	30.1	32.6
t value	-2.99	-4.41	-4.04	-5.02	-3.04	-3.76	-1.72	-1.77	0.72	-0.75
p value	.003	< .001	< .001	< .001	.003	< .001	.086	.077	.471	.453
All students	67.7	63.5	44.2	34.8	57.1	48.5	47.6	42.2	31.0	31.6

Entry confidence levels

The confidence that students had in their ability to correctly answer the questions also varied across the courses, as shown in Table 4.24.

Table 4.24 Student Confidence Levels in Mathematics Entry Test Scores: Course Comparison for 2006 and 2007

Course	Number of students		Mean confidence level (%)		Standard deviation (%)	
	2006	2007	2006	2007	2006	2007
Early Childhood	63	114	65.8	61.8	15.2	17.2
Primary	159	182	73.8	67.5	17.3	15.5
All students	222	296	71.5	65.3	17.1	16.4

The differences between the two course groups are significant in both years (t = -3.22, df = 220, p = .001 in 2006; t = -2.98, df = 294, p = .003 in 2007). Primary students showed higher levels of confidence in their ability to correctly answer the questions in the entry assessment test than their ECS peers. When the responses in each strand are considered, ECS students were less confident than the primary students in all areas in both years (Table 4.25). The differences in Number, Measurement and Chance and Data were significant (p < .10) but not in Space (2007) and Algebra. This is consistent with the performance data where Algebra scores were similar for both groups.

Table 4.25 Mean Entry Confidence Scores (out of 100) for each Strand: Course Comparison for 2006 and 2007

Course	Number		Measurement		Chance and Data		Space		Algebra	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
Early Childhood	68.3	6.39	61.7	57.7	68.4	57.7	63.8	61.6	73.3	65.2
Primary	76.4	71.5	70.8	66.8	74.3	66.8	72.9	65.3	73.6	68.7
t value	-3.10	-3.67	-3.23	-3.21	-1.66	-3.21	-2.84	-1.54	-0.07	-1.20
p value	.002	.000	.001	.001	.099	.001	.005	.126	.944	.232
All students	74.1	68.6	68.2	63.4	72.8	63.4	70.5	63.9	73.6	67.3

Exit performance

Students from both courses were provided with the same resources and teaching and learning experiences during the three week mathematics module and had ongoing access to Mathletics during the rest of the semester if they needed to complete resit assessments. Due to timetabling requirements, the ECS students were enrolled in tutorials on one day and primary students in tutorials in the rest of the week and different tutors took each cohort. It was therefore important to examine whether there were variations in the effectiveness of the intervention, and if so to try to identify reasons for them. Table 4.26 shows the comparison between the cohorts in terms of the highest achieved score, regardless of number of attempts.

Table 4.26 Highest Achieved Scores in Mathematics Tests: Course Comparison for 2006 and 2007

Course	Mean exit test score (%)		Standard Deviation Score (%)	
	2006	2007	2006	2007
Early Childhood	77.2	76.5	9.37	14.4
Primary	79.2	77.2	9.96	11.7
All students	78.4	76.9	9.78	12.8

The differences in exit test scores between the students enrolled in the two degree courses were marginally significant in 2006 (t = -1.68, p = .095) but not significant in 2007. Table 4.27 shows the results for performance measured by number of attempts to pass the tests. There was no significant difference between the course cohorts in either year in terms of the mean number of attempts at the assessment tests.

Table 4.27 Number of Times Students Attempted to Meet Benchmark: Course Comparison for 2006 and 2007

Course	Mean number of attempts		Standard Deviation	
	2006	2007	2006	2007
Early Childhood	2.21	2.30	0.714	0.872
Primary	2.01	2.21	0.662	0.847
All students	2.08	2.24	0.688	0.856

Table 4.28 shows the comparison of exit performance across strands and, with the exception of Algebra in both years and Space in 2007, ECS students were generally weaker than their primary peers. However, the differences are only significant in Number in 2006.

Table 4.28 Highest Achieved Scores in Mathematics Tests: Comparison by Course for Each Strand for 2006 and 2007

Gender	Number		Measurement		Chance and Data		Space		Algebra	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
Early Childhood	79.1	83.3	62.4	66.2	74.2	75.5	71.2	72.9	75.6	80.8
Primary	83.0	84.3	66.2	68.9	78.0	78.7	73.1	72.2	72.2	78.0
t value	-2.34	-0.64	-1.70	-1.12	-1.46	-1.23	-0.89	-0.39	1.08	1.08
p value	.020	.526	.090	.263	.145	.219	.376	.698	.279	.283
All students	81.6	83.9	64.7	67.9	76.6	77.5	72.4	72.5	73.5	79.1

Comparison of entry and exit performance

ECS students did not complete the exit confidence survey so it is only possible to compare before and after performance. The data in Table 4.29 supports the premise that the intervention has been of benefit to both cohorts of students in terms of their performance in the entry and exit tasks with the ECS students demonstrating a greater absolute improvement in both years.

Table 4.29 Comparison of Test Scores by Course: 2006 and 2007

	2006				2007			
	ECS		Primary		ECS		Primary	
	Entry mean	Exit mean	Entry mean	Exit mean	Entry mean	Exit mean	Entry mean	Exit mean
Test score	47.2	77.2	53.2	79.2	40.6	76.5	48.7	77.2

In summary, on entry to the course ECS students had lower test scores than their Primary peers and were generally less confident about their mathematical ability. However, by the end of the *Becoming Multiliterate* unit, the exit test scores were much closer and ECS students therefore showed greater improvement. With no data available on exit confidence levels for these students it is not possible to say whether there were corresponding increases in confidence.

Gender comparisons

The overall representation of males in primary education is relatively low and in early childhood settings is even smaller. This was also true of the cohorts involved in this study. On the other hand, stereotyped perceptions usually associate males with higher performance in mathematics so an analysis of the data was carried out to identify the extent to which this applied to these students.

Entry test performance

The entry test mean scores were compared for males and females for the two years of the study and the results are shown in Table 4.30.

Table 4.30 Mathematics Entry Test Scores out of 100: Gender Comparison for 2006 and 2007

Gender	N		Mean		Standard Deviation	
	2006	2007	2006	2007	2006	2007
Female	264	292	49.0	43.6	17.2	16.0
Male	56	52	59.9	57.6	13.2	15.6
All students	320	344	50.9	45.6	17.0	16.6

The differences between the means for male and female students were significant for both years (t = -4.44, df = 317, p < .001 in 2006; t = -5.33, df = 304, p < .001 in 2007) with males outperforming females overall. The variation in scores was greater for females and their minimum scores were 3% and 10% in 2006 and 2007 respectively compared to 36% and 22% for males. Maximum scores for both groups were above 86% in both years. The disparate size of the two groups needs to be considered when making gender comparisons, with females outnumbering males by almost 5:1 in 2006 and 6:1 in 2007. As a result the overall average is heavily weighted towards the lower performance levels of the female students. However, as can be seen in Table 4.31, male students did not answer significantly more questions than their female counterparts. It would seem that their better performance was based on answering those questions they did attempt more effectively that the female students did.

Table 4.31 Mean Number of Questions Attempted in Mathematics Entry Test: Gender Comparison for 2006 and 2007

Gender	Mean Number of questions attempted (out of 20)	
	2006	2007
Female	16.9	16.7
Male	17.3	17.4
All students	16.9	16.8

Table 4.32 Mean Entry Test Scores (out of 100) for each Strand: Gender Comparison for 2006 and 2007

Gender	Number		Measurement		Chance and Data		Space		Algebra	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
Female	65.6	61.1	42.0	32.2	55.2	45.6	45.6	40.7	30.4	31.2
Male	77.3	78.3	54.7	50.3	66.1	66.3	56.9	51.3	33.9	33.9
t value	-4.21	-5.59	-4.30	-5.50	-2.54	-4.36	-3.44	-3.15	-0.76	-0.59
p value	< .001	< .001	< .001	< .001	.012	< .001	.001	.002	.449	.556
All students	67.7	63.5	44.2	34.8	57.1	48.5	47.6	42.2	31.0	31.6

When results for each strand are compared (Table 4.32), male students outperformed females in Number, Measurement, Chance and Data and Space. However, the differences in means for the Algebra strand were not significant.

Entry confidence level

Anecdotally, staff teaching into the unit commented that the male students tended to be more confident than the female students when they started the unit. The data in Table 4.33 tends to support this as the differences in perceived confidence for male and female students are significant for both years ($t = -5.13$, $df = 220$, $p < .001$ in 2006; $t = -5.45$, $df = 294$, $p < .000$ in 2007). Male students reported higher levels of confidence than their female counterparts.

When the students with the highest levels of confidence were examined over the two years, 6 females and 4 males indicated 100% confidence which is an over-representation of males relative to their proportion of the whole student cohort. Of the 11 students who rated themselves at the lowest levels of confidence (score below 30%) none were male.

Table 4.33 Student Confidence Levels in Mathematics Entry Test Scores: Gender Comparison for 2006 and 2007

Gender	Number of students		Mean confidence level (%)		Standard deviation (%)	
	2006	2007	2006	2007	2006	2007
Female	178	255	68.8	63.3	17.0	16.2
Male	44	41	82.7	77.7	12.4	12.0
All students	222	296	71.5	65.3	17.1	16.4

When scores for each strand are examined (Table 4.34) male students had significantly higher confidence levels than their female counterparts in all strands in both years (t = -5.13, df = 220, p < .001 in 2006; t = -5.45, df = 294, p < .001 in 2007), reflecting the overall confidence data.

Table 4.34 Mean Entry Confidence Scores (out of 100) for each Strand: Gender Comparison for 2006 and 2007

Gender	Number		Measurement		Chance and Data		Space		Algebra	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
Female	71.0	66.3	65.3	61.3	71.1	61.3	67.3	62.4	70.8	65.5
Male	86.4	82.0	80.1	75.2	79.6	75.2	83.2	72.6	83.9	77.5
t value	-5.67		-3.66		-3.66		-3.14		-3.12	
p value	< .001		< .001		< .001		.002		.002	
All students	74.1	68.6	68.2	63.4	72.8	63.4	70.5	63.9	73.6	67.3

Exit performance

All students had access to the same resources and support during the three week mathematics module and continued to use both web and paper based materials through the rest of semester if they needed to improve further and complete a resit paper. The results in Table 4.35 show the means of the highest achieved scores for male and female students after the final resit sessions. Overall, males performed better than females in both years (t = -2.05, df = 277, p = .041 in 2006; t = -2.14, df = 286, p = .033). As they were starting from a higher base, this was to be expected.

Table 4.35 Highest Achieved Scores in Mathematics Tests: Gender Comparison for 2006 and 2007

Gender	Mean exit test score (%)		Standard deviation (%)	
	2006	2007	2006	2007
Female	77.8	76.2	10.1	12.9
Male	81.0	80.8	7.65	11.7
All students	78.4	76.9	9.78	12.8

The mean scores on entry in 2007 had a difference of 14% (43.6 for females compared to 57.6 for males) whereas on exit the difference was less than 5% so the gap between the two groups was much less than it was on entry. On the other hand males took fewer attempts to meet the benchmark than females in both years ($t = 3.98$, $df = 286$, $p < .001$, in 2006; $t = 2.83$, $df = 313$, $p = .005$, in 2007) as indicated in Table 4.36. The figures are marginally impacted by the fact that a few female students actually did extra resits to improve their scores, and their confidence, beyond the benchmark requirements.

Table 4.36 Number of Times Students Attempted to Meet Benchmark: Gender Comparison for 2006 and 2007

Gender	Mean Number of attempts		Standard Deviation	
	2006	2007	2006	2007
Female	2.16	2.30	0.697	0.867
Male	1.74	1.91	0.527	0.709
All students	2.08	2.24	0.688	0.856

When the scores for each strand are compared (Table 4.37) male students scored higher than females in virtually all areas, but the differences are only significant in Number in 2006 ($p = .06$) and Measurement in 2007 ($p = .02$) and the Algebra scores are almost the same.

Table 4.37 Highest Achieved Scores in Mathematics Tests: Comparison by Gender for Each Strand for 2006 and 2007

Gender	Number		Measurement		Chance and Data		Space		Algebra	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
Female	80.9	83.5	64.4	66.8	75.7	76.7	71.6	72.0	73.3	79.1
Male	84.8	86.6	66.6	74.3	80.8	82.7	75.8	75.5	74.2	79.0
t value	-1.87	-1.44	-0.77	-2.28	-1.58	-1.64	-1.56	-1.32	-0.23	0.03
p value	.062	.152	.439	.024	.115	.101	.120	.189	.818	.973
All students	81.6	83.9	64.7	67.9	76.6	77.5	72.4	72.5	73.5	79.1

Exit confidence

As can be seen in Table 4.38, male students were more confident than females in their own ability to answer the questions (t = -2.06, df = 119, p = .041 for 2006; t = -1.75, df = 103, p = .083 for 2007). Table 4.39 shows that the gender differences applied across all strands but not always to a significant extent.

Table 4.38 Student Performance Confidence on Exit from Unit: Gender Comparison for 2006 and 2007

Gender	Number of students		Mean confidence level (%)		Standard deviation (%)	
	2006	2007	2006	2007	2006	2007
Female	94	83	84.2	78.3	8.84	11.2
Male	27	22	88.5	82.8	12.2	9.56
All students	121	105	85.1	79.2	9.80	11.0

Table 4.39 Student Performance Confidence on Exit from Unit: Comparison by Gender for Each Strand for 2006 and 2007

Gender	Number		Measurement		Chance and Data		Space		Algebra	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
Female	84.9	81.1	81.7	74.4	89.1	81.4	84.0	75.7	83.7	78.8
Male	89.7	88.8	87.4	80.9	91.2	85.2	87.2	79.5	88.9	83.2
t value	-2.19	-2.63	-2.06	-1.94	-0.70	-1.02	-1.22	-1.05	-1.68	-1.16
p value	.030	.010	.041	.054	.487	.310	.226	.296	.096	.250
All students	86.0	82.7	82.0	75.8	89.6	82.2	84.7	76.5	84.9	79.7

Comparison of entry and exit performance and confidence

The ECS students have been removed from this data as they did not complete the exit confidence survey. The before and after comparison by gender is in Table 4.40 and shows that, while both males and females have improved significantly in competence (as measured by percentage test score) and confidence, the females started from a lower base and their improvement is greater. As a result, the exit scores for males and females are closer in value than they were on entry.

Table 4.40 Comparison of Entry and Exit Competence and Performance Confidence by Gender: 2006 and 2007

	2006				2007			
	Female		Male		Female		Male	
	Entry mean	Exit mean	Entry mean	Exit mean	Entry mean	Exit mean	Entry mean	Exit mean
Competence	49.0	77.8	59.9	81.0	43.6	76.2	57.6	80.8
Performance confidence	68.8	84.2	82.7	88.5	63.3	78.3	77.7	82.8

Overall the male students demonstrated higher skill levels and confidence on entry to the course with similar trends evident across most strands. The same was true in the exit tests but the differences in scores were much less, indicating that the female students showed relatively greater improvement in both competence and performance confidence.

Age group comparisons

As students had used a range of different pathways to enter university, there was a wide spread of ages in both the ECS and primary cohorts. Some students had left school only a few months prior to commencing the course and had completed tertiary entrance mathematics subjects. At the other extreme, some mature age students who were returning to study had not done any formal mathematics for several decades. The concerns about the impact that assessing competence would have on confidence levels were particularly acute for this latter group.

Entry test performance

When the variation in entry test performance across age groups was analysed, the differences between the year groups were apparent with all scores in 2007 being lower than the corresponding 2006 values (Table 4.41). However, ANOVA results showed that there is no significant difference in performance across age groups. This would seem to indicate that mature age students were no more likely to have problems with mathematics at this level than their younger classmates despite frequently expressed concerns.

Table 4.41 Mathematics Entry Test Scores out of 100: Age Group Comparison for 2006 and 2007

Age Group (years)	Mean		Standard Deviation	
	2006	2007	2006	2007
18 and under	52.3	45.5	15.2	16.1
19-21	50.5	46.9	17.5	17.1
22-25	52.0	45.9	16.4	18.8
26-35	49.8	47.2	20.9	16.8
36-50	43.3	38.9	18.0	14.0
Over 50	36.2	33.1	[a]	[a]
All students	50.9	45.6	17.1	16.6

[a] Only one student in this age group for each year.

When performance is measured in terms of the number of questions attempted (Table 4.42), the differences among students in different age groups were not significant. It would appear that the rate at which students were able to attempt the questions was relatively independent of age group.

Table 4.42 Mean Number of Questions Attempted in Mathematics Entry Test: Age Group Comparison for 2006 and 2007

Age Group	Mean Number of questions attempted (out of 20)	
	2006	2007
18 and under	17.4	17.1
19-21	16.9	16.9
22-25	17.1	16.4
26-35	16.2	16.6
36-50	16.0	16.2
Over 50	17.0	12.0
All students	16.9	16.8

When performance by strand across age groups is analysed using ANOVA, the only strand where age group is a factor in performance is for Space in 2006 ($F(5,312) = 2.354$, $p = .040$). All other strands show no significant relationship between performance and age group in either year (Table 4.43).

Table 4.43 Mean Entry Test Scores (out of 100) for each Strand: Age Group Comparison for 2006 and 2007

Age Group	Number		Measurement		Chance and Data		Space		Algebra	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
18 and under	67.0	61.7	46.2	35.1	58.3	49.0	50.1	42.1	33.5	33.4
19 – 21	66.6	64.6	44.4	35.2	59.7	48.7	45.5	42.2	30.3	37.4
22 – 25	70.1	65.1	44.0	35.0	56.9	48.2	52.4	45.7	29.7	25.0
26 – 35	69.4	65.8	42.2	37.9	54.8	50.5	44.4	44.5	29.0	28.2
36 – 50	64.6	63.2	35.6	25.0	41.6	45.8	35.5	30.0	29.5	23.6
Over 50[a]	64.0	54.5	15.0	14.7	44.0	0.0	18.0	40.0	42.0	33.3
All students	67.6	63.5	44.2	34.8	57.1	48.6	47.6	42.1	31.1	31.7

[a] Only one student in this age group for each year

This analysis indicates that while individual questions may have produced some minor variations, the overall trends evident in the total scores for the entry test are paralleled when the test is broken down by strand, indicating that age variations in student entry performance are similar across all topics.

Entry confidence levels

The variation across age groups in student confidence in their ability to answer the questions in the test is shown in Tables 4.44 and 4.45. Analysis of variance for each year shows that the differences in confidence levels across the age groups are not significant ($F(5,216) = 1.362$, $p = .360$ in 2006; $F(5,289) = 0.732$, $p = .600$ in 2007). The groups with maximum confidence (100%) and with low levels of confidence (less than 30%) included students from all age groups except the eldest.

None of the strands show any particular age group effect in confidence levels apart from Chance and Data in 2006 ($F(5,194) = 2.44$, $p = .036$).

Table 4.44 Student Confidence Levels in Mathematics Entry Test Scores: Age Group Comparison for 2006 and 2007

Age Group (years)	Number of students		Mean confidence level (%)		Standard deviation (%)	
	2006	2007	2006	2007	2006	2007
18 and under	81	120	71.6	66.3	15.3	15.6
19-21	63	70	70.4	63.4	16.0	15.3
22-25	41	40	74.8	63.7	14.6	17.7
26-35	29	46	72.9	67.8	24.4	19.6
36-50	7	18	59.3	62.2	21.9	14.6
Over 50	1	1	52.5	72.7	[a]	[a]
All students	222	295 [b]	71.5	65.3	17.1	16.4

[a] Only one student in this age group.
[b] Age data not available for one student

Table 4.45 Mean Entry Confidence Scores (out of 100) for each Strand: Age Group Comparison for 2006 and 2007

Age Group	Number		Measurement		Chance and Data		Space		Algebra	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
18 and under	72.9	68.1	67.1	65.2	74.3	65.2	72.4	65.0	75.5	68.6
19 – 21	73.4	66.4	68.2	62.8	69.4	62.8	68.8	62.7	74.1	67.8
22 – 25	78.8	66.7	70.7	60.1	75.0	60.1	73.5	66.4	73.4	65.7
26 – 35	75.5	73.8	70.8	66.4	79.3	66.4	67.6	64.1	73.3	64.2
36 – 50	60.1	69.8	59.8	52.7	47.9	52.7	60.2	56.0	62.5	67.9
Over 50[a]	75.0	83.3	50.0	75.0	62.5	75.0	50.0	25.0	25.0	-
All students	74.1	68.6	68.2	63.4	72.8	63.4	70.5	63.9	73.6	67.3

[a] Only one student in this age group

Exit performance

Given there were limited age group differences on entry to the course, it was to be expected that exit scores would also show only minor age group effects.

Table 4.46 shows that mean scores were lower in 2007 for three of the age groups (as they were for the cohort as a whole) and close in value in the other two, and standard deviations were greater for all age groups i.e. there was greater variation in the 2007 scores. The ANOVA results indicate that age group was not a significant factor affecting performance in the exit test in either year.

Table 4.46 Highest Achieved Scores in Mathematics Tests: Age Group Comparison for 2006 and 2007

Age Group (years)	Mean exit test score (%)		Standard Deviation Score (%)	
	2006	2007	2006	2007
18 and under	79.2	77.8	9.28	12.0
19-21	77.3	77.8	9.18	9.32
22-25	79.5	72.9	10.4	17.6
26-35	77.1	77.8	11.3	12.3
36-50	77.9	74.1	10.5	16.9
Over 50	73.8	[a]	[a]	[a]
All students	78.4	76.9	9.78	12.8

[a] Only one student in this age group completed the exit test in 2006 and none did so in 2007.

Table 4.47 shows the variation in number of attempts amongst students by age group. There were no significant differences in the mean number of assessment test attempts across the age groups for either year.

Table 4.47 Number of Times Students Attempted to Meet Benchmark: Age Group Comparison for 2006 and 2007

Age Group (years)	Mean number of attempts		Standard Deviation Score (%)	
	2006	2007	2006	2007
18 and under	2.04	2.34	0.556	0.823
19-21	2.14	2.25	0.812	0.788
22-25	1.98	2.14	0.589	0.966
26-35	2.07	2.19	0.787	0.951
36-50	2.58	2.19	0.793	0.750
Over 50	2.00	1.00	[a]	[a]
All students	2.08	2.24	0.688	0.856

[a] Only one student in this age group for each year.

Similarly, applying ANOVA to exit performances in individual strands (Table 4.48) indicates that there were no age related differences in exit performance in any of the strands in either year, apart from Measurement in 2007 ($F(4,286)=2.447$, $p=.047$).

Table 4.48 Highest Achieved Scores in Mathematics Tests: Comparison by Age Group for Each Strand for 2006 and 2007

Age Group	Number		Measurement		Chance and Data		Space		Algebra	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
18 and under	81.9	84.7	67.5	71.2	80.0	80.6	75.5	73.0	78.2	80.3
19 – 21	80.8	84.2	63.8	68.2	74.7	78.5	71.1	73.9	77.8	82.2
22 – 25	80.7	82.8	64.0	62.5	75.8	74.9	71.2	70.2	68.4	72.4
26 – 35	82.8	82.8	62.9	68.5	75.6	76.2	69.8	73.9	71.9	80.4
36 – 50	81.4	86.4	57.9	60.1	66.3	69.6	72.0	68.2	69.2	77.4
Over 50[a]	90.9		50.0		83.3		63.0		83.3	
All students	81.6	83.9	64.7	67.9	76.6	77.5	72.4	72.5	73.5	79.1

[a] Only one student in this age group in 2006 and no-one in 2007

Exit confidence levels

The confidence scores for primary students only were then analysed by age group for both years. Confidence levels for different age groups are shown in Table 4.49. While there is some variation in confidence across age groups in both years, ANOVA indicates that the differences are not significant. All age group scores are higher in 2006 than 2007 with the exception of one (26-35 year olds in performance confidence).

Table 4.49 Student Performance Confidence on Exit from Unit: Age Group Comparison for 2006 and 2007

Age Group (years)	Number of students		Mean confidence level (%)		Standard deviation (%)	
	2006	2007	2006	2007	2006	2007
18 and under	47	47	84.4	80.7	9.19	10.8
19-21	37	26	85.1	78.3	8.53	8.69
22-25	19	14	88.4	75.4	8.43	14.4
26-35	12	13	81.9	82.4	17.2	9.84
36-50	6	5	87.0	73.0	4.88	13.2
Over 50	-	-	-	-	-	-
All students	121	105	85.1	79.2	9.80	11.0

Age Group for Each Strand for 2006 and 2007

Age Group	Number		Measurement		Chance and Data		Space		Algebra	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
18 and under	84.7	83.4	81.8	75.5	91.8	83.5	83.5	76.4	85.1	81.3
19 – 21	85.7	82.6	82.4	76.8	90.2	81.0	84.9	78.4	84.2	79.8
22 – 25	88.6	78.3	89.1	72.1	89.6	84.8	88.3	72.9	87.0	72.6
26 – 35	85.8	87.1	77.1	78.8	82.3	81.2	80.4	81.7	85.4	85.1
36 – 50	89.2	78.3	88.3	77.0	83.3	70.0	90.8	65.0	79.2	70.0
Over 50[a]										
All students	86.0	82.7	82.0	75.8	89.6	82.2	84.7	76.5	84.9	79.7

[a] Only one student in this age group in 2006 and no-one in 2007

When confidence scores are analysed by strand for each age group (Table 4.50), only the 2006 results for Measurement show any age effect ($F(4,116)=2.212$, $p=.072$) for performance confidence.

Comparison of entry and exit performance and confidence

Given that age group was not a significant influence on entry and exit performance and entry and exit confidence levels, before and after data is not presented here.

In summary, contrary to anecdotal comments from staff about mature age student skill levels and voiced lack of confidence, there was little variation across the age groups in competence and confidence before and after the unit. Possible reasons for this are discussed in the following chapter.

Unit and Teaching Effectiveness Instrument results

The university requires the evaluation of every unit each semester using the Unit and Teaching Effectiveness Instrument (UTEI) so data generated from the survey was used to determine how students felt about the unit and its delivery as this was an indirect measure of some of the affective issues being investigated.

Within the Unit and Teaching Evaluation Instrument (UTEI), 20 questions related to aspects of the delivery of the unit. These are listed in Table 4.51 along with the mean scores for each statement.

Table 4.51 Unit Evaluation Data

Item No	Statement	Year	Mean	Percentage agree	N
1	The unit was well organised.	2006	51	85	321
		2007	59	94	48
2	The unit materials were helpful.	2006	58	89	320
		2007	55	88	48
3	The content of the unit was well organised.	2006	50	84	313
		2007	58	91	46
4	My roles and responsibilities within the unit were made clear.	2006	52	85	312
		2007	54	79	48
5	The facilities were adequate.	2006	60	90	315
		2007	67	94	48
6	The unit challenged my thinking.	2006	50	81	304
		2007	59	85	48
7	The unit advanced my understanding of the subject.	2006	56	87	306
		2007	58	88	48
8	The unit enhanced my knowledge and skills in the subject.	2006	56	87	303
		2007	60	90	48
9	The unit was engaging and interesting.	2006	33	66	304
		2007	42	75	48
10	The unit improved some of my general skills (eg problem solving, communication, reasoning, teamwork, writing, creative interpretation).	2006	51	82	308
		2007	60	92	48
11	I had a clear idea of what had to be completed and the level of work that was expected.	2006	51	85	306
		2007	57	85	48
12	Clear details of the assessment were provided.	2006	51	83	304
		2007	57	87	47
13	The content was clearly related to the aims and objectives in the unit outline.	2006	53	86	302
		2007	55	89	47
14	The assessments were strongly linked to the unit aims and objectives.	2006	55	88	302
		2007	56	88	48
15	The assessments assisted my learning.	2006	51	84	302
		2007	48	83	48
16	All required resources were available and accessible.	2006	57	87	303
		2007	57	92	48
17	The unit materials were current and up to date.	2006	58	89	302
		2007	59	96	48
18	The unit materials contributed to my understanding.	2006	58	90	300
		2007	56	92	48
19	The activities in the unit supported my learning.	2006	54	86	299
		2007	58	92	48
20	The unit enabled me to apply my learning to relevant tasks and problems.	2006	50	82	299
		2007	59	94	48
21	Overall I was satisfied with the unit.	2006	54	86	298
		2007	64	91	47
	School – overall satisfaction	2006	55	87	6410
		2007	54	85	4990
	Faculty – overall satisfaction	2006	53	85	9187
		2007	51	83	11455

The scale ranges from – 100 (all students strongly disagree) to + 100 (all students strongly agree) so a positive score is an indication that more students agreed than disagreed with the statement. The *Percentage agree* column records the total percentage of students who either agreed or strongly agreed with the statement and the final column is the total number of responses received.

The low response rates for 2007 coincide with the introduction of online surveys and it was difficult to accommodate the modular nature of the unit in the new system. However, results are consistent across the two years and indicate high levels of student satisfaction with these particular aspects of teaching and learning.

To place the data in context, the results for other units in the School of Education and in the rest of the Faculty of Education and Arts have been included at the bottom of the table. In all but a few areas, scores are higher than those for the School or Faculty. In addition, scores in 2007 are higher than 2006 which, despite the low response rate, provides some evidence that any student concerns in 2006 were at least partially addressed in 2007.

Table 4.52 Lecturer Evaluation Results (averaged over individual lecturers)

No	Statement	Year	Mean	Percentage agree	Number
1	The lecturer was enthusiastic about the subject.	2006	72	96	160
		2007	64	100	17
2	The lecturer stimulated me to think.	2006	62	90	161
		2007	56	88	17
3	The lecturer encouraged me to take responsibility for my own learning.	2006	69	90	160
		2007	65	94	17
4	The lecturer was available to answer student inquiries.	2006	79	96	157
		2007	68	100	17
5	The lecturer helped make the content interesting and engaging.	2006	58	85	157
		2007	41	76	17
6	The lecturer made clear the standard of the work expected.	2006	67	92	156
		2007	59	100	17
7	The lecturer helped me to understand problems with which I had difficulty.	2006	74	90	158
		2007	62	100	17
8	The lecturer organised the subject matter in a way that helped my learning.	2006	62	84	159
		2007	59	88	17
9	The lecturer catered for my individual needs in this unit.	2006	58	80	156
		2007	53	82	17
10	The lecturer was responsive to students' requests and suggestions.	2006	76	95	157
		2007	62	94	17
11	Overall I was satisfied with the performance of this lecturer.	2006	75	94	158
		2007	59	94	17
	School – overall satisfaction	2006	61	88	7221
		2007	63	88	5103
	Faculty – Overall satisfaction	2006	59	86	10801
		2007	61	87	11234

Table 4.53 Tutor Evaluation Results (averaged over individual tutors)

No	Statement	Year	Mean	Percentage agree	Number
1	The tutor assisted in developing my understanding of the subject matter.	2006	70	94	206
		2007	68	96	49
2	The tutor encouraged my participation in the unit.	2006	64	91	208
		2007	56	90	49
3	The tutor was available to answer students' inquiries.	2006	80	97	206
		2007	76	94	49
4	The tutor encouraged and supported my learning.	2006	71	93	206
		2007	66	92	49
5	My interactions with the tutor were productive.	2006	70	92	209
		2007	64	94	49
6	The tutor made clear what I was expected to do and learn.	2006	70	91	207
		2007	74	96	49
7	The tutor responded well to my requests for assistance.	2006	78	97	207
		2007	74	94	49
8	The tutor provided useful feedback and guidance on my work.	2006	67	90	206
		2007	62	94	49
9	The tutor assessed my work fairly.	2006	68	89	205
		2007	68	94	49
10	The tutor returned assessed work within reasonable time.	2006	66	87	192
		2007	70	98	49
11	Overall I was satisfied with the teaching of this tutor.	2006	76	95	207
		2007	73	96	49
	School – overall satisfaction	2006	64	89	5929
		2007	63	89	4732
	Faculty – overall satisfaction	2006	62	88	8006
		2007	61	87	8218

Tables 4.52 and 4.53 show the UTEI results for the staff involved in teaching the mathematics module. As staff taught varying numbers of classes and students, their scores were weighted according to the number of responses they received in order to provide an overall sense of the student perceptions of the unit.

There are some limitations in the survey in that it is structured to allow students to comment on a lecturer (in most units a tenured academic who presents a mass lecture to the whole unit cohort for one hour a week) and their tutor (often a casual staff member who works with a group of up to 30 students for two hours a week using more practical, student centred activities). In this unit, students had the same staff member for three hours and activities more closely resembled those of a tutorial. Hence, not all the statements were relevant to the unit but the survey could not be adapted.

Again, lecturer and tutor evaluation scores were nearly all higher than the School and Faculty averages and were evidence of the hard work put in by the staff to ensure positive outcomes for the students in terms of achievement and confidence.

Students have the option to write in additional comments in the UTEI and these were also supportive of the approach that has been taken in the unit. Over the two years of the study, 29% of responses specifically commented positively on the use of the Mathletics site and 29% stated the unit had improved or refreshed their skills, knowledge or understanding. The individualised or self paced nature of the unit, the identification and targeting of weaknesses, the easy to access resources and the helpful knowledgeable tutors were all mentioned in at least 10% of the comments. About 35% of written responses referred to the tutors always being available and willing to help, an acknowledgment of the key role they played in ensuring students developed and maintained positive attitudes towards improving their mathematical skills. The comments are perhaps best summed up in the following words written by a student in answer to the question, “What aspect of this tutor’s apprach to teaching best helped your learning?”

> Her enthusiasm was awesome, she made me enjoy maths which I usually hate. I liked her availability, no question was too hard or too stupid. She explained why, how etc without making me feel inadequate, which is how I usually feel in mathematics.

Conclusion

The data presented in this chapter supports the concerns about levels of confidence and competence in mathematics amongst pre-service primary teachers and a number of areas of weakness have been identified. While the information for each of the two years of the study has been examined separately, similar patterns have emerged which support the efficacy of the intervention in improving competence without having a deleterious effect on confidence. Differences between students from different courses are consistent across the two years, as are gender differences and age group variations. The following chapter will discuss the results in more detail and address the implications of the findings.

Chapter 5

Results summary and discussion

This chapter summarises the findings of the study as presented in the previous chapter and presents some potential explanations based on the context. The implications of the results for the degree course and for other pre-service teacher educators are also addressed. The chapter concludes with a short discussion of the events since the data was collected and the ongoing plans for improving teacher literacy and numeracy at the university.

Context and significance of the study

Government reports and academic researchers have long expressed concern over literacy and numeracy levels in the population as a whole, and amongst school children in particular. One area which has received particular attention is the quality of teaching in mathematics and ways that this can be improved. Teacher knowledge, both of content and pedagogy, has been a focus of a number of reports (Ball & Wilson, 1990; Council of Australian Governments (COAG), 2008; Galbraith, 1984; Groves et al., 2006; Louden, 2006; Rowland, Martyn, Barber, & Heal, 2002; Steffe, 1990).

While there are varied views on the extent to which teacher subject content knowledge (SCK), as distinct from pedagogical content knowledge (PCK) (Shulman, 1986), can be correlated with student achievement (Council of Australian Governments (COAG), 2008), there is agreement that without adequate content knowledge, teachers cannot develop the “deep understanding” (L. Ma, 1999) needed to effectively teach important underlying concepts.

The students who participated in the study were enrolled at the second largest School of Education in Australia which produces a significant proportion of the primary school teachers in the state. They were from a variety of backgrounds in terms of age and socio-economic and cultural background, and had entered university through a number of different pathways. With over 300 students each year and data from two years of the program, trends which are apparent in the results can be considered as representative of the wider primary pre-service teacher population in the state.

This chapter will discuss the extent to which the students beginning the Bachelor of Education degree demonstrated the low levels of mathematical literacy and confidence identified by other researchers and whether their competence and confidence varied across different areas of mathematics. The efficacy of the unit in addressing any deficiencies identified on entry will then be discussed together with implications for students of different genders and ages and enrolled in different courses. A summary of events subsequent to the years in which the data was collected will be provided as well as comments on the future delivery of the unit and the rest of the degree program.

Mathematical competence of first year pre-service primary teachers

The first research question was addressed by considering the results of the entry assessment task for the mathematics module which had been designed to serve a number of purposes. Its primary aim was to recognise the existing mathematical skills of students entering the degree while at the same time enabling areas of weakness to be identified so that appropriate support could be provided. In addition, the results produced baseline data on student competence for the study so the effectiveness of the intervention program could be investigated.

Performance was measured in terms of overall score and the number of questions attempted in the time available. Considering that the students had already met the requirements for university entry, the mean overall scores of 51% in 2006 and 46% in 2007 are a major concern (Table 4.1). The poor results are consistent with other findings in Australia and elsewhere (Glennon (1949) cited in Louden, 2006; Rech, et al., 1993; Zevenbergen, 2005).

The significant differences between the two cohorts both in mean and distribution, together with the change in the benchmark level between 2006 and 2007 led to the data for each year being treated separately. This had the advantage of improving the reliability of any conclusions based on trends in the two years.

The results for repeating students (Table 4.2) are a major concern for the long term impact of the intervention. Nineteen of the students who completed the unit in 2006 had to repeat it in 2007. In some cases they had previously passed the mathematics module but because they had failed the writing and/or science modules they were required to repeat the whole unit. These students had achieved a mean score of 63% by the end of 2006 but were unable to reach the same standard in what was essentially the same test at the start of 2007. This may have been a function of the nature of students who have limited skills in the first place but some retention of skills would have been expected over the relatively short period of time. An even greater source of worry is that four of the students had also attempted the unit in 2005, meaning that they were attempting essentially the same assessment task for at least the seventh time. While their scores increased during the course of the semester each year, they regressed in the time between enrolments.

A further aspect of performance was the time students took to answer the questions (Table 4.3). There was very little difference in the number of questions attempted across the two year groups, so the weaker students in 2007 therefore appear to have lost more marks than those in 2006 through incorrect answers rather than through running out of time. While about 20% of the groups in each year of the study managed to attempt all 20 questions in the 55 minutes available, and 75% of them attempted 15 or more questions, others only managed to record some sort of response to less than ten questions. Given that most questions required only brief written responses, the time appears to have been taken up with thinking and staring at the page rather than writing. The instructions given to students, both in writing on the paper and orally by the tutors, recommended that they leave questions that they could not answer easily and move on to those where they could be more successful. Despite this, those who did not finish the task showed evidence that they had started at question one and worked through in order. The questions were not in order of difficulty so this meant that some relatively straightforward questions near the end of the paper were missed when students spent too long on earlier ones. Weaker students may well have been too stressed to pay any heed to strategic approaches to the task, while more able ones may have had the presence of mind to maximise their scores through an efficient use of time and question choice.

The standard for the required outcomes was based on Level 4 of the Western Australian Outcomes and Standards Framework for mathematics (Curriculum Council, 2005a) and, at the time of the study, this was the achievement target for year nine students in government schools in the state. The intent of the target was that it represented the level of content knowledge and skill which at least 75% of year nine students should be demonstrating. As the corresponding achievement target for year seven students was Level 3, a significant number of primary school children would have achieved the Level 3 outcomes and be working towards Level 4 before moving to high school in year eight. Primary teachers therefore needed to be competent to at least this level if they were to teach the mathematics curriculum effectively.

In trying to find some explanations for the poor performance of these students, a number of issues arise. The pre-service teachers in this study had completed a high school education, or had provided evidence of study and life experiences of an equivalent standard, so it was of concern that they could not demonstrate these relatively low levels of mathematical literacy. However, in 2005 and 2006, the state requirements for secondary graduation and the award of the WA Certificate of Education (WACE) did not include a specific numeracy standard so it would technically have been possible for a student to successfully graduate from high school with very limited mathematical competence. Some years prior to this study, there had been a mathematics criterion but this only required students to have met year nine outcomes in mathematics before receiving their secondary graduation certificate. Even this low level had since been dropped. The WACE changes which began implementation in 2008 for year 11 students still do not have a specific numeracy or mathematics requirement (Curriculum Council, 2010). While school leavers and others completing high school courses or their equivalent are required to pass an English subject at year 12 level, they do not need to have studied mathematics beyond year 10, let alone passed it at that level. Many high schools set their own requirement for students to take a mathematics subject as part of their timetable, but there is no external requirement to be successful apart from its potential use as one of four subjects contributing to the Tertiary Entrance Rank (TER). Hence students in the study with an aversion to mathematics may have been able to avoid studying it at school beyond year ten when it ceased to be a core curriculum subject. Data on students' highest level of mathematics study prior to entry to the degree course was not available, although anecdotal evidence and comments in the unit evaluation feedback indicated that for many their last experiences had been some time previously and were less than positive.

Another issue relates to the status of teaching as a profession in the current social and economic climate. It may be that a poor perception of teaching in the eyes of the community has led to its failure as a profession to attract high ability students as indicated in the Australian report *Attitudes to teaching as a career* (Stokes & Tyler, 2003). In addition, during the two years of this study the resources boom in the north west of the state provided high paying jobs for both school leavers and mature workers. As a result, more able students who could find more lucrative employment elsewhere may have chosen other career paths and perhaps some students entering the primary teaching degree included those who were not able enough to find careers elsewhere.

Increasing numbers of students are entering university through alternative pathways involving non-TEE and vocational education and training (VET) subjects at school or in colleges of Technical and Further Education (TAFE). Adult education programs, such as the Certificate of General Education for Adults, do include mathematics units, but workplace training packages for trades and professions tend to embed the mathematics within other units as an "underpinning skill". For example, a number of students had completed the Certificate IV in Community Services (Children's Services) which is part of the Community Services Training Package (Commonwealth of Australia, 2007). In the past the units of competence were mapped against the Mayer Key Competencies which included "using mathematical ideas and techniques", although since 2006 these have been replaced by Employability Skills. For the students in the study who used this qualification to meet university entrance requirements, the key competency mapping included links to mathematics in a number of units. However, on closer examination, the skills and knowledge required were limited to aspects of planning, time management, data recording and interpretation, basic measurement and simple accounting, all in the context of working under supervision in a child care centre. These do not provide a sound basis for the deep understanding required in primary mathematics teaching.

The current trend in the university entry requirements seems to be to maximise the number of successful applicants as part of an agenda which dictates that everyone should be able to access a tertiary education. Since this study, the Bradley Review has recommended “that the Australian Government set a national target of at least 40 per cent of 25- to 34-year-olds having attained a qualification at bachelor level or above by 2020” (Department of Education, Employment and Workplace Relations, 2008, p. xviii). Unfortunately, this may be at the expense of the numeracy standards amongst new undergraduates. It is unlikely that the calibre of future entrants to the degree course will improve in this area at least and hence there will be a need for ongoing support through measures such as the one described in this study.

Entry confidence levels

In developing the unit, and in the literature, there were major concerns about the impact of the entry assessment on student confidence, both in terms of test anxiety and reactions to having weaknesses identified (Bibby, 2002; Morris, 2001; Sanders & Morris, 2000). To monitor any effects, students were asked to indicate how confident they felt about the correctness of their answer for each question they attempted on the entry test. The determination of initial confidence levels enabled staff to identify students who had unrealistically high or low levels of confidence compared to their actual performance and to monitor those with low confidence levels during the three week module. The data also provided a benchmark for comparison with confidence levels at the end of the unit to verify that confidence had not been adversely affected by the intervention.

Approximately a quarter of the students each year indicated that overall they were at least reasonably confident about having answered the questions correctly by rating themselves with an average score of 3 or 4 on the Likert scale (Table 4.4).

Ten students over the two years rated themselves as very confident for all the questions they attempted and so were scored at 100%. They were all enrolled in the primary course and four were male which is an over-representation of males compared to the group as a whole. At the other end of the scale, 11 students, all female, scored themselves at less than 30% meaning that in most questions they were not at all confident about their answers.

While absolute scores cannot be directly compared, student confidence levels were higher than their performance would indicate was appropriate. Entry test competence and confidence scores were significantly correlated indicating that students with high skill levels had high confidence levels and vice versa (Table 4.5). Mean scores in each area indicated that while students had relatively low skill levels they rated themselves as “reasonably” confident about having answered many of the questions correctly. While students knew that the benchmark for success in the task was 75%, it may be that their previous experiences with mathematics rated half marks as a pass and they perceived themselves as confident they had reached that lower benchmark. Alternatively, they may simply have assumed that incorrect answers were in fact correct and would be marked accordingly. In general, 2007 students were less confident than those in 2006 and this is consistent with their weaker overall performance.

The competence and confidence results in the entry task justified the design of the intervention program in that it used approaches which clearly identified weaknesses without having a negative impact on confidence. The CRC - Commend, Recommend, Commend - approach was intended to enable students to maintain relatively positive feelings about mathematics.

A number of students did not complete the confidence rating, particularly in 2006, and this may have skewed the figures, as evidence indicates that it was generally weaker students who had not responded. This supports the conjecture that these students were stressed and/or ran out of time and were primarily focused on answering as many questions as they could.

Variation in performance across mathematics content

Rather than focusing on individual questions in great detail when analysing student performance in the entry task the questions were grouped according to strand (Number, Measurement, Space, Chance and Data and Algebra) (Table 4.6). The students scored best for questions on Number topics, followed by Chance and Data, Space, Measurement and Algebra with the relative differences between each successive strand mean being significant, for example the Chance and Data scores were significantly higher than the Space scores (Tables 4.7 and 4.8). Those who reached the end of the paper and answered the Algebra questions did reasonably well but only 60 students each year were able to work quickly enough to answer the whole paper. While the order of the questions on the paper may have had some impact, particularly for the Algebra section, Measurement questions were early in the paper and were also badly done.

Given that most "real life" applications of mathematics use number and measurement skills, there are major concerns about the inability of students to use metric units to estimate length and mass, to convert between units in the metric system and to understand the differences between perimeter and area for plane shapes made up of squares and between surface area and volume for three dimensional shapes made up of cubes.

In both Number and Measurement, discussions with students following the entry assessment revealed a heavy reliance on rules and algorithms and the general reason given to tutors for poor performance was along the lines of "I never could do long multiplication (or division)" or "I haven't done this for a long time and I have forgotten the formula". As none of the number questions involved anything more than multiplication and division by single digits or powers of ten, this should not have been a problem and the Measurement questions simply required students to count line segments, squares or cubes as appropriate.

Analysis of the entry confidence data by strand shows only minimal variation from the overall trends already identified. Highest confidence levels were associated with the Number questions although these were closely followed by Algebra (Table 4.9).

This may be a reflection of the fact that mainly able students reached the Algebra section at the end of the paper and provided confidence data. Measurement had lowest confidence levels which is commensurate with the low levels of performance in this area.

The weaknesses identified amongst the students were consistent with previous research with a number of students unable to subtract decimals with differing numbers of decimal places (Chick, et al., 2006). Others did not even attempt the short division calculation in the same question which would indicate lack of confidence, if not competence, with that operation beyond recall of table facts (Robinson, et al., 2002). Similar errors to those reported by Steinle and Stacey (1998) were observed in ordering fractions and decimals and answers showing confusion between area and perimeter reflected the findings of Reinke (1997) and Menon (1998).

Given that the required standard for the entry task was already as low as it was, being the level expected in a typical year seven class, none of the strands showed particular strengths in any area of the mathematical curriculum. One or two individual questions were reasonably well done but these were often very basic, including Question 1 based on the outcome N1 *Write large and small numbers in ,figures and words*. Other questions with high mean scores were only attempted by a few more capable students who were able to complete the task and included Question 20 which related to the outcome A3 *Solve "find the missing number" problems.* A notable exception was the high mean score for Question 6 which was linked to N6 *Perform calculations involving money using the four operations*. Students were able to perform calculations and use algebraic thinking more complex than they had used in some of the other questions where scores were lower. This was attributed to the fact that the question presented a situation they were likely to encounter in everyday life which involved money. In many cases students' written answers showed an intuitive approach rather than a formal calculation in that they appeared to relate the questions to their personal experiences rather than to what they had learned at school. An example of one of the questions used to assess this outcome was:

A lawyer charges $250 for a face to face appointment and then $450 an hour while he is working on the case, regardless of the particular tasks he carries out.

a) What would be the charge for a case involving one face to face appointment and five hours work?
b) At the end of a month which included two face to face appointments, the invoice was for $2300. How many hours did he work on the case?

Part b) involved the same skills as solving a two-step linear equation yet students with relatively low scores on other questions were able to complete this one correctly, often using guess and check methods or listing the charges for an increasing number of hours till they found a match. This supports the use of contextualised examples in the teaching of mathematics and the encouragement of idiosyncratic methods. However, pre-service teachers need to demonstrate skills and understanding in a range of formal and informal contexts and using a variety of methods if they are to present different strategies to children with different intelligences or to understand non-standard methods which children my present to them.

It would seem that with only a few exceptions, students performed relatively poorly across all strands of the mathematics curriculum in the entry task and that the variation in confidence levels mirrored variations in competence.

Effectiveness of the Intervention

The success or otherwise of the intervention program can be discussed against a number of criteria. The study focused on the impact of the unit on competence and confidence but information was also available on issues such as variation across strands and retention rates within the course as well as broader attitudinal changes.

Mathematics competence levels at the end of the unit

As it was not possible for students to attain lower scores on exit than they had achieved on entry, statements such as “performance improved as a result of the intervention” mean little. However, the extent of the improvement was of interest as were any variations across different strands.

In 2006 students were considered to have met the benchmark if they achieved an overall score of 70% in the exit test. This included retaining the scores for individual questions where they had achieved at least three quarters of the available marks in the entry assessment. In 2007 the benchmark was raised to 75%. As a result the mean exit scores in 2006 are lower relative to the 2007 scores than they could have been if the same standard had been applied. In both years however, the mean scores increased from 50% or less to over 75% (Table 4.10).

Unfortunately, students repeating the unit continued to perform significantly less well than those attempting the unit for the first time (Table 4.11). It would seem that if students cannot meet the required standard within one semester of this unit, they are unlikely to improve much more if they repeat at least as far as this unit is concerned. While the results support the efficacy of the relatively short intervention in “fixing” the weaknesses of a majority of students, the longer term impact is less clear cut as these repeating students did not retain even their limited improvement from one year to the next. An alternative explanation might be that these students, and others who had multiple attempts within a single semester, were not prepared to put in the time and effort required to improve their skills and there was some anecdotal evidence of a belief that simply repeating the test would result in higher scores. For example, students requested that they be able to sit a second assessment within the same week when they were not successful. This may have been an unforeseen outcome of the promotion of the “your score cannot go backwards” message which was intended to maintain confidence but may have led to complacency. With up to 30 students attempting the exit test 4 times in a year, the value of multiple opportunities could be questioned, especially as some of them had up to a dozen attempts over two or three years.

The fact that the largest proportion of students passed at the end of the three week intervention module, suggests that the module has been effective, at least in the short term, for many students. The next largest group includes students who improved during the module and continued to work on their skills so that they passed at the end of semester on their third attempt (Tables 4.12 and 4.13). The benefits of allowing further attempts are mixed with more than half those students failing yet again.

The trends in the overall performance of students on exit from the unit are mirrored when the results are analysed by strand. Of note is that while the questions on Number continued to generate the highest scores, the relative position of Algebra improved in the exit tests, ranking third after Number and Chance and Data in 2006 and second in 2007. Measurement was still the area of greatest weakness in both years (Table 4.14).

The improvement in Algebra may be partly attributed to a number of students adopting a strategy of beginning the exit task at the end of the paper as many of them had not even attempted those questions in the entry task as they ran out of time. As they were encouraged to maximise their improvement by focussing on questions in which they had scored lowest, this was a sensible approach but did distort the strand analysis of the exit data. The Algebra questions had also presented a challenge on entry simply because they were labelled as Algebra and when the classroom activities and exercises showed how straightforward they were (completing the next two terms of a simple sequence and finding the missing number in a number sentence), students tended to do quite well.

On the other hand, the Measurement questions may have suffered from these tactics. They were in the middle of the checklist and the paper and so were rarely the first questions attempted or the ones on which students placed much focus. The entry scores for some questions were only one or two marks below the benchmark so there was little to be gained in overall scores in spending a lot of time addressing deficiencies in knowledge and skills. Of particular note were the poor estimation skills across all students. Question 10 had one of the lowest mean exit scores and required students to estimate two dimensions of a three dimensional shape, one in mm and one in cm, and also to estimate the mass. The shapes were changed in each task and varied from a collection of cylinders (to estimate height and radius or diameter) to a range of different prisms and pyramids (to estimate the lengths of the longest and shortest edges). While skills in estimating lengths improved when students adopted the strategy of using referents such as their own thumb width or finger joint length, estimating mass proved a significant challenge with very few students providing answers within the required range. It may be worth noting that the distinction between mass and weight was not a major emphasis in the mathematics module but was discussed in science.

Exit confidence levels at the end of the unit

As a primary reason for designing a unit with this format and approach was to ensure that students did not lose confidence when their weaknesses were identified, the exit confidence scores were of particular interest.

The overall level of performance confidence amongst students on exit from the unit showed similar trends to the entry results. Students enrolled in 2006 were significantly more confident about their ability to answer the questions correctly than those in 2007 (Table 4.15). Primary students were also asked to indicate how confident they felt about teaching children to answer the questions in the tasks. These scores were lower than those for performance confidence, indicating that students recognised a difference between being able to do something yourself and being able to teach someone else how to do it.

The more attempts a student had to reach the benchmark, the less confident they were about their ability to answer the questions (Table 4.16). This was as might be expected; weaker students who kept being presented with evidence of their weakness were likely to have their performance confidence affected more than those who met requirements on the first or second attempt. However, even those who had four attempts still reported themselves as “reasonably confident” about their ability by the end of the unit.

When exit confidence was considered for each separate strand of questions, the overall trends were repeated in that all strands showed significant improvements in confidence compared to entry levels and the 2006 students continued to report higher confidence levels than those in 2007 (Table 4.17).

Competence and performance confidence were significantly positively correlated on exit for both year groups meaning that those who performed well had higher confidence levels and vice versa (4.18). In addition performance confidence and teaching confidence were also significantly correlated, so students who were more confident about their ability to answer the questions were also more confident about their ability to teach someone else. However, this conclusion needs to be viewed with some caution as there is evidence of a “donkey vote” approach in the survey with some students scoring the same in both areas for all questions.

Entry and exit confidence scores were also highly correlated each year meaning that students who had low levels of confidence compared to their peers on entry still had lower scores on exit despite their absolute improvement.

Retention rates

The extent to which the unit, and in particular the mathematics module, influenced decisions to withdraw from the unit or course cannot be determined definitively although early withdrawal from the unit could be seen as an indication of the impact of the entry test on student confidence.

The 2007 figures do not include 29 students who enrolled in the unit but failed to complete any of the mathematics assessments. Of these 23 withdrew but a further 6 students failed to take any formal action to change their enrolment status and were recorded as having failed the unit. In 2006 there were 17 students who completed no assessments in mathematics and they were not included in the study as they were no longer in the system when formal data collection was commenced. As this is a core unit, students who withdrew from the unit generally withdrew from the course as a whole, with a few exceptions deferring their enrolment to the following year. It may be that the unit is acting in part as a *critical filter* in that it helps students to realise that they may not have the academic skills required to be a successful primary teacher. Anecdotal comments from students about having chosen primary or early childhood teaching because they would not have to know much mathematics would support this possibility. Conversely, it would be of interest to know how many students were concerned about their low levels of mathematical content knowledge and actually stayed in the course because the unit helped them to fill any gaps.

The university is concerned about high attrition rates amongst first year students and there has been discussion regarding the impact of this unit on student retention. While 31 students withdrew early from the unit in each year of the study and all but three of these students subsequently withdrew from the course, this could also be attributed to a number of other factors including late enrolment, experience during school placements and issues associated with any life transition such as starting university. In exit surveys conducted by the university in 2008, no students mentioned the unit as influencing their decision to discontinue their studies. Reported factors did include financial reasons, recognising that teaching was not the career for them, and family and work commitments.

Unit and Teaching Effectiveness Instrument results

As an indication of the efficacy of the CRC approach to intervention, the results of the UTEI and the associated written comments were analysed. When the questionnaire responses for the two years were examined, there were high levels of satisfaction with the unit and the teaching staff (Table 4.51). In terms of percentage agreement with the statements, virtually all scores were above the Faculty mean and many were above the School mean. At least 90% of respondents agreed that the unit materials were of high quality and 87% overall indicated that their knowledge and understanding had improved as a result of the unit.

Teaching scores for staff were also positive with scores above 90% for the majority of the lecturer and tutor statements (Tables 4.52 and 4.53). In particular, students appreciated that staff were available and responsive to their needs and played a major role in enhancing their mathematical understanding.

The written comments provided a deeper insight into the student feelings about the unit. Their reactions to having their weaknesses identified were ameliorated by the immediate availability of support to address their problems. In some cases students expressed a sense of relief that they would not be presented with units about teaching mathematics before they had the opportunity to bring their own skills up to the required standard. Students wrote positive statements about what could have been a stressful experience and the following was typical; “This unit has helped me to realise my weaknesses and begin work on them. I feel it has been of great benefit.”

Comments such as; “Knowing exactly what was expected of you and being able to get on with your work yourself,” and “I really liked that we did an exam and then were able to resit the test to improve,” indicate that students appreciated the individualised approach and the diagnosis and intervention structure.

When asked about the best aspects of the unit, feedback on Mathletics affirmed that the decision to use the site had benefited the company as well as the students.

> I really enjoyed getting on the Mathletics site because that’s where I really learnt what I was doing wrong and I even learnt a few things too.
> Great site, even my son is now using it and my daughter is going to start using it too.

A number of comments took the opposite stance to the majority view in that while most students liked being able to work on their own skills, others wanted more class teaching. A few reacted negatively to the use of Mathletics, some because of an aversion to computers and others because they saw it as childish although for most students these aspects were perceived to be advantages.

Flexible, knowledgeable, committed and skilled tutors were the prime reason for the success of the unit and this was acknowledged by students.

> The tutor was good as she provided us with resources and left us to explore and do things how we wanted and when we needed help she was there. She also explained things easily.
> It was fantastic that the tutor never made you feel stupid, regardless of how basic the question was.

Even when asked whether they wanted tutors to do anything differently, most students specifically wanted them to continue what they were already doing.

> No, if I needed anything she always helped. I was never very good at maths at school and I found the maths in this unit beneficial and fun, which is a huge surprise!

Course, gender and age variations

The participants

Over 300 students completed the mathematics entry task in each year of the study. Just over a third of them were enrolled in early childhood education and the rest in primary education. As might be expected, given the distribution within the profession, more than four fifths of the students across the primary and early childhood (ECS) courses were female, with only a handful of male students enrolled in the ECS course.

Students ranged in age from just turned 17 to over 60 years of age at the time they were enrolled in the unit, and more than one third were over 21 years of age and hence were not recent school leavers. On average, male students were older than their female counterparts.

A number of different pathways had been used by students to meet the course entry requirements including completing tertiary entrance examinations (TEE) or TAFE qualifications, sitting the Special Tertiary Admissions Test (STAT), submitting a portfolio of educational and life experiences or completing a University Preparation Course. While a detailed analysis of performance based on entry pathway is beyond the scope of this study, any consideration of differentiation of performance according to age group includes a de facto comparison of school leavers with those who have used non-TEE entry pathways.

Mathematics competence

Primary education students performed better than their ECS peers in terms of overall entry score in both years and this supports student comments and anecdotal evidence which indicate that one reason students chose ECS was that the mathematics content would be less (Table 4.21). Unfortunately, this greatly underestimates the importance of early numeracy teaching in the development of children's mathematical skills and understanding. Pre-school and junior primary teachers must have a clear sense of the key understandings which children need to develop and this can only come from their own knowledge of the content and structure of mathematics, and number in particular. Personal observations of classroom teachers attending a professional development course on the use of the First Steps in Mathematics materials (Western Australian Minister for Education, 2004) revealed that some of them had serious deficiencies in their own personal numeracy to the extent that they were unable to analyse work samples from children and identify what assistance they might need. In fact, a number of participants demonstrated the very misunderstandings that they were meant to diagnose and remediate in the children they were teaching. Key concepts such as what counting actually involves and how place value works, even with small numbers, were problematic. Hopefully the mathematics pedagogy units later in the degree have assisted the ECS pre-service teachers in this study to recognise that there is more to early childhood mathematics than singing the counting numbers to twenty à la Sesame Street.

The differences in performance support anecdotal evidence from students that a number of them had chosen the Early Childhood course because they thought they would not have to know much mathematics. The following excerpt from the UTEI responses was typical of the reaction when told they would have to demonstrate that they could do mathematics to at least year seven level as a requirement of the unit.

> As an ECS student who will possibly not be employed in years above year three I see the extra pressure of the math requirement at year seven level as unnecessarily difficult and stressful. As a mature age student I practised night after night and all over Easter but there is no way that I could cram in all I needed to know. I also think a 75% mark is a huge expectation.

Unfortunately for this student, ECS graduates have been employed to teach in all years in primary schools when there are problems with teacher shortages. For example, a fourth year internship student who was about to complete the Early Childhood BEd course was placed in a rural school as a support teacher. This role included being the in-school relief teacher for all years from one to seven. Another primary education intern worked as a physical education specialist in a district high school with students from years eight to ten. While these may be isolated examples, students need to recognise that their course has to prepare them to teach beyond the context for which their degree ostensibly qualifies them.

The mean entry task scores for male students in both years were significantly higher than those for the female students (Table 4.30). Virtually all the male students were in the primary course so this may go some way towards explaining the variation between the courses, although female primary students still outperformed their ECS counterparts when the data was separated by gender.

If teacher content knowledge is a factor in the effective teaching of mathematics in primary schools, this suggests a potential strategy for addressing concerns about numeracy. The promotion of primary teaching as a career could be targeted differentially at males and, in addition, career pathways could be further developed to encourage male teachers to continue in classroom roles rather than moving into administrative positions.

Those who had recently left school and had qualified for university via a sufficiently high Tertiary Entrance Rank (TER), might have been expected to be more successful than their mature age counterparts who had often not studied mathematics for a number of years. However, there were no significant differences across the different age groups in either year of the study. 2007 students were less successful than those in 2006 in all age groups (Table 4.41).

This would seem contrary to the anecdotal evidence from tutors that mature age students were less able. It is possible that these students tended to seek more assistance from staff and hence raised awareness of their issues, whereas the school leavers tended to try to solve their problems on their own. It may also be that tutor perceptions are affected by differences in confidence rather than competence and this will be considered later in the chapter.

The data showed no significant difference between various groups of students in the number of questions which they were able to attempt in the allotted time. Hence the differences in performance described above were related to whether they could actually answer the questions correctly rather than the time taken to produce those answers (Tables 4.22, 4.31 and 4.42).

Primary education students scored significantly higher marks than their ECS peers in Number, Measurement and Chance and Data. Scores were closer in questions related to Space but still in favour of the Primary students. Algebra scores were similar for both courses with the mean for the ECS students slightly higher in 2006 (4.23).

In both years, male students performed significantly better than female students in all strands except Algebra where the scores for males were higher but not significantly so (Table 4.32).

When results for each strand are compared across age groups, the only strand to show any significant age related variation was Space in 2006 (Table 4.43). Again this reflects the trend in the overall scores and provides further evidence that recent school leavers and mature age entry students have similar strengths and weaknesses.

Confidence on entry

Primary course students were significantly more confident than those in Early Childhood Studies and male students were more confident than females at the start of the unit but there was no significant variation in confidence at the start of the unit for students of different ages and, by implication, different entry backgrounds (Tables 4.24, 4.33 and 4.44)

Ten students over the two years rated themselves as very confident for all the questions they attempted and so were scored at 100%. They were all enrolled in the primary course. Four of these were male and as the mean of their scores for the attempted questions was over 80% this may well have been justified. Of the six females one scored only 39% on the questions she answered and so she was identified as needing encouragement to be more realistic about her ability without causing her to lose all her confidence. The other five had a mean score of 72% so they were still somewhat optimistic about their ability. Only four of these students completed exit confidence surveys and their scores were consistent with data from other students, i.e. performance confidence scores were higher on exit than on entry and exit teaching confidence scores were lower than exit performance confidence scores.

At the other end of the scale, 11 students, all female, scored themselves at less than 30% i.e. in most questions they were not at all confident about their answers. Eight of these were enrolled in the Early Childhood course and had a mean score of 42% on the questions they had attempted, while the other three Primary students had a mean of 45%. Hence their lack of confidence was probably justified. Only one of these primary students completed the exit confidence survey and had scores over 90 for teaching and performance confidence. Even seen through the rosiest of glasses, this seems a little unrealistic as a general expectation and may be a function of this individual student.

Primary students had more confidence than ECS students in all strands in both years, although scores in Algebra were close (Table 4.25). Again this is similar to the performance data. Male students were significantly more confident than female students across all strands (Table 4.34). There were no significant age group effects in confidence levels apart from Chance and Data questions in 2006 but there do not appear to be any particular reasons for this anomaly (Table 4.45).

Effectiveness of the intervention

The gap between ECS and primary students was much narrower on exit than at the start of the unit (Tables 4.26 and 4.29). ECS students improved their scores more than primary students and, while a number of possible explanations have been proffered by staff, there is no direct evidence to support any particular factor. ECS students were almost exclusively female and in general female students showed greater levels of improvement than males. ECS students may have been more motivated to address their weaknesses because they scored lower marks in the entry task. ECS students had their own tutorials with a different tutor who was not usually a mathematics specialist and tended to focus on algorithmic approaches to answering the questions rather than the broader skill development encouraged by the tutors in the Primary tutorials. ECS students seem to have more highly developed peer networks in a smaller program and this may have provided weaker students with extra support and more able students with an opportunity to clarify their understandings through sharing their skills.

Male students continued to outperform female students although the gap between the two groups was smaller than in the entry test (Table 4.35). Tutors kept attendance records and noted that male students had more absences than female students and when they did come to class there was a tendency for them to arrive late and leave early. This seems symptomatic of an attitude where they were only prepared to put in the minimum effort required to reach the benchmark and may be one reason they did not show as much improvement.

Age group was not a significant factor influencing exit performance in either year.

There were no differences between ECS and Primary students in terms of the number of attempts they had to pass the unit and male students generally had fewer attempts than females. The number of attempts did not vary significantly across age groups (Tables 4.27, 4.36 and 4.47).

The trends in the overall performance of students on exit from the unit were mirrored when the results were analysed by strand. Males scored higher than females in virtually all areas and Primary students scored better than ECS students. However the scores generally were closer than they were on entry to the unit for students from different courses (Table 4.29) and different genders (Table 4.40). There were virtually no age related differences in performances in either year (Tables 4.28, 4.37 and 4.48).

Male students were more confident on exit than female students (Table 4.38) but the differences across age groups were not significant in either year (Table 4.49). The latter finding is at odds with the anecdotal evidence from tutors that mature age students were more worried about their performance. A possible explanation is that older students were more comfortable discussing their concerns about their lack of skills and confidence with the staff whereas younger students recorded low confidence levels but did not openly talk about them.

Course comparisons in exit confidence were not possible as ECS students did not complete the survey.

When exit confidence levels were considered for each separate strand of questions, the overall trends were repeated. While male students were more confident than their female counterparts in their performance in Number and Measurement, there were no significant differences in performance confidence for the other strands (Table 4.39). Measurement questions showed some age related differences in performance confidence (Table 4.50) with 22-25 year old students more confident in 2006. However this group was the least confident in 2007 so the variation is not consistent.

Subsequent events and implications for the future

Since the data for the study was collected, the *Becoming Multiliterate* unit has been delivered in 2008 and 2009 in virtually the same format. Minor changes have included:

- Removal of the two week ICT module as new students had better skills in this area and the content was addressed in other units such as *Becoming Effective Learners.* Higher order ICT skills and the use of ICT in the classroom were covered in a later unit in the course which focused on the Technology and Enterprise learning area.
- Splitting the entry tasks so that the diagnostic assessment for each module was held in the first week of its rotation.
- Using all twelve weeks of the unit for the three remaining modules so each area had four weeks, although time was devoted to the entry and assessment tasks in weeks one and four of each rotation.

Student performance data for those two years showed very similar trends to 2006 and 2007 as can be seen in Table 5.1. If anything, students were entering their course with lower standards of numeracy, possibly linked to an extension of alternative entry programs. The extent to which this was the case is the subject of other research at the university into factors affecting retention amongst first year students. Fortunately, substantial improvement in scores was demonstrated by the end of the unit with the particularly weak students in 2009 showing greatest gains, possibly due to the change to a four week module.

Table 5.1 Mathematics Results for Years 2006 to 2009

Year	Number of students enrolled	Passed on entry		Mean score on entry	Passed on exit		Mean score on exit
		n	%	%	n	%	%
2006	337	38	11	51	250	74.4	78
2007	344	19	5.5	46	228	66.3	77
2008	371	19	5.1	47	246	66.3	71
2009	344	19	5.5	37	262	76.1	77

Based on the experience with repeating students, the concerns about the extent to which the improvement was maintained in subsequent years have led to the inclusion of mathematics skills sections in each of the examinations for the second and third year mathematics methods units. However, it has not been possible to set a benchmark above 50% within the university assessment guidelines for these units, so students have not had the incentive to achieve high scores. Staff and students have still reported high levels of anxiety about mathematical competence and extra revision classes have been well attended.

While there has not yet been a formal statement of a requirement for teacher registration in Western Australia to include mathematics competence, Queensland will have such a standard in place shortly (Ferrari, 2009). The draft *National Professional Standards for Teachers* (Australian Education, 2010) includes specific reference to teachers being able to “know and understand the theoretical basis of how students develop literacy and numeracy and understand the supportive role of literacy and numeracy in underpinning student learning” (p. 9) and “know and understand how to select content appropriate to students’ stages of development and proficiency in literacy and numeracy” (p. 10). How it will be determined that teachers can meet these standards has yet to be defined.

The planned introduction of the Australian Curriculum has seen the production of a draft consultation document for mathematics in schools from kindergarten to year 10. (Australian Curriculum Assessment and Reporting Authority, 2010). While still in developmental form, the indications are that the new standards for primary school will be significantly higher than they have been in Western Australia. The Achievement Standard for year 7 states that

> By the end of Year 7, students work fluently with index notation. They are able to use the operations to calculate accurately with integers, fractions and decimals, choosing appropriate operations when solving problems, and correctly applying the order of operations. They extend this understanding to algebraic representations, selecting and applying formulas for area and volume and begin to generalise arithmetic patterns, including linear functions, representing them algebraically and graphically. Students conduct systematic data-based enquiry using univariate and bivariate data, choosing appropriate graphs, calculating measures of spread and centre and drawing conclusions. They identify equally likely outcomes and calculate probabilities and relative frequencies from data. Students have a sound understanding of the geometric properties of angles, triangles and quadrilaterals and two-dimensional views of three-dimensional objects. They are beginning to construct logical geometric arguments about properties of triangles and quadrilaterals. (Australian Curriculum Assessment and Reporting Authority, 2010, p.18).

A number of these topics will be new to year 7 in Western Australian schools and pre-service teachers will need more skill development than has currently been available in the *Becoming Multiliterate* unit. In particular the following will need to be added:

- Index notation
- Arithmetic with fractions
- Algebraic representations
- Formulas for area and volume
- Linear functions
- Geometrical reasoning

As a result of the staff concerns and the governmental changes discussed above, the single *Becoming Multiliterate* unit has been split in 2010 to form two units, one in each semester of the first year of the degree for primary students. The first is LAN1000 *Literacy for Teachers* which implements the original recommendation from Rivalland (2005) that a full unit focusing on written literacy be introduced. Primary students complete this unit in semester one and ECS students have a similar unit LIT1000 *Principles and Practices of Academic Literacy.* In semester two primary students (but not ECS students) enrol in a new unit SAM1000 *Science and mathematics for teachers* in which mathematical and scientific literacy are developed in an integrated way. Scientific process and content knowledge are addressed through practical activities using mathematical skills and understanding in areas such as space and measurement, data collection and processing, classification and ordering. Mathematical activities use science related contexts to develop and practise key competencies and understanding. Many of the staff who have worked in the *Becoming Multiliterate* unit for a number of years were involved in the development of the two new units and see them as a natural and necessary extension of the work they have been doing previously. It is anticipated that a similar exercise to this study will be used to evaluate the impact of the expanded units on student performance and confidence.

A more recent event is the establishment of working parties to develop a single Bachelor of Education - Primary degree across all campuses of the university. This will replace the existing degree and the BEd - Kindergarten through Primary degree and will be complemented by a separate BEd in Early Childhood Studies which is also being reviewed. A key feature of the new programs will be the importance of producing graduates with high standards of personal literacy and numeracy so the work that has been done in this study will be valuable in informing the debate in the working parties.

Results summary

Mathematical competence

The evidence gathered in this study indicates that widespread concerns about low levels of mathematical skills and knowledge amongst pre-service teachers are well founded, in Western Australia at least. Given that the university produces the largest number of primary teachers in the state in a given year compared to the other institutions, the students enrolled in *Becoming Multiliterate* represent a significant part of the state’s future primary school workforce. Despite the variety of backgrounds from which they enter university, few of them were able to achieve a reasonable score in an assessment task which is based on work that might typically be within the capabilities of a year seven student. There appears to be a clear need for intervention programs such as the unit described in this study.

Mathematical confidence

While absolute scores cannot be directly compared, student confidence levels were higher than their actual performance would indicate was appropriate. Mean total confidence scores of 72% and 65% correspond to most students feeling reasonably confident that they were able to answer the questions correctly.

Primary education students were more confident than those in the Early Childhood course and males were more confident than females. Males were over-represented in the group that scored 100% and no males were in the group which reported they had virtually no confidence at all.

While confidence levels were higher than performance indicated they should be, the design of the intervention was intended to address poor skills and low levels of understanding without adversely impacting on confidence. The extent to which this was achieved is the focus of the third research question.

Areas of strength and weakness

As might be expected, students performed best in questions related to Number topics as the content was familiar and the questions were early in the paper. They did not perform well in Measurement questions, including knowledge of the metric system, and demonstrated some confusion between perimeter and area, and surface area and volume. Those who reached the end of the paper and answered the Algebra questions did reasonably well but few students were able to work quickly enough to answer the whole paper.

Effectiveness of intervention program in improving competence and confidence

The unit was designed so that individual student performance in the exit assessment could not be worse than it was on entry so student scores had to improve. The extent to which this occurred was significant with mean scores increasing from 51% and 46% on entry to 78% and 77% on exit in 2006 and 2007 respectively.

Students were able to attempt all questions on exit as the ones they had already completed successfully did not have to be repeated and this meant more time was available for the remaining questions. This was a deliberate strategy to improve attitude as well as performance and appears to have been successful.

Confidence levels on exit were assessed in two ways. Students indicated the extent to which they were now confident they could answer the questions correctly and these scores were significantly higher than they were on entry, with some justification as skills had improved. Students also rated their confidence in their ability to teach the content exemplified by the question and while there are no comparisons with entry data, these levels were reasonably high. However, they were not as high as their performance confidence indicating that the students recognised that being able to do something yourself is not the same as being able to do it well enough to explain it to others.

As well as analysing the data collected through the assessment tasks, the effectiveness of the unit was investigated through the student evaluations. High scores were obtained for virtually all aspects of the Unit evaluation and scores for Teaching Effectiveness were better than the overall School and Faculty results. The optional comments written by students indicated high levels of satisfaction with the approach taken in the unit, with very positive statements about the work of the tutors.

Age, gender and course variations

There are some variations between courses (Primary degree students performed better than Early Childhood students) and genders (males performed better than females) but results were consistent across age groups indicating that mature age students, who may not have studied mathematics for a number of years, were no weaker than their peers who had recently left school.

Primary education students were more confident on entry than those in the Early Childhood course and males were more confident than females. Males were over-represented in the group that scored 100% and no males were in the group which reported they had virtually no confidence at all. When the confidence data from students from different age groups was analysed, there were no significant differences, refuting tutor perceptions that older students were more lacking in confidence than their younger peers.

Gaps between courses and genders narrowed in the exit tests so there was greater uniformity of performance across the various sub-groups. Male students continued to be more confident than females about their own ability but there were no significant variations in confidence across age groups at the end of the unit although there had been an overall improvement.

Chapter 6

Conclusion

This chapter revisits the original research questions and summarises the extent to which they have been answered and then considers the implications for further study and the education of pre-service primary teachers. While the study was based at a single institution, a number of findings reflect those of other researchers and confirm that concerns about pre-service teacher numeracy are well founded. Results indicate that the intervention approach was successful in the short term but it remains to be seen whether the improvements in competence continue through the rest of the course.

How competent are first year pre-service primary teachers in primary school mathematics curriculum content?

In this study, the performance of the students on entry to their degree course was determined through a short answer test where each question was linked to a specific desirable outcome. As the questions were based on the Western Australian benchmarks for year nine students and were therefore within the capabilities of many year seven students, one might have expected that students who had met university entrance requirements would have been able to demonstrate mathematical skills and knowledge at that level. Unfortunately, student results were similar to the standards identified in other research both in Australia and overseas (Committee for the Review of Teaching and Teacher Education, 2003; Education Queensland, 2004; Goulding, et al., 2002; Hungerford, 1994).

As the study was conducted over a two year period, it was possible to verify that results were not simply a function of a particular cohort and although there were differences between the 2006 and 2007 students, the overall patterns and trends were similar. The mean scores in the entry task were 50.9% and 45.6% for 2006 and 2007 respectively, meaning that students could not demonstrate half the required content.

The pass mark was set at 70% in 2006 when 37 (11.6%) students passed on entry but was raised to 75% in 2007 when only 18 (5.2%) students achieved the required standard out of a total of over 300 students each year.

How confident are pre-service primary teachers about their mathematical ability?

Students indicated their level of confidence in having answered each question correctly as they completed the entry task and in general most of them were "reasonably confident" with what they had done. This was at odds with the level of actual performance and was not expected as it was believed that students would express higher levels of anxiety and stress than are reflected in the mean confidence scores. However, this finding was consistent with the results obtained by (Southwell, et al., 2005) who also found that quite weak students had high, albeit misplaced, levels of confidence. In terms of this study it was therefore important to ensure that identifying poor performance levels was done in such a way that students could demonstrate more realistic levels of confidence without being significantly disheartened and this confirmed the need for the Commend-Recommend-Commend (CRC) approach.

What are the particular areas of mathematical strength and weakness amongst pre-service primary teachers?

Students generally performed better in the questions related to the number outcomes although this may be related to the fact that these were at the start of the paper while students were fresh and less rushed, as well as students being more familiar with the calculation aspects of mathematics. Students scored lowest on the algebra questions at the end of the paper and many did not even attempt these on entry. However, the Measurement questions preceded those on Chance and Data and Space outcomes but students achieved lower mean scores in that section. It was therefore seen as important that the intervention considered student needs in each cluster separately rather than just considering overall performance. The approach of identifying specific outcomes where competence had not been demonstrated, and providing materials and resources to students to improve those particular skills, enabled staff and students to target weaknesses and avoid the frustration of having to practise and repeat skills which were already of a satisfactory standard.

How effective is a specially designed intervention program in improving competence and confidence in mathematics amongst pre-service primary teachers?

While the structure of the module and assessments was such that students could not go backwards, the degree of improvement shown between the entry and exit tasks was significant. The majority of students who did not pass on entry were able to meet the required benchmarks in their first attempt at the exit assessment, immediately after completing the three week module. The rest continued to have further attempts at the exit tasks with mixed success, with some taking full advantage of the extra time to refine their skills, but others seemed to labour under the misapprehension that simply taking the test again would mean they would eventually pass, regardless of the fact that they had done little more practice. A number of students who failed the unit in 2006 re-enrolled in 2007 but, despite more time and opportunity to improve, they still performed less well than students enrolled for the first time. It would seem that if problems are deep seated enough to not be addressed within one semester, they are unlikely to improve in the longer term either, at least as far as this particular intervention is concerned. The role of the unit as a *critical filter* for entry into teaching is worthy of further investigation through tracking the ongoing progress of students who only just met the standards after multiple attempts.

As well as helping students to improve their competence, the design of the unit was intended to ensure that identifying weaknesses did not have a negative impact on confidence. As the students showed a tendency to over-confidence on entry, it would have been reasonable to accept a small decrease to a level more in keeping with actual performance but in fact scores increased indicating that students were more confident about their actual performance to answer the questions at the end of the unit than they had been at the beginning. This would seem to indicate that the CRC strategy was successful as a way of formalising what many staff already did as part of their supportive approach to teaching. However, it should be noted that exit confidence data was not available for ECS students who were generally less confident than their primary peers on entry and the response rate for primary students was only about 50%.

In addition, the exit confidence survey asked students to indicate how confident they felt about being able to teach the concepts associated with each question. Scores here were generally lower, reflecting what might be considered to be a realistic sense that knowing something yourself was different to teaching it to someone else. While not intended, this is a positive outcome from the intervention; students recognise that there is more to teaching than just “knowing your stuff” (Sobel & Maletsky, 1975), important as that is.

Are there any gender, age or course differences in pre-service primary teachers’ performance, confidence and self efficacy before, during and after the intervention program?

Gender

There were significant differences between male and female students although effects were potentially distorted by the relative small proportion of males enrolled in the courses and the fact that on average they were older than the female students.

Male students significantly outperformed females on entry to the unit in terms of their overall score and across the individual clusters. In addition they had higher levels of confidence on entry, not necessarily as misplaced as the lower achieving females.

In the exit assessments males continued to do better but the gender gap was considerably smaller. Evidence from tutors indicated that males had poorer attendance records and showed a tendency to do enough to pass – and little more. When exit results were analysed by cluster, the gender differences were still in favour of males but were barely significant. They were still marginally more confident about their actual performance to answer the questions than the female students but confidence in teaching the content was virtually the same for all students.

Age

Despite anecdotal comments from staff and perceptions from previous experience, students did not show any significant variation in competence or confidence across different age groups, neither on entry nor exit. It would seem that while mature age students returning to study after a break of several years may protest that they lack confidence and skills compared to their school leaver peers, in fact the school leavers demonstrate many of the same shortcomings but are less vocal about expressing them. This was reassuring as it meant that similar strategies and approaches appear to be effective with all students regardless of age and educational background.

Course

The results for the two cohorts of students enrolled in the primary and early childhood degrees were compared and showed that primary students were more able and more confident on entry than their early childhood peers. However, the exit scores were not significantly different meaning that the ECS students had improved proportionately more than those in the primary course. While there do not seem to be definitive reasons for this, suggested causes included the smaller cohort and sense of peer support amongst ECS students, and the fact that lower entry scores provided a spur to greater improvement. A complicating factor may have been the gender imbalance in the courses with very few higher achieving males in ECS to boost overall scores.

As ECS students did not complete exit confidence surveys, course comparisons of those scores were not possible.

Implications for ongoing practice

The *Becoming Multiliterate* unit was taught in the same form in 2008 and 2009 with similar results. Changes were made to the actual questions in the tasks to prevent students becoming over-familiar with the content and to allow a wider coverage of the outcome content. It became increasingly clear that the relatively low level of intervention was not sufficient to ensure student literacy and numeracy standards were sufficiently high in the long term. The prospect of externally imposed standards for graduating teachers provided extra incentive to course approval committees to approve staff requests for more time to develop the personal literacies of students and in 2010 two units replaced *Becoming Multiliterate* in the primary BEd course. The first of these, LAN1000 *Literacy for teachers*, was offered in semester one of first year and focused on written literacy and academic writing skills. The second, SAM1000 *Science and mathematics for teachers*, ran semester two and focused on developing numeracy and scientific literacy skills. It was not delivered in separate modules but sought to develop mathematics skills in the context of working scientifically. The synergies of combining the content enabled richer tasks to be completed in class while students still had access to Mathletics and other resources to practise their numeracy skills, including those relevant to science such as measurement, classification, data processing and presentation and investigating. The units maintained their philosophical emphasis on improving both competence and confidence with the same staff involved in their delivery and a continued use of the CRC approach.

Concerns about maintaining the improvement shown in the unit through the following three years of the course have been addressed by requiring students in mathematics education units to demonstrate their personal mathematical competence in end of semester examinations. Access to resources and the Mathletics site continues and tutorial activities on mathematics pedagogy have a dual role in modelling good teaching practice and serving as a reminder of concepts and skills.

Ongoing contact with students indicates that their appreciation of the unit increases when they find themselves in schools during practicum and feel more confident about their actual performance to cope with helping children to learn mathematics.

Implications for further research

This research has raised a number of questions which warrant further investigations. The particular areas of strength and weakness amongst students deserve deeper analysis in an attempt to identify particular misconceptions held by pre-service teachers and to identify more effective intervention strategies. The restrictions of a three week module with over 300 students required a broad brush approach but with the experience that has already been gained and a longer time frame it would be of benefit to staff and students to look more closely at those outcomes where students performed particularly badly as well as trying to learn from areas where students had few problems.

It will also be of interest to see whether a whole semester unit leads to a significantly greater improvement in skills and understanding than was possible in three weeks and whether the effects on confidence are mirrored in the new units.

The content of the unit was designed to meet WA curriculum requirements but was probably generic enough to enable most graduate students to deal with the forthcoming changes to a national curriculum. Some changes to the intended outcomes have been developed and implemented in the new SAM1000 *Science and Mathematics for Teachers* unit in 2010 and 2011 based on the documents now available (Australian Curriculum Assessment and Reporting Authority, 2011).

The importance of having primary teachers who are both competent and confident in mathematics cannot be underestimated in a world which is increasingly reliant on science and technology and where business requires a strong knowledge of mathematics and statistics to make sense of the masses of data generated by economic analysts. If students are to graduate from high school with the requisite skills, they need a firm foundation in primary school and it is not enough to assume that pre-service teachers who have met university entry requirements have the appropriate mathematical knowledge to teach others. Nor is it enough to simply provide resources and hope they will fix their own shortcomings. This research describes an approach which recognises that students need personal support as well as practical resources if they are to succeed in developing both their ability to perform mathematical tasks and their confidence in that ability. The two pronged approach to address the nexus between confidence and competence is what makes this study significant.

The results of this study indicate that the intervention program based on the mathematics module *Becoming Multiliterate* unit has been successful in achieving its intended goals. Students have an improved knowledge of their “stuff” but efforts need to continue throughout the course to ensure they learn about “the students they intend to stuff” and develop their repertoire of strategies to “stuff them artistically” (source unknown, cited in Sobel & Maletsky, 1975, p. 2). All three aspects are required if pre-service primary teachers are to be adequately prepared to meet the challenges of teaching mathematics in schools further into the twenty first century.

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Appendix A Unit outline report

EDITH COWAN UNIVERSITY
FACULTY OF EDUCATION & ARTS
SCHOOL OF EDUCATION

UNIT TITLE : Becoming Multi Literate
UNIT CODE : EDF1103
CREDIT POINTS : 15
FULL YEAR UNIT : No
MODE OF DELIVERY : On-campus

DESCRIPTION
This is a competency based unit that platforms all students in terms of written English literacy, numeracy, basic scientific literacy and the use of information and communications technology. Following a benchmarking process across the first three areas, students complete designated modules to complete to enrich their current levels of literacy. Students are given multiple opportunities to achieve the required standards.

LEARNING OUTCOMES
On successful completion of this unit, students should be able to:

1. demonstrate competence in the responsible use of technology systems, information and software to locate, evaluate and collect information from a variety of sources, and interact with peers, experts and other audiences;
2. demonstrate competence with Science process and investigation skills;
3. demonstrate competence in Mathematics skills and content knowledge appropriate for primary school teaching:
4. demonstrate competence in writing across a range of genres and the correct use of English grammar, syntax and punctuation.

UNIT CONTENT
Learning tasks and processes that develop competence and confidence in personal written, mathematical, scientific and ICT literacies. Students will be enabled to identify their personal learning needs and tutors will then provide print and electronic resources as well as the personal support required to improve individual skill levels.

TEACHING AND LEARNING PROCESSES
This unit will be taken through a series of practical workshops and laboratory sessions. Online activities will be a major feature.

TEACHING AND LEARNING RESOURCES
Workshops, laboratories, online, library.

GRADUATE ATTRIBUTES

- Communication
- Teamwork
- Enterprise, Initiative and Creativity
- Problem solving / Decision Making
- Use of Technology / Information Literacy

ASSESSMENT

Grading Schema 4

Pass/Fail. As this is a competency based unit, students will be awarded a Passing grade (P) on the successful completion of each of four benchmark tests. A student who receives a fail grade (F) will be required to repeat any or all of the modules of learning until a pass grade is awarded. If a student fails the modules after multiple attempts, the student will be asked to repeat the unit. Where a student has failed the unit twice, the student shall be excluded from the course.

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WEB SITES

Free shared access to a specifically tailored mathematics skill development website will be available from any computer with internet connectivity. The site also provides practice in improving spelling skills.

http://www.mathletics.com.au

Academic Misconduct

Edith Cowan University has firm rules governing academic misconduct and there are substantial penalties that can be applied to students who are found in breach of these rules. Academic misconduct includes, but is not limited to:

- plagiarism;
- unauthorised collaboration;
- cheating in examinations;
- theft of other students' work.

Additionally, any material submitted for assessment purposes must be work that has not been submitted previously, by any person, for any other unit at ECU or elsewhere.

The ECU rules and policies governing all academic activities, including misconduct, can be accessed through the ECU website.

Appendix B Orientation information

EDF1103 Becoming Multiliterate

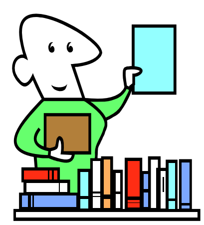
Welcome to the beginning of a rewarding career in teaching. As many of you will have seen in the media, there is widespread concern about the standards of literacy and numeracy in Australian schools, so when you graduate it will be essential for you to be able to teach these important skills. This unit will help you to do this and ensure you gain maximum benefit from the rest of your program of study at university.

Some of you will have just left school, others have taken a short break between school and university and for some your own school days are becoming a distant memory. In addition you have a wide range of reading, writing and mathematical skill levels, not to mention your actual performance to use computers and understand scientific principles. To cater for this variety of needs this unit has been designed to first identify your existing skills and then provide personalised programs to help you to fill any gaps.

How will it work?

In week one you will be given a Unit Plan which will have full details of the structure of the unit and what you have to do to succeed. What follows here is a summary to help alleviate any concerns you may have.

First of all, the unit is competency based ie you have to show us what you can **do**. Everyone starts with a clean slate and in the first week of classes we will be asking you to complete a series of tasks in written, mathematical and scientific literacy. **Please bring a ruler to this first class as well as pens and pencils.** The standard required for mathematics and science is about Level 4 of the WA Curriculum, roughly year 8/9. In writing and ICT you need skills both for teaching and for your own studies so we will be ensuring you can write and use a computer at an appropriate academic level.



Over the following two weeks all students will be required to complete further tasks in information and communication technology, in particular using the various e-learning facilities at Edith Cowan University. **You will need to purchase a thumb drive** (memory stick, iPod or similar device) to save any work you do in class, as all documents are wiped off the laboratory computers each day. This also means you can work on tasks at home and bring them in to show your tutor what you have achieved.

The staff will use this time to mark the tasks from week one and some of you will have met the required standards in all areas. Those students will be considered to have passed the unit once their ITC tasks are completed. While they do not have to attend classes after week four, but are welcome to continue in their tutorial group to refine their skills and learn some new ideas for use in classrooms on teaching practice. Other students may have met the standards in one or two areas and some may need help in all three. The remaining nine weeks of semester will be devoted to completing modules of work in these areas and students will attend as needed.

EDF1103 Calendar for Semester One 2006

Date	Week	
27 Feb	1	**All students complete entry tasks in Written, Scientific and Mathematical Literacy**
6 Mar	2	**ITC Week 1**
13 Mar	3	**ITC week 2**
20 Mar	4	**Module 1 Week 1**
27 Mar	5	**Module 1 Week 2**
3 Apr	**Assigned work**	
10 Apr	**Assigned work**	
17 Apr	**Mid-semester break**	
24 Apr	6	**Module 1 Week 3**
1 May	7	**Module 2 Week 1**
8 May	8	**Module 2 Week 2**
15 May	9	**Module 2 Week 3**
22 May	10	**Module 3 Week 1**
29 May	11	**Module 3 Week 2**
5 Jun	12	**Module 3 Week 3**
12 Jun	**EXAMINATIONS FOR OTHER UNITS**	
19 Jun	Students may use these weeks to complete assessment tasks.	

Each module will have a checklist of tasks to be demonstrated and a range of resources will be available – CDs, websites, print materials, hands-on tasks and of course patient tutors. As you will only be in class for less than three hours per week, the modules will require you to practise skills and work on tasks between sessions. This may be at home, if you have access to suitable resources, or on campus using the student computer laboratories, the library or the coffee shop (to meet and study with friends!). Tutors are facilitators – they will help you find out what you need to do and suggest appropriate activities to fill any gaps but they cannot do your work for you!

The Unit Guide lists some texts that you will need to purchase from the bookshop if you need to complete the written literacy modules. If you need help with your mathematical literacy there is a recommended website with personal access at any time. Those who meet the required standard will also find these useful for extra practice and for teaching ideas so they should consider accessing for use in their ongoing studies.

What about those students who need more time to demonstrate skills?
Although most students will meet the unit requirements within each three week module, some may need more assistance or more time. Various options are available. The School of Education has access to a Faculty Academic Support Adviser who runs workshops throughout the semester on academic writing. She is also available for small group support, but only for students who have already attended her workshops. You can visit the website at
http://www.ea.ecu.edu.au/fo/teaching_learning/learning_support.php
Courses are also available at Canning College and information will be provided on these as needed.

If the required competencies have not been demonstrated by the end of semester one, you will receive a Hold grade on your transcript. You will then have till the beginning of semester two to complete the necessary tasks and do some extra practice over the break. Any student who has not passed this unit by the end of week one of semester two will need to repeat the unit.
More questions? Contact Brenda Hamlett (Unit Coordinator)
Room 16.150 Ph 9370 6646 Email: b.hamlett@ecu.edu.au

Appendix C Mathematical Literacy Checklist

Student Name ________________________

The table below contains a list of the mathematical skills you will need to demonstrate to successfully complete this unit. It is based on the outcomes expected of children working at level 4 of the Mathematics Curriculum who are probably in years seven to nine. The pass mark is 75%. Use the middle column to record whether you passed the outcome in the entry task. You might also like to make some notes or put in some examples to remind yourself what you have to do.

		Notes
Working Mathematically Students use mathematical thinking processes and skills in interpreting and dealing with mathematical and non-mathematical situations.		
WM1 Check all answers carefully using methods such as estimation and checking reasonableness.	***Not assessed directly – you should do this for every question.***	
Number Students use numbers and operations and the relationships between them efficiently and flexibly.		
N1 Write large and small numbers in figures and words		
N2 Put fractions and decimals in increasing or decreasing order		
N3 Locate fractions and decimals on number lines and scales		
N4 Explain which will be the correct operations to use when presented with word problems		
N5 Add, subtract, multiply and divide whole numbers and decimals using mental arithmetic and pen and paper methods		
N6 Perform calculations involving money using the four operations		
Measurement Students use direct and indirect measurement and estimation skills to describe, compare, evaluate, plan and construct.		
M1 Measure the length of line segments		
M2 Convert among units within the metric system eg cm to m, kg to g		
M3 Determine the perimeter, area or volume of shapes which can be decomposed into squares or cubes		
M4 Find lengths, areas and volumes of shapes which have been enlarged or reduced by a simple scale factor eg on maps or scale models		
M5 Provide estimates of the size or mass of objects within the room		

		Notes
Chance and Data **Students use their knowledge of chance and data handling processes in dealing with data and with situations in which uncertainty is involved.**		
C1 Estimate the probactual performance of simple events eg a particular outcome when rolling a die		
C2 Summarise a data set eg find mean, maximum, range, relative frequency of a given value.		
C3 Answer questions about data presented in the form of tables and graphs.	*Included in science assessment task*	
Space **Students describe and analyse mathematically the spatial features of objects, environments and movements.**		
S1 Draw representations of simple three dimensional shapes eg plan and elevation, perspective view		
S2 Interpret maps in terms of the direction and distance between points.		
S3 Identify the symmetry properties of figures in two and three dimensions		
S4 Sketch the image of 2D shapes after reflection or rotation		
S5 Identify properties of shapes such as parallel and perpendicular lines, congruent and similar figures, acute and obtuse angles		
Pre-algebra and Algebra **Students use algebraic symbols, diagrams and graphs to understand and to reason.**		
A1 Write a simple story explaining the changes in a quantity represented on a graph eg mood changes during the day, traffic flow data		
A2 Continue simple sequences of numbers or shapes, explaining how to obtain the answer		
A3 Solve "find the missing number" problems		

Note that in many cases a single question in the assessment task can cover several skills. For example:

- **Continuing a sequence may involve multiplying numbers and solving a "missing number" problem.**
- **Reading a map may require measuring a length and using a scale factor**
- **You may be asked to draw a shape made up of cubes and also find its surface area and volume**

Appendix D Western Australian Progress Maps: Mathematics Level 3 and 4 Descriptors

Working Mathematically *Students use mathematical thinking processes and skills in interpreting and dealing with mathematical and non-mathematical situations.*		
	LEVEL 3	**LEVEL 4**
Mathematical strategies Students call on a repertoire of general problem-solving techniques, appropriate technology and personal and collaborative management strategies when working mathematically.	WM 3.3 **The student:** Poses mathematical questions prompted by a specific stimulus or familiar context and uses problem-solving strategies that include those based on representing key information in models, diagrams and lists.	WM 3.4 **The student:** Asks questions to clarify the essential mathematical features of a problem and uses problem-solving strategies that include those based on identifying and organising key information.
Apply and verify Students choose mathematical ideas and tools to fit the constraints in a practical situation, interpret and make sense of the results within the context and evaluate the appropriateness of the methods used.	WM 4.3 **The student:** Uses alternative ways, when prompted, to check working and choice of method.	WM 4.4 **The student:** Checks, when prompted, that answers are roughly as expected and that methods and answers make sense.
Reason mathematically Students investigate, generalise and reason about patterns in number, space and data, explaining and justifying conclusions reached.	WM 5.3 **The student:** Understands mathematical conjectures as being more than simply a guess, makes straightforward tests of conjectures and discards those that fail the test.	WM 5.4 **The student:** Uses examples to support or refute mathematical conjectures and attempts to make simple modifications of conjectures on the basis of examples.

Extracted from:

Curriculum Council. (2005b). *Curriculum Framework: Progress Maps - Mathematics.* Perth. WA: Curriculum Council.

Number *Students use numbers and operations and the relationships between them efficiently and flexibly.*		
	LEVEL 3	**LEVEL 4**
Understand numbers Students read, write and understand the meaning, order and relative magnitudes of numbers, moving flexibly between equivalent forms.	N 6a.3 *Understand whole numbers and decimals* **The student:** Reads, writes, says, counts with and compares whole numbers into the thousands, money and familiar measurements. N 6b.3 *Understand fractions* **The student:** Reads, writes, says and understands the meaning of unit fractions, flexibly partitioning and rearranging quantities to show equal parts	N 6a.4 *Understand whole numbers and decimals* **The student:** Reads, writes, says, counts with and compares whole numbers into the millions and decimals (to an equal number of decimal places). N 6b.4 *Understand fractions* **The student:** Reads, writes, says and understands the meaning of fractions. The student estimates the relative size and order of readily-visualised fractions, including key percentages, and shows equivalence between them.
Understand operations Students understand the meaning, use and connections between addition, multiplication, subtraction and division.	N 7.3 **The student:** Understands the meaning, use and connections between the four operations on whole numbers, and uses this understanding to choose appropriate operations and construct and complete simple equivalent statements.	N 7.4 **The student:** Understands the meaning, use and connections between the four operations on whole and decimal numbers, and uses this understanding to choose appropriate operations (whole multipliers and divisors), including those for familiar everyday rates, and constructs and completes equivalent statements.
Calculate Students choose and use a repertoire of mental, paper and calculator computational strategies for each operations, meeting needed degrees of accuracy and judging the reasonableness of results.	N 8.3 **The student:** Adds and subtracts whole numbers, money and fractions with the same denominator, multiplying and dividing by one-digit whole numbers, using mainly mental strategies for doubling, halving, adding to 100 and additions and subtractions derived readily from basic facts.	N 8.4 **The student:** Calculates with whole numbers, money and measures (at least multipliers and divisors to 10), drawing mostly on mental strategies to add and subtract two-digit numbers and for multiplications and divisions related to basic facts, including finding the unit fraction of a number which is a multiple of the denominator.

Extracted from:

Curriculum Council. (2005b). *Curriculum Framework: Progress Maps - Mathematics.* Perth. WA: Curriculum Council.

Measurement *Students use direct and indirect measurement and estimation skills to describe, compare, evaluate, plan and construct.*		
	LEVEL 3	**LEVEL 4**
Understand units and direct measure Students decide what needs to be measured and carry out measurements of length, capacity/volume, mass, area, time and angle to needed levels of accuracy.	M 9a.3 *Understand units* **The student:** Realises that using a uniform unit repeatedly to match an object gives a measure of the size of the object, and chooses suitable and uniform things to use as units and a common unit to compare two things. M 9b.3 *Direct measure* **The student:** Compares directly and indirectly and orders things by length, area, capacity, mass, time and angle, measures them by counting uniform units and uses standard scales to measure length and time.	M 9a.4 ***Understand units*** **The student:** Selects appropriate attributes, distinguishes perimeter from area, area from volume and time from elapsed time, and chooses units of a sensible size for the descriptions and comparisons to be made. M 9b.4 *Direct measure* **The student:** Measures area by counting uniform units, including part-units where required, volume by counting cubes and length, mass, capacity, time and angle by reading whole-number scales.
Indirect measure Students select, interpret and combine measurements, measurement relationships and formulate to determine other measures indirectly.	M 10a.3 *Measurement relationships* **The student:** Understands and measures perimeter directly and uses straightforward arithmetic to determine perimeters, key elapsed time and other measurements which cannot be obtained directly. M 10b.3 *Scale* **The student:** Attends informally to scale when making and using plans, maps and models.	M 10a.4 *Measurement relationships* **The student:** Understands elapsed time and relationships involving the perimeter of polygons, the area of regions based on squares and the volume of prisms based on cubes, and uses these for practical purposes. M 10b.4 *Scale* **The student:** Understands and uses scale factors involving small whole numbers and unit fractions for straightforward tasks, including those that involve making figures and objects on grids and with cubes.
Estimate Students make sensible direct and indirect estimates of quantities and are alert to the reasonableness of measurements and results.	M 11.3 **The student:** Makes sensible numerical estimates using units that can be seen or handled and uses language such as ‘between’ to describe estimates.	M 11.4 **The student:** Uses the known size of familiar things to help make and improve estimates, including centimetres, metres, kilograms, litres and minutes.

Extracted from:
Curriculum Council. (2005b). *Curriculum Framework: Progress Maps - Mathematics.* Perth. WA: Curriculum Council.

Space *Students describe and analyse mathematically the spatial features of objects, environments and movements.*		
	LEVEL 3	**LEVEL 4**
Represent spatial ideas Students visualise, draw and model shapes, locations and arrangements and predict and show the effect of transformations on them.	S 15a.3 *Represent location* **The student:** Understands a map or plan as a 'bird's-eye view' and uses order, proximity and directional language associated with quarter and half turns on maps and in descriptions of locations and paths. S 15b.3 *Represent shape* **The student:** Attends to the shape and placement of parts when matching, making and drawing things, including matching 3D models that can be seen and handled with conventional drawings of them and with their nets. S 15c.3 *Represent transformations* **The student:** Recognises repetitions of the same shape within arrangements and patterns and uses repetitions of figures and objects systematically to produce arrangements and patterns.	S 15a.4 *Represent location* **The student:** Uses distance, direction and grids on maps and plans and in descriptions of locations and paths. S 15b.4 *Represent shape* **The student:** Attends to the shape, size and placement of parts when matching, making and drawing things, including making nets of 3D models that can be seen and handled using some basic conventions for drawing them. S 15c.4 *Represent transformations* **The student:** Recognises rotations, reflections and translations in arrangements and patterns, and translates, rotates and reflects figures and objects systematically to produce arrangements and patterns.
Reason geometrically Student reason about shapes, transformations and arrangements to solve problems and justify solutions.	S 16.3 **The student:** Interprets common spatial language and uses it to describe and compare features of things.	S 16.4 **The student:** Selects, describes and compares figures and objects on the basis of spatial features, using conventional geometric criteria.

Extracted from:
Curriculum Council. (2005b). *Curriculum Framework: Progress Maps - Mathematics.* Perth. WA: Curriculum Council.

Chance and Data *Students use their knowledge of chance and data handling processes in dealing with data and with situations in which uncertainty is involved.*		
	LEVEL 3	**LEVEL 4**
Understand chance Students understand and use the everyday language of chance and make statements about how likely it is that an event will occur based on experience, experiments and analysis.	C&D 12.3 **The student:** Distinguishes certain from uncertain events and describes familiar, easily-understood events as having equal chances of happening or being more or less likely.	C&D 12.4 **The student:** Places events in order from those least likely to those most likely to happen on the basis of numerical and other information about the events.
Collect and process data Students plan and undertake data collection and organise, summarise and represent data for effective and valid interpretation and communication.	C&D 13a.3 *Collect and organise data* **The student:** Contributes to discussions to clarify what data would help to answer particular questions and takes care in collecting, classifying, sequencing and tabulating data in order to answer those questions. C&D 13b.3 *Summarise and represent data* **The student:** Displays and summarises data using frequencies, measurements and many-to-one correspondences between data and representation.	C&D 13a.4 *Collect and organise data* **The student:** Collaborates with peers to plan what data to collect and how to classify, sequence and tabulate them to answer particular questions, and sees the need to vary methods to answer different questions. C&D 13b.4 *Summarise and represent data* **The student:** Displays frequency and measurement data using simple scales on axes and some grouping, and summarises data with simple fractions; highest, lowest and middle scores and means.
Interpret data Students locate, interpret, analyse and draw conclusions from data, taking into account data collection techniques and chance processes involved.	C&D 14.3 **The student:** Reads and makes sensible statements about the information provided in tallies and in simple tables, diagrams, pictographs and bar graphs.	C&D 14.4 **The student:** Reads and makes sensible statements about the information provided in tables, diagrams, line and bar graphs, fractions and means, and comments on how well the data answers questions.

Extracted from:

Curriculum Council. (2005b). *Curriculum Framework: Progress Maps - Mathematics.* Perth. WA: Curriculum Council.

Algebra *Students use algebraic symbols, diagrams and graphs to understand, to describe and to reason.*		
	LEVEL 3	**LEVEL 4**
Functions Students recognise and describe the nature of the variation in situations, interpreting and using verbal, symbolic, tabular and graphical ways of representing variation.	PA 17a.3 *Understand graphs* **The student:** Is working toward achieving Level 4. PA 17b.3 *Represent variation* **The student:** Is working toward achieving Level 4.	PA 17a.4 *Understand graphs* **The student:** Interprets tables and graphs showing two quantities changing with respect to each other in everyday situations. PA 17b.4 *Represent variation* **The student:** Understands that some quantities display variation.
Expressing generality Students read, write and understand the meaning of symbolic expressions, moving flexibly between equivalent expressions.	PA 18.3 **The student:** Recognises, describes and uses spatial patterns and patterns involving operations on whole numbers, following and describing rules for linking materials by changes in shape and size or linking terms in a sequence by multiplication or addition-based or subtraction-based strategies.	PA 18.4 **The student:** Recognises, describes and uses spatial patterns and patterns involving whole, decimal and fractional numbers, following and describing rules for linking objects or figures by changes in size and orientation or linking successive terms in a sequence or paired quantities by a single operation.
Equivalence, equations and inequalities Students write equations and inequalities to describe the constraints in situations and choose and use appropriate solution strategies, interpreting solutions in original context.	PA 19.3 **The student:** Uses own strategies to maintain equivalence between two quantities or two expressions.	PA 19.4 **The student:** Constructs and completes statements of equality, including where more than one solution exists, using their understanding of numbers and number relationships.

Extracted from:
Curriculum Council. (2005b). *Curriculum Framework: Progress Maps - Mathematics.* Perth. WA: Curriculum Council.

Appendix E Links to Mathletics website

EDF1103

BECOMING MATHEMATICALLY LITERATE

Using the Mathletics website

EDF1103 Becoming Mathematically Literate

The Mathematics Curriculum in WA Primary Schools is defined by learning outcomes which are grouped under the following headings.

Working Mathematically
Students use mathematical thinking processes and skills in interpreting and dealing with mathematical and non-mathematical situations.

Number
Students use numbers and operations and the relationships between them efficiently and flexibly.

Measurement
Students use direct and indirect measurement and estimation skills to describe, compare, evaluate, plan and construct.

Chance and Data
Students use their knowledge of chance and data handling processes in dealing with data and with situations in which uncertainty is involved.

Space
Students describe and analyse mathematically the spatial features of objects, environments and movements.

Pre-algebra and Algebra
Students use algebraic symbols, diagrams and graphs to understand and to reason.

The outcomes in each area have been used to define the mathematical skills and understanding you will need to successfully complete the Mathematics Education units in your degree and become an effective mathematics teacher when you graduate.

The questions in the assessment tasks link directly to the outcomes so you should be able to focus on exactly what you need to do to improve your scores in any areas of weakness. Use the checklist, on which your tutor will have indicated the questions you will need to do in the exit assessment, to tell you which skills to practise, revise or learn for the first time.

This workbook has sections for each outcome with references to activities on the Mathletics website. While your priority in the three week module is to focus on your areas of weakness, you will find it of long term benefit to spend time later on looking at the rest of the topics so you can improve your skills even more – no one scored 100% in the entry assessment!

THE MATHLETICS WEBSITE

This is available to you at no charge at http://www.mathletics.com.au. You can log on using your laptop, from the Megalab or Education computer labs in Building 16, or from your home computer – in fact from anywhere with internet access.

We have created a list of topics relevant to your unit and within each topic there are a number of exercises. Each time you do an exercise the site generates a new set of examples so you can do lots of practice. If you are stuck or want an explanation, click on Support and you will be led through a similar question step by step. There is also an opportunity on this page to look at easier or harder examples of similar questions.

Once you finish an exercise you will see your total score and the answers you gave to each question. You can identify questions that were incorrect and click on the Support button next to them so the computer can show you what you should have done. Once you have cleared any misunderstandings, have a go at another exercise on the same topic. You will notice that when you get a few questions in a row correct, the computer raises the difficulty level automatically. Conversely, if you get several incorrect, it starts asking easier questions.

Your tutor will tell you the areas you need to develop, so focus on those first and then extend your skills in the areas where you were okay but not necessarily perfect. Some of the topics go beyond what we expect you to be able to do in this unit but the skills will be useful when you are actually teaching mathematics – it is good to feel that you know more than your students!

You will also be given extra materials and exercises to cover topics that it is difficult to do on line, such as estimating mass and working with three dimensional objects. These can be added to your file as the module progresses.

The next pages list each of the outcomes you need to achieve and alongside each is a list of topics and exercises from the website which will help you to improve your skills. While you need to score 75% to meet the unit requirements, you will be a more effective and more confident mathematics teacher if your scores on the practice exercises are as close to perfect as you can manage.

The website also gives you access to a mental arithmetic site where you can compete against other students or the computer. This is the Mathletics Live area and you can build up your accuracy and speed in basic calculation skills. Check it out and see if you can get your name onto the top scorers list.

For those who need to practise their spelling, there is now the Spellodrome area of the site – make sure the volume is turned up on the computer so you can hear them read the sentence and the word you have to spell.

If you enjoy extrinsic as well as intrinsic rewards, the more exercise and games you complete, the more points you can accumulate. There are then certificates for various levels of achievement. You can also earn credits to buy accessories for your Mathlete! So log on, give it a go and have fun doing mathematics – for a change!

EXERCISES MARKED WITH * ARE BEYOND WHAT IS REQUIRED TO MEET THE BENCHMARKS FOR THIS UNIT. TRY THEM IF YOU ARE DOING WELL WITH THE CORE MATERIAL OR WANT TO CHALLENGE YOURSELF.

Outcome number	Outcome	Topic	Exercise
WM1	**Checks all answers carefully using methods such as estimation and checking reasonableness.**	Not assessed specifically so no exercises – just remember to always check your work carefully before moving on to the next question or handing in a task.	
N1	Writes large and small numbers in figures and words	Whole Numbers	Expanding numbers Expanded notation Nearest 100 Place value to millions Rounding numbers
N2	Puts fractions and decimals in increasing or decreasing order	Whole numbers	Greater than or less than Ascending order Descending order
		Fractions	What fraction is shaded? Shading equivalent fractions Equivalent fractions Simplifying fractions Ordering fractions
		Decimals	Comparing decimals Decimal order
N3	Locates fractions and decimals on number lines and scales	Fractions	What fraction is shaded? Shading equivalent fractions?
		Decimals	Decimals on a number line
N4	Explains which will be the correct operations to use when presented with word problems	Addition and Subtraction	Problems – add and subtract
		Multiplication and division	Problems – times and divide
		Metric units	Mass word problems
		Money and Word Problems	Rates word problems Ratio word problems

EXERCISES MARKED WITH * ARE BEYOND WHAT IS REQUIRED TO MEET THE BENCHMARKS FOR THIS UNIT. TRY THEM IF YOU ARE DOING WELL WITH THE CORE MATERIAL OR WANT TO CHALLENGE YOURSELF.

Outcome number	Outcome	Topic	Exercise
N5	Adds, subtracts, multiplies and divides whole numbers and decimals using mental arithmetic and pen and paper methods	Addition and subtraction	Column addition Column subtraction Adding colossal columns Subtracting colossal columns Estimation – add and subtract
		Multiplication and Division	Multiplying by 10, 100, 1000 Dividing by 10, 100, 1000 Contracted multiplication *Long multiplication Short division Estimate – multiply and divide
		Decimals	Adding decimals Subtracting decimals Multiply decimals by 10, 100, 1000 Divide decimals by 10, 100, 1000 Decimals by whole numbers Rounding decimals
N6	Performs calculations involving money using the four operations	Money	How much change? Money *Calculating percentages Best buy *Profit and loss *Wages and salaries

EXERCISES MARKED WITH * ARE BEYOND WHAT IS REQUIRED TO MEET THE BENCHMARKS FOR THIS UNIT. TRY THEM IF YOU ARE DOING WELL WITH THE CORE MATERIAL OR WANT TO CHALLENGE YOURSELF.

Outcome number	Outcome	Topic	Exercise
M1	Measures the length of line segments	Metric units	Measuring length How long is that?
M2	Converts among units within the metric system eg cm to m, kg to g	Metric units	Centimetres and metres Metres and kilometres Converting units of length Grams and kilograms Converting units of mass Hours and minutes 24 hour time Time taken What time will it be? Millilitres and litres Litre conversions
M3	Determines the perimeter, area or volume of shapes which can be decomposed into squares or cubes	Perimeter, Area and Volume	Perimeter – squares and rectangles *Perimeter of shapes Equal areas Biggest shape Area – squares and rectangles *Area of shapes Comparing volume How many blocks?
M4	Finds lengths, areas and volumes of shapes which have been enlarged or reduced by a simple scale factor eg on maps or scale models	Maps and Scales	Scale Scale measurement *Scale factor
M5	Provides estimates of the size or mass of objects within the room	Practical activities will be provided in class	

EXERCISES MARKED WITH * ARE BEYOND WHAT IS REQUIRED TO MEET THE BENCHMARKS FOR THIS UNIT. TRY THEM IF YOU ARE DOING WELL WITH THE CORE MATERIAL OR WANT TO CHALLENGE YOURSELF.

Outcome number	Outcome	Topic	Exercise
C1	Estimates the probability of simple events eg a particular outcome when rolling a die	Whole numbers	Prime or composite?
		Chance and Probability	How many combinations? What are the chances? Simple probability Probability scale Complementary events
C2	Summarises a data set eg finds mean, maximum, range, relative frequency of a given value.	Statistics	Tallies Column graphs Picture graphs Finding the average Mean Mode Median
C3	Answers questions about data presented in the form of tables and graphs.	Statistics	Interpreting tables Reading from a column graph Line graphs – interpretation *Sector graphs *Divided bar graphs
S1	Draws representations of simple three dimensional shapes eg plan and elevation, perspective view	Three dimensional geometry	Nets Elevations Floor plans
S2	Interprets maps in terms of the direction and distance between points.	Maps and Scales	Following directions Using a key What direction was that? More directions Scale Map coordinates Coordinates meeting place *Scale factor

EXERCISES MARKED WITH * ARE BEYOND WHAT IS REQUIRED TO MEET THE BENCHMARKS FOR THIS UNIT. TRY THEM IF YOU ARE DOING WELL WITH THE CORE MATERIAL OR WANT TO CHALLENGE YOURSELF.

Outcome number	Outcome	Topic	Exercise
S3	Identifies the symmetry properties of figures in two and three dimensions	Symmetry and Transformations	Flip, slide, turn Shapes Symmetry or not Rotational symmetry
S4	Sketches the image of 2D shapes after reflection or rotation	Symmetry and Transformations	Flip, slide, turn Symmetry or not Rotational symmetry
S5	Identifies properties of shapes such as parallel and perpendicular lines, congruent and similar figures, acute and obtuse angles	Geometric Properties	Equal angles Sides, angles, diagonals What type of angle? Comparing angles Classifying angles Shapes Plane figure terms *Labelling circles Parallel lines *Circle terms *Measuring angles *Angle sum of a triangle
		Three Dimensional geometry	How many faces? How many edges? How many corners? What pyramid am I? What prism am I? Prisms and pyramids

EXERCISES MARKED WITH * ARE BEYOND WHAT IS REQUIRED TO MEET THE REQUIREMENTS FOR THIS UNIT. TRY THEM IF YOU ARE DOING WELL WITH THE CORE MATERIAL OR WANT TO CHALLENGE YOURSELF.

Outcome number	Outcome	Topic	Exercise
A1	Writes a simple story explaining the changes in a quantity represented on a graph eg mood changes during the day, traffic flow data	Statistics	Line graph interpretation Travel graphs *Step graphs
A2	Continues simple sequences of numbers or shapes, explaining how they obtained their answer	Pre-Algebra	Pattern error Increasing patterns Decreasing patterns Missing values Pick the next number Describing patterns *Tables of values *Find the pattern rule
A3	Solves “find the missing number” problems	Pre-Algebra	Find the missing number 1 I am thinking of a number Find the missing number 2

Appendix F Sample test paper

EDF1103 (BECOMING MULTILITERATE): MATHEMATICAL LITERACY ASSESSMENT

Question	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Outcome	N1	N2	N3	N4	N5	N6	M2	M3	M4	M5	C1	C2	S1	M1 S2	S3	S4	S5	A1	A2	A3

NAME ______________________ **STUDENT ID** __________

TUTOR ______________________ **DAY / TIME** __________

You are to answer as many of the following questions as you can in the time available. Use the spaces next to each question to work out your answers. You must show all your working out so that you can be given part marks for your method even if the final answer is incorrect. The numbers in brackets indicate the maximum marks available for each question. If you cannot answer a question, or get stuck, move on to a question you can do and come back to the others later.

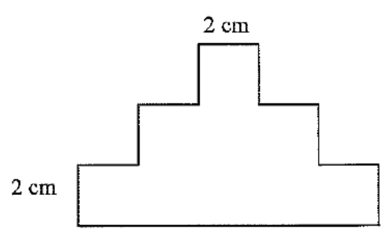
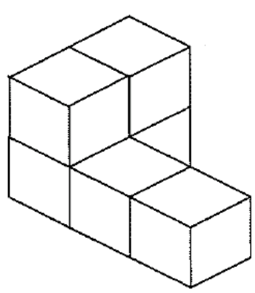
For each question you also need to indicate how confident you feel about having obtained the correct answers. You do this by circling the appropriate number in the box next to the question. The numbers represent the following responses:

1 **Not at all confident**
2 **A little confident**
3 **Reasonably confident**
4 **Very confident**

You may **not** use a calculator to answer the questions.

1 **(4)**	**N1**	Write each of the following numbers in words. For example, 235 would be written as two hundred and thirty five a) 50 050 b) 3 401 003 Write each of the following numbers using numerals. For example three thousand two hundred and sixty two would be 3 262 c) five hundred thousand, four hundred d) three hundred and two million, five thousand and twenty	**1 2 3 4**
2 **(4)**	**N2**	Each part of this question contains a list of numbers in fraction or decimal form. In each case, rewrite the list so the numbers are in increasing order. a) $\frac{3}{4}, \frac{3}{10}, \frac{3}{7}, \frac{3}{9}$ b) $\frac{1}{2}, \frac{5}{9}, \frac{2}{5}, \frac{2}{3}$ c) 0.39, 0.44, 0.33, 0.43 d) 0.22, 0.022, 0.202, 0.20	**1 2 3 4**

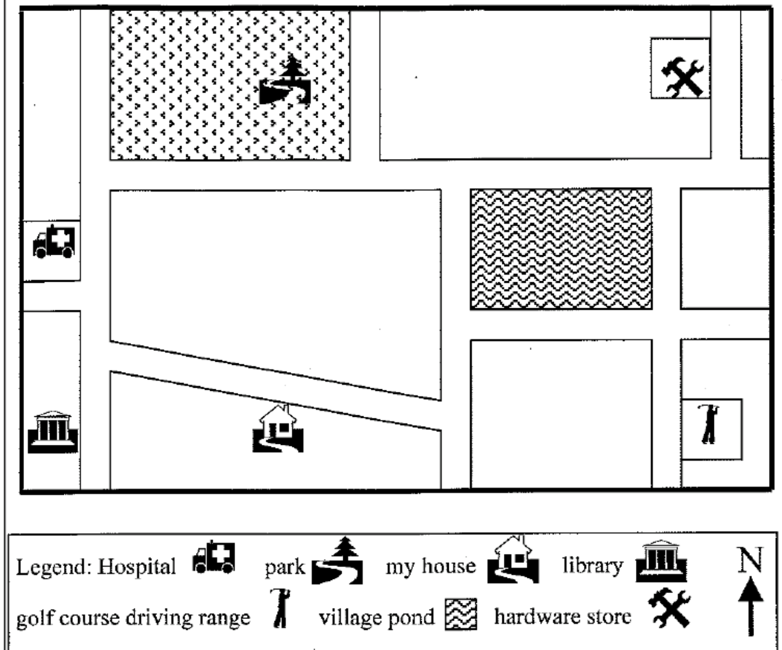
3 **(2)**	**N3**	For each part of this question you are to mark the number line at a suitable approximate point for the fraction or decimal number. For example 0.5 0 |————————+————————| 1 0.5 a) 0.6 0 |————————————————| 1 b) $\frac{3}{5}$ 0 |————————————————| 1	**1 2 3 4**
4 **(2)**	**N4**	For the following question, just describe **how** you would find the answer; you do **not** have to perform the calculation. For example if the question was: *What is the cost of 5 kg of sausages at \$4.50 per kg?* you might write something like: *Multiply \$4.50 by 5* In a test on decimals a student scored 13 out of 20. In a measurement test she scored 16 out of 25. Which was the better score?	**1 2 3 4**
5 **(6)**	**N5**	Calculate the following showing all steps of your working. a) $39.2 + 2.75 + 0.354 =$ b) $75.4 - 2.654 =$ c) $53.6 \times 9 =$ d) $0.004506 \times 10\,000 =$ e) $59.44 \div 8 =$ f) $4.63 \div 100\,000 =$ (Working out space only, write your answers next to each question)	**1 2 3 4**

6 **(4)**	**N6**	A lawyer charges $250 for a face to face appointment and then $450 an hour while he is working on the case, regardless of the particular tasks he carries out. What would be the charge for a case involving one face to face appointment and five hours work? At the end of a month which included two face to face appointments, the invoice was for $2300. How many hours did he work on the case?	**1 2 3 4**
7 **(3)**	**M2**	A couple are renovating their kitchen and need to buy laminate strip to line the edge of the workbenches. They each measure the lengths needed for various sections and then try to combine their results so they can buy a single length. If the wife has noted they need one piece 1.3 m long and another 65 cm long and the husband has recorded lengths of 730 mm and 1 m 25 cm, what is the total length of laminate strip needed?	**1 2 3 4**
8 **(6)**	**M3**	a) Find the perimeter and area of this figure (assume that lengths that appear equal are actually equal). Don't forget to show your working or explain your thinking.  b) Find the surface area and volume of this shape assuming it is made of 1 cm cubes. 	**1 2 3 4**

9 **(2)**	**M4**	If the lengths of all the sides of the shape in part a) of Question 8 were doubled, what would be the new perimeter and area?	**1 2 3 4**
10 **(3)**	**M5**	Ask your tutor for one of the objects labelled "Question 10". **Without** using your ruler or other instruments write down your estimates of the following measurements. Make sure you write down the letter on the label for your object. **LETTER** ☐ a) its height in centimetres b) its diameter in millimetres c) its mass (weight) in grams	**1 2 3 4**
11 **(5)**	**C1**	If you roll a six sided die, what is the probability that you will obtain: a) an even score? b) a score which is a multiple of five? c) a score which is a factor of six? Don't forget to explain your answers!	**1 2 3 4**
12 **(4)**	**C2**	In an attempt to improve behaviour in a classroom, a teacher gives tokens to children who show appropriate behaviour and keeps a note of how many tokens are awarded each day. 3, 5, 7, 4, 9, 10, 14, 11, 16, 20, 15, 6 a) What was the average number of tokens awarded per day? b) On what percentage of the days was at least the average number of tokens awarded?	**1 2 3 4**

13 (5)	**S1**	Ask your tutor for one of the shapes made of coloured cubes. The front face is the one with the paper strip sticking out. **Write down the number which is on this strip so we know which shape you tried to draw.** NUMBER ☐ Your drawings do **not** have to be the exact measurements and you only need to draw plain cubes or squares. a) On a sheet of isometric graph paper, or in the space at the bottom of this page, sketch a diagram of your shape in the style of the one shown in question 8b) ie so it looks "real". Make sure you put your name on the graph paper. b) In the space below draw three views of the same shape, one from directly above (a plan), one from the front (front elevation) and one from the right hand side (side elevation). Plan Front elevation Side elevation	**1 2 3 4**

14 **(6)**	**M1** **S2**	The map below shows the area round my house in Suburbia. The scale is 1 cm represents 30 m.	**1 2 3 4**

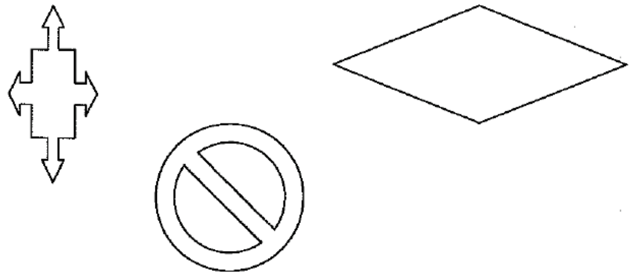
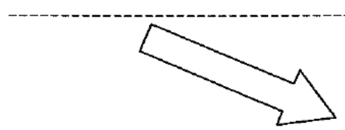
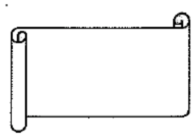
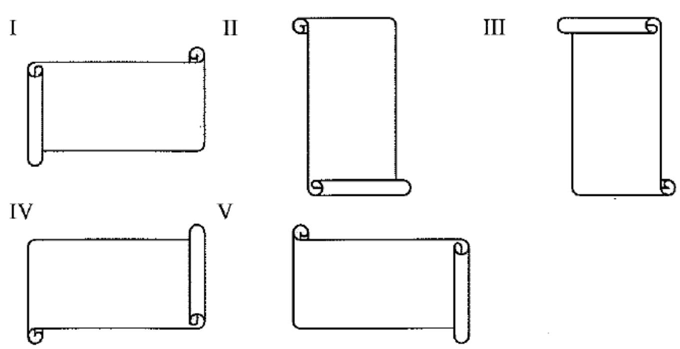


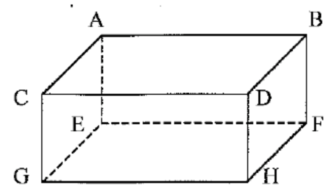
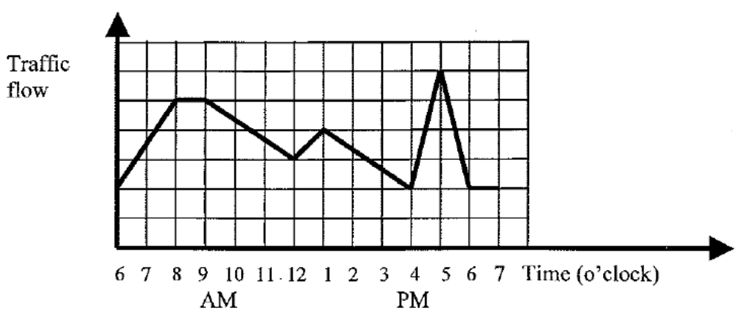
a) One afternoon at home I decide to go to practise my golf swing. Show the route you would take on the map.

How far is it on the map from my house to the golf course driving range?

How far do I actually have to walk in real life?

b) My Dad is keen on do-it-yourself and has just come out of the library with a book about how to build his own garden shed. He wants to drive straight to the hardware store to get the materials he needs. Draw his route on the map and describe it in detail including distances and directions travelled and the landmarks he would pass on the way.

15 **(3)**	**S3**	How many lines of symmetry are there for each of the following shapes? Draw them all. 	**1 2 3 4**
16 **(4)**	**S4**	a) If the dotted line represents a mirror, draw in the reflection of the shape shown below:  b) Consider the following shape which represents a piece of a mosaic tile.  Which of the diagrams below show the shape after it has been: (i) rotated through a quarter turn clockwise? __________ (ii) rotated through a half turn anticlockwise? __________ 	**1 2 3 4**

17 **(5)**	**S5**	 a) What is the mathematical name of the shape shown above? ____________________________________ b) Use letters to name **two** pairs of parallel edges. ____ , ___ & ____ , ____ c) Name a line through C which is perpendicular to AB. ___________ d) Is the angle CDB an acute angle, an obtuse angle or a right angle? ____________________	**1 2 3 4**
18 **(5)**	**A1**	The graph below represents the changes in the volume of traffic along a Perth road over the course of a particular day. Write a story which might explain the traffic flow at various times during the day. 	**1 2 3 4**

19 **(4)**	**A2**	Find the next two terms in the following sequences of numbers and explain the "rule" that you used to obtain your answer in each case. a) 128, 32, 8, __ __ b) 1, 5, 13 , 29, __ __	**1 2 3 4**
20 **(3)**	**A3**	Find the number that needs to be written into the box to make these statements true. Explain how you obtained your answers. a) $\square \div 3 + 12 = 18$ b) $15 + (\square \times 4) = 43$	**1 2 3 4**