NUMERACY IN TEACHER EDUCATION: THE WAY FORWARD IN THE 21ST CENTURY

A report of the
Numeracy in Preservice Teacher Education Working Party

BOARD OF TEACHER REGISTRATION
QUEENSLAND

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- CONTENTS -

Letter of Transmittal v

Acknowledgments vii

Introduction ix

Executive Summary xi

Section One: Seeking Numeracy 1

1.1 Australian interpretations of numeracy 1
1.2 How does numeracy differ from mathematics? 3
1.3 How does numeracy differ from literacy? 4

Section Two: Numeracy Practices in Out-of-School Contexts 5

Section Three: Numeracy Learning in Schools: Expectations and Opportunities 7

3.1 Expectations of numeracy knowledge and competence at different levels of schooling 7

3.2 Numeracy learning opportunities across the curriculum 10

Section Four: Numeracy Achievement of Queensland School Students 15

4.1 Years 3, 5, and 7 testing programs in Australia 15
4.2 International comparative studies of mathematics achievement and mathematical literacy 17

Section Five: Effective Numeracy Teaching: The View from Research 21

5.1 Effective mathematics teaching 21
5.2 Beliefs and attitudes towards mathematics 22
5.3 Knowledge about numeracy and mathematics 23
5.4 Teaching numeracy across the curriculum 24

5.5 Implications for ongoing professional learning 30

Section Six: Preparing Teachers of Numeracy 33

6.1 Profiles of Queensland preservice teachers 33
6.2 Numeracy education in Queensland preservice teacher education programs 42
6.3 Preservice teacher education programs for numeracy education 42

Section Seven: Numeracy Standards for Graduates of Preservice Teacher Education Programs 47

7.1 Formulating numeracy standards for graduate teachers: some key points 47
7.2 Overview of the standards 48
7.3 The numeracy standards for graduates of preservice teacher education programs 49

References 55

Appendix 1
Membership of Numeracy in Preservice Teacher Education Working Party 63

Appendix 2
Examples of good practice provided by Faculties/Schools of Education in Queensland Higher Education Institutions 65

LETTER OF TRANSMITTAL

24th October, 2005

Mr John Dwyer
Chair
Board of Teacher Registration
Toowong, Queensland.

Dear Mr Dwyer,

In February 2005, through the Board's Professional Education Committee, you commissioned a Numeracy in Preservice Teacher Education Working Party under the following terms of reference:

1. To provide definitions of numeracy and mathematics.
2. To consider what is meant by the teaching of numeracy as distinct from the teaching of mathematics.
3. To examine current approaches to numeracy in Queensland preservice teacher education programs.
4. To foreground appropriate pedagogy and teacher knowledge required for teaching numeracy.

The Working Party is pleased to present to you a report entitled *Numeracy in Teacher Education: The way forward in the 21st century*, and makes the following recommendations:

1. That the Report be endorsed for publication and distribution by the Board of Teacher Registration.

2. That the Board of Teacher Registration* convey the following recommendations to the Queensland College of Teachers:
   - 2a That the Queensland College of Teachers adopt the report as a resource to supplement its new professional standards.
   - 2b That the Queensland College of Teachers give consideration to conducting or commissioning research in the area of preparation of teachers to teach numeracy.
   - 2c That the Queensland College of Teachers give consideration to extending the Numeracy Standards for Graduates of Preservice Teacher Education Programs to include Professional Standards for all teachers of numeracy within the Queensland context.

The Working Party is confident that the adoption of the Numeracy Standards for Graduates of Preservice Teacher Education Programs will result in shared understanding of the inherent differences among numeracy, literacy and mathematics, in renewed commitment to the quality of numeracy experiences within preservice programs, and in attendant benefits to numeracy teaching throughout the state.

Yours sincerely

Associate Professor Elizabeth Warren
Chair, Numeracy in Preservice Teacher Education Working Party.

* New legislation, the *Education (Queensland College of Teachers) Act 2005*, came into effect on 1 January 2006, establishing the Queensland College of Teachers to replace the Board of Teacher Registration.

ACKNOWLEDGMENTS

The Board of Teacher Registration would like to express its appreciation to the following people who contributed to the project and to the preparation of this report:

- The members of the Numeracy in Preservice Teacher Education Working Party (listed in Appendix 1) for the time and expertise they invested in this project.

- Staff members from the relevant school or faculty of each Queensland teacher education institution who provided information about, and examples from their preservice teacher education programs of, good practice in developing personal numeracy competence and numeracy teaching skills.

- Staff members of the Office of the Board of Teacher Registration – Ms Marilyn Cole (Education Officer) and Ms Jill Manitzky (Senior Education Officer) for professional support during the project and in preparation of the report, and Ms Celeste Mahony for graphic design of the report.

INTRODUCTION

This publication reports on a project of the Board of Teacher Registration* that commenced in February 2005.

Background

The Board of Teacher Registration publishes *Professional Standards for Graduates and Guidelines for Preservice Teacher Education Programs* to assist teacher education institutions to develop programs which will enable graduates to be registered as teachers in Queensland. These standards and guidelines are supplemented by a range of reports in key areas.

At the beginning of 2005 the Board decided to produce a report on Numeracy in Preservice Teacher Education. The Board's Professional Education Committee invited nominations to serve on a Working Party to oversee the project. Membership of the Working Party included representatives of universities, teacher employers, the Queensland Studies Authority and the Board (see Appendix 1).

The Project

Terms of reference

The terms of reference for the Working Party were:

1. To provide definitions of numeracy and mathematics.
2. To consider what is meant by the teaching of numeracy as distinct from the teaching of mathematics.
3. To examine current approaches to numeracy in Queensland preservice teacher education programs.
4. To foreground appropriate pedagogy and teacher knowledge required for teaching numeracy.

The process for the project

The project commenced with a review of the literature related to numeracy in preservice teacher education, numeracy teaching, numeracy performance and numeracy across the school curriculum.

The second phase of the project included developing a definition of numeracy, clarifying the relationships between, firstly, numeracy and mathematics and, secondly, numeracy and literacy, as well as identifying the issues related to the preparation of teachers to teach numeracy.

The next task was to invite Queensland teacher education institutions to provide

* New legislation, the *Education (Queensland College of Teachers) Act 2005*, came into effect on 1 January 2006, establishing the Queensland College of Teachers to replace the Board of Teacher Registration.

examples of good practice, from their preservice teacher education programs, in the areas of:

- developing personal numeracy competence; and
- preparing teachers to teach numeracy.

The final phase involved the development of Numeracy Standards for graduates of preservice teacher education programs.

The Report

The report outlines the theoretical framework for the project and provides information about current practice in preservice teacher education programs to prepare teachers to teach numeracy. The numeracy standards were developed in response to the information gathered throughout the project.

EXECUTIVE SUMMARY

What is numeracy?

Any discussion of numeracy – whether in teacher education or another context – needs to begin by identifying what ‘numeracy’ means. This can be difficult because the term is not used in all countries, the concept it refers to has different names in some countries, and much confusion exists as to whether and how numeracy differs from mathematics and from literacy. This report adopts a definition of numeracy, widely accepted and used in Australia, that appears in the Australian government’s national numeracy policy document *Numeracy, a Priority for All: Challenges for Australian Schools* (DETYA, 2000): 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. Unlike mathematics, which focuses on generalisation and abstraction, numeracy is embedded in specific contexts and has real world purposes. People who are numerate draw on three kinds of ‘know-how’: mathematical (using mathematical concepts and skills), contextual (making sense of unfamiliar situations), and strategic (being critical of how mathematics is used). Numeracy is clearly distinct from literacy because it rests on conceptually different foundations.

Numerate practices in out-of-school contexts are highly contextualised, often requiring intuition, tools or rules of thumb tailored to specific circumstances, estimation, and problem solving – not the methods traditionally taught in school mathematics. The generalised mathematics taught at school cannot be transferred directly to out-of-school contexts such as different workplaces. Instead, numeracy learning in schools needs to build adaptive thinking and confidence in applying mathematical knowledge and methods in a variety of contexts, including in subjects other than mathematics.

Where is numeracy in school curricula?

Because numeracy develops with age and experience it is important at all levels of schooling. Numeracy learning opportunities also need to be recognised and exploited across all curriculum contexts. While mathematics lessons are the site for developing mathematical knowledge and techniques and learning how to apply these, learning experiences in other curriculum areas can help students investigate issues or problems that are not explicitly mathematical but that require mathematical skills and knowledge.

How well do Queensland students perform in numeracy assessments?

Queensland school students participate in national and international tests that assess numeracy performance, often under the guise of mathematics achievement or mathematical literacy. Although pen-and-paper tests are not ideal for authentic assessment of numeracy, the results can be illuminating. There is evidence that the numeracy performance of Queensland students has declined somewhat over the last 30 years, and that Queensland students in a range of year levels do not achieve as well as students in other states and territories. Because evidence from research on numeracy learning shows quite clearly that what teachers do in classrooms is the most important influence on students' achievement, efforts to improve students' performance need to focus on teachers and teaching practices.

What do we know about effective numeracy teaching?

A substantial body of Australian research now exists on effective numeracy teaching practices which include: developing significant mathematics; challenging students to think mathematically; stimulating curiosity and interest; and making links between mathematical ideas and between mathematics, other curriculum areas, and the real world. Teachers' subject matter knowledge, pedagogical content knowledge, beliefs, attitudes and confidence, and knowledge of curriculum models that connect mathematics across the curriculum have all been shown to be factors influencing the quality of numeracy teaching.

What are the implications for design of preservice teacher education programs?

Research in numeracy education confirms that 'numeracy is everyone's business', and not just the responsibility of the primary school teacher or secondary mathematics teacher. However, achieving the goal of shared responsibility for numeracy education by all teachers presents many challenges. In the Queensland context, there is enormous diversity amongst preservice teachers in terms of their ages, mathematical backgrounds, beliefs and attitudes towards mathematics, and numeracy skills. Currently in Queensland, preservice teacher education programs give uneven attention to the development of personal numeracy skills and preparation for numeracy teaching. Research also shows that high quality programs for preservice teacher education are essential to develop the necessary knowledge, skills and attitudes for numeracy teaching so that preservice teachers can overcome any conflicting perspectives about numeracy teaching or professional inertia they may encounter in schools after graduation. The numeracy standards for graduates have been formulated with these ideas, challenges and goals in mind.

SECTION ONE

Seeking Numeracy

Coming to a common understanding of the meaning of numeracy is not an easy task, for several reasons. First, the idea of numeracy is a relatively recent one – the term was first introduced in the UK by the Crowther Report (1959) as the mirror image of literacy, but involving quantitative thinking. Another early definition proposed by the Cockcroft Report (1982) described 'being numerate' as possessing an at-homeness with numbers and an ability to use mathematical skills to cope confidently with the practical demands of everyday life. Second, *numeracy* is a term common in Australia and the UK but rarely found in North America or other parts of the world, where expressions like *quantitative literacy* or *mathematical literacy* are used. Third, these different names convey different connotations that may not be interpreted in the same way by all people. For example, some definitions of quantitative literacy focus on the ability to use quantitative tools for everyday practical purposes, while mathematical literacy is understood more broadly as the capacity to engage with mathematics in order to act in the world as an informed and critical citizen (OECD, 2000). The transformative possibilities of a critical mathematical literacy curriculum have been well documented by Frankenstein (2001) and Gutstein (2003), both of whom advocate approaches to teaching and learning mathematics for social justice to help their students interpret and challenge inequities in their own contexts. From these diverse sources we may conclude that the meaning of numeracy extends beyond the use of mathematical skills to incorporate notions of practical purposes, real world contexts, and critical citizenship.

1.1. Australian interpretations of numeracy

In the Australian context, Willis (1990, 1998a, 1998b) has argued persuasively that being numerate involves more than mastering mathematical facts and skills. Instead, the essence of numeracy is expressed as 'intelligent practical mathematical action in context' (1998a). This definition shows that being numerate requires a blend of different kinds of know-how or 'nous'. She identifies three aspects of numeracy and the types of know-how associated with each (1998b):

- Numeracy as *mathematics*: this is the basic skills view, which also dominates in schools. *Mathematical know-how* is developed by increasing students' mathematical repertoire or knowledge.
- Numeracy as *communicative competence*: this view acknowledges that mathematics is embedded in everyday situations and numeracy is context specific. *Contextual know-how* is developed by increasing students' repertoire of situations or practical contexts in which they need to use mathematics for a specific purpose. While this perspective is common in adult education, it is difficult for schools to provide authentic contexts that match those in which numeracy skills are exercised in everyday life.

- Numeracy as *strategic mathematics*: this view emphasises the importance of mathematical processes, applications, dispositions, in choosing and using mathematical skills in the service of non-mathematical goals. S*trategic know-how* is developed by increasing students' repertoire of strategies for dealing with unfamiliar problems.

Numerate behaviour involves *all three* of these interpretations. Strategic know-how may be particularly important as a potential bridge between school mathematics (content focus) and mathematics as practised in the real world (context focus) (see Figure 1).

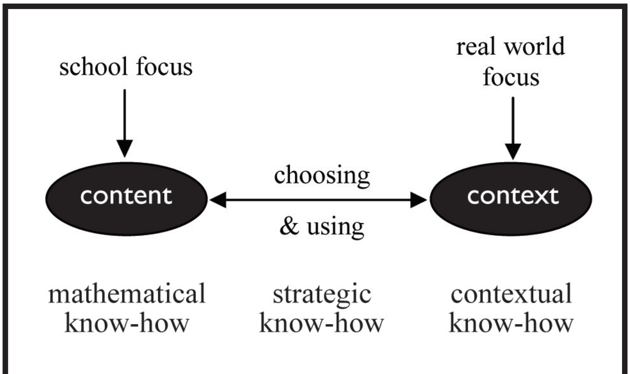

Figure 1. Aspects of numeracy

Hogan (2000 in DEST, 2004e) has extended this framework by arguing that the blend of these three types of know-how needed for a particular situation is determined, in part, by a person's capacity to take up three corresponding roles:

- the *fluent operator*: showing fluency of use of mathematical knowledge and skills in familiar contexts;
- the *learner*: using mathematics to make sense of something new or to cope with unfamiliar situations;
- the *critic*: being critical of the mathematics chosen and used in order to judge and question the appropriateness of its use.

The 1997 Numeracy Education Strategy Development Conference identified the following elements as central to any description of numeracy: 'numeracy involves using some mathematics to achieve some purpose in a particular context' (DEETYA, 1997, p. 13). From this discussion emerged the following description of numeracy which it was hoped would inform future work in numeracy education:

'To be numerate is to *use mathematics effectivel*y to meet the general demands of life at *home*, in paid *work*, and for participation in *community* and *civic life*' (DEETYA, 1997, p. 15, emphasis added).

Because this description was later cited in the Commonwealth's numeracy policy document *Numeracy, A Priority for All: Challenges for Australian Schools* (DETYA, 2000) as reflecting the Australian interpretation of numeracy, it forms the basis for all that follows in this report.

This description, like Willis's, highlights three important aspects of numeracy and the types of know-how associated with each:

- Using *mathematics*: Students need to understand and be able to use the mathematical concepts and skills described in mathematics syllabuses, which are typically organised into strands labelled Number, Measurement, Space, Chance and Data, and Algebra. This requires *mathematical* know-how.
- Using mathematics *effectively*: Students need to be willing and able to choose and apply mathematical concepts and skills that are appropriate for dealing with unfamiliar problems. This is often expressed in syllabus documents as 'working mathematically', and requires *strategic* know-how.
- Meeting the general demands of *life*: Numerate practice is revealed in real world tasks that have a purpose. Hence numeracy is context-specific because mathematics is embedded in everyday situations – at home, at work, and through participating in community and civic life. This requires *contextual* know-how.

1.2. How does numeracy differ from mathematics?

While there may be different interpretations of the distinctions between numeracy and mathematics, Steen (1999) suggests 'nearly everyone seems to agree that numeracy is both broader than and different from mathematics – at least as mathematics has traditionally been viewed by school and society'. In elaborating on this distinction he identifies *multiple* numeracies – practical, civic, leisure, professional, and cultural – representing different perspectives that correspond loosely to the differing purposes and emphases found in the traditional levels of mathematics education. Following this theme, it may be more helpful to highlight the contrasting *purposes* of mathematics and numeracy than to attempt to answer such questions as 'Is mathematics a subset of numeracy or is numeracy a subset of mathematics?' or 'How do mathematics and numeracy overlap?'.

Steen (2001, pp. 17-18) offers the following distinction between the purposes of mathematics and numeracy:

> *Mathematics climbs the ladder of abstraction to see, from sufficient height, common patterns in seemingly different things. Abstraction is what gives mathematics its power; it is what enables methods derived in one context to be applied in others. But abstraction is not the focus of numeracy. Instead, numeracy clings to specifics, marshalling all relevant aspects of setting and context to reach conclusions. (…) Numeracy is driven by issues that are important to people in their lives and work, not by future needs of the few who may make professional use of mathematics or statistics.*

The definition of numeracy discussed above indicates that the connection is close but that mathematics and numeracy are not the same thing. Mathematics is often seen as skills, procedures and a particular type of 'mathematical knowledge' (Willis, 1990, 1998a, 1998b). To be numerate, an individual requires the strategic and contextual knowledge as well.

Throughout the 1990s there was much discussion about the relationship between mathematics and numeracy. Johnston (1994) argues that numeracy is more than being able to manipulate numbers, or even being able to 'succeed' in school or university mathematics. Mathematics, the subject, provides the content on which to base the development of numeracy; but mathematical knowledge is only one aspect of numeracy. Further, the mathematics that is used strategically in context is not the complete domain of mathematics.

1.3. How does numeracy differ from literacy?

Literacy and numeracy are often grouped together when considering the essential knowledge and competencies to be developed by school students for participation in contemporary society. In 1990, the International Literacy Year definition of literacy stated that literacy includes numeracy, and it has become common to use the term 'literacy' to mean 'competence with' (as in technological literacy, information literacy, and so on). More recently in Australia the Adelaide Declaration announced the national literacy and numeracy goal – that Australian students:

> *should have attained the skills of numeracy, and English literacy: such that, every student should be numerate, able to read, write and spell, and communicate at an appropriate level.* (MCEETYA, 1999)

However, subsuming numeracy into literacy has not been helpful either in increasing research on and development of numeracy, or directing attention to numeracy as an educational issue. Only recently have State and Commonwealth governments started to undertake substantial work on investigating the nature of numeracy in different contexts, numeracy teaching and assessment strategies, curricula supportive of numeracy development, teacher professional development, and community information strategies (DEETYA, 1997). The focus on literacy at the expense of numeracy in recent years has left teachers with limited knowledge and confidence relating to this area of the curriculum (DEST, 2003). Similarly, numeracy has received little attention in whole school planning. As one principal in Queensland commented, 'Numeracy simply has not been on our agenda' (DEST, 2004a, p. 21).

Although language and communication are clearly important in numeracy development, mathematics education researchers insist that literacy and numeracy are distinct as they rest on conceptually different foundations:

> *While there has been a historic link between literacy and numeracy, even some attempt to suggest that literacy includes numeracy, it seems clear that the foundation on which numeracy is built – mathematics – is clearly not the same as a foundation on which literacy is built. Even at the early childhood level, this distinction remains valid, in spite of the curriculum integration with the focus on the 'whole child' rather than specific discipline areas.* (Arthur, Beecher, Dockett, Farmer & Death, 1996, p. 13)

SECTION TWO

Numeracy Practices in Out-of-School Contexts

Numeracy is driven by issues arising in people's lives outside school contexts. Much research has been carried out to identify numeracies in different situations and practices, and studies have investigated the activities of craft, trade, and professional workers, shoppers, and various social and cultural groups (e.g., Bessot, 2000; Lave, Murtaugh & de la Rocha, 1984; Kanes, 1996; Zaslavsky, 1994). While this work has been useful in showing how situated numeracy practices differ from school mathematics, other studies focusing on the mathematics of the workplace have aimed to identify real world examples that teachers could incorporate into their classroom practice (e.g., Hogan & Morony, 2000).

Studies of numeracy practices in out-of-school contexts highlight the dangers of assuming that there is a simple or direct relationship between school-based learning and the numeracy demands of workplace settings, especially when the value of specific numeracy practices changes over time. Zevenbergen (2004) argues that new forms of numeracy emerge in 'new times' characterised by significant social change, globalised economies, and increasing use of information and communication technologies. She investigated how technology has changed the numeracy demands of workplaces, and how these changes are viewed by younger and older workers. One phase of the research involved a large-scale survey of young people who were either in work, in school and working part-time, or seeking work, and older people including teachers, employers, and job placement officers. The survey asked participants to rate various aspects of literacy and numeracy in terms of their importance to the person's work environment. For older people, numeracy equated with number and calculation using written or mental methods, and they expressed concerns that young people were too dependent on technology for carrying out these calculations. In contrast, younger people's views of numeracy placed more importance on applied mathematics (e.g., measurement and statistics) and the use of ICTs as a tool for performing routine calculations. A later phase involving work shadowing of research participants (Zevenbergen & Zevenbergen, 2004) showed that actual workplace tasks required estimation and problem solving rather than manual calculation, as technological tools such as cash registers and computer programs now take care of lower order aspects of these tasks. Also, workers often used situated methods for calculating that differed from school mathematical methods because the former were more efficient in the particular context.

Similar findings were reported by Noss, Hoyles and Pozzi (2000), who explored how mathematics was used and described by workers in the contexts of investment banking, paediatric nursing and commercial aviation. Routine workplace practice was characterised by four activities: (a) measurement and recording; (b) using algorithms to find unknown quantities from known quantities; (c) using personal, mental approaches or rules of thumb that were finely tuned to specific problems and circumstances; and (d) using ‘look-up’ methods or tools (e.g., tables or charts) rather than standard mathematical procedures. These activities often involved intuition and judgment in making decisions to resolve conflict between information from different sources. While the methods used were speedy and highly efficient in context, they were not ‘efficient’ in the sense of being generalisable to other contexts. Noss, Hoyles and Pozzi concluded that ‘orientations such as generalisability and abstraction away from the workplace are not part of the mathematics with which practitioners work’ (p. 32).

Studies of numeracy practices in the workplace provide insights into numerate practices consistent with the different kinds of know-how identified by Willis. Although it is clear that mathematical know-how is needed, this is applied in ways that are very specific to the work context (contextual know-how) and that require adaptive thinking, intuition and judgment (strategic know-how). Other studies that take a different approach by attempting to identify ‘the mathematics needed’ in different workplaces assume, mistakenly, that the generalised mathematics learned in school can be transferred directly to a workplace. Such an approach cannot account for the authentic, situated practices of different workplaces and the different numeracy demands embedded within them.

SECTION THREE

Numeracy Learning in Schools: Expectations and Opportunities

What does it mean to become numerate within school contexts? Curricular implications of the DEETYA (1997) definition of numeracy can be explored in two dimensions. The first dimension identifies numeracy learning expectations at different levels or phases of schooling, and the second suggests numeracy learning opportunities across all disciplines.

3.1 Expectations of numeracy knowledge and competence at different levels of schooling

Numeracy is not associated with, nor limited to, any level of mathematics. Johnston (1994, p. 34) argues that ‘it is as important for an engineer to be numerate as it is for a primary school child, a parent, a car driver or a gardener. The different contexts will require different mathematics to be activated and engaged in’. As numeracy develops with age and experience it is possible to outline expectations for students’ numeracy at different stages of schooling. This section does so by drawing on information from The Office of the Queensland School Curriculum Council (2001) Numeracy Position Paper and work of delegates to the Numeracy Education Strategy Development Conference (DEETYA, 1997).

Early Years

During the early years of schooling (Preparatory to Year 3) children’s numeracy experiences are developed using the context of home and school. Through play, children use and extend oral language capabilities, explore a range of ways to symbolise experiences and develop imagination and creativity. In the process of developing mathematical knowledge and skills, they experience situations involving choosing and using mathematics (e.g., using numbers in games, using informal strategies to measure, deciding what is ‘fair’ in interactions with others) and begin to display confidence in, persistence with and awareness of the usefulness of mathematics in a range of contexts.

Learners in the early years:

- possess sufficient mathematical knowledge to deal with their everyday needs, both in and out of school, and persist in attempts to make sense of contexts and their mathematical demands;
- begin to understand that the application of mathematical ideas involves an element of risk taking;

- can select aspects of mathematical knowledge to be applied and be willing to take risks, even though this may result in errors;
- are active participants in both the thinking and communicating of ideas that involve simple mathematical concepts;
- can interpret what their classmates and significant adults mean when they use simple mathematical concepts and processes;
- develop concepts of number, space, measurement and data while exploring and manipulating their immediate environments, usually during play.

Middle Years

During the middle years of schooling (Years 4-9) students consolidate the basic knowledge and skills acquired in the early years. They are also able to make connections to the world beyond home and school. Students need to see the relevance of what they are doing in the classroom to their lives beyond the school. In addition, research has found that success is a major component in student preparedness to engage in mathematics in the middle years. Evolving numeracy demands of life and work, the distinctive and diverse needs of students, and the need to build in success impact on the design of effective learning experiences.

Students in this age group have an increasing ability to interpret data, use time, locate in space, use and plan use of money and they often do so without prompting, independently and in increasingly abstract ways. Their use of mathematical language becomes more accurate and precise and they choose from a variety of strategies to seek solutions – even though they are still to develop verification and evaluation skills that would assist in choosing the most *efficient* strategy. Planning for development of numeracy know-how needs to incorporate many contexts within mathematics, in other disciplines and students' lives outside school.

Learners in the middle years:

- demonstrate positive attitudes towards the usefulness of mathematics;
- apply appropriate practices in a given context;
- take reasonable risks in the application of knowledge;
- have a reasonable store of readily accessible mathematical facts and procedures;
- can readily access mathematical concepts as required within the contexts of the other key learning areas, that is, they choose and use appropriate mathematical/numeracy practices when needed;
- are willing to listen to the explanations and interpretations of others and identify aspects that they support or deny;
- select appropriate mental, pen-on-paper and calculator methods for calculating in a given context;

- check the reasonableness of calculated results;
- use spatial visualisation and appropriate mathematical terminology to make sense of simple maps, plans and two-dimensional representations of objects;
- collect, organise and represent data to inform decisions and provide answers;
- differentiate among the various words and symbols used in measurement and provide answers to measurement problems in units appropriate to the context.

Senior Years

During the senior years of schooling students become increasingly oriented towards their futures beyond school and achieving high-level qualifications that will enable them to fulfill their goals. This will be a time when many students will be asked to build on their unique strengths and work towards achieving specific aims in their transition to adulthood.

Numeracy engagement of students in the senior years ranges in scale from the personal to the global. In school, they appreciate and use numeracy know-how integral to the content, discourse structures, and practical demands of subjects they are studying. They also draw on numeracy know-how in managing their study and making predictions about prospects of success in pursuing different post-school pathways. Out-of-school, numerate judgments and actions contribute to their personal independence and responsibility in managing their finances, their time, and their health and safety. Numeracy know-how is also important for participating in situations where actions have important consequences, such as in part-time jobs or membership of sporting or community organisations. Informed citizenship and critique of wider society require students to take up numerate roles in situations ranging from routine (e.g., obtaining a driver’s licence, using a bank account) to sophisticated (e.g., comparing benefits and drawbacks of different credit cards, forming opinions about social and political issues).

Learners in the senior years:

- show a capacity to solve problems and use mathematical language to do so;
- interpret and make accurate drawings of three-dimensional shapes using a variety of tools and techniques;
- move easily between various ways of representing numbers and quantities, such as decimals, ratios, fractions, and percentages;
- are independent when measuring or solving measurement problems and can use a wide range of formulae to calculate areas and volumes;
- understand that probability statements give a measure of how likely something is to happen;
- use algebraic conventions to represent variables with letters and use analytical methods to solve linear and graphical equations;

- use appropriate statistical procedures to interpret data;
- recognise situations where data representations convey bias and influence thinking.

3.2. Numeracy learning opportunities across the curriculum

The development of numeracy requires that students gain the confidence and experience to use their mathematical knowledge in everyday situations and in all disciplines. As Steen (2001) points out, ‘because numeracy is ubiquitous, opportunities abound to teach it throughout the curriculum’ (p. 18). Hogan (2000, in DEST 2004d) elaborates on how this may be possible via the framework presented in Figure 2. Numeracy learning opportunities can be exploited *within mathematics lessons*, by developing mathematical knowledge and techniques and learning how these may be applied in other situations, and also in *other curriculum contexts*, either to explicitly teach mathematical concepts and skills or to use mathematics to deal with issues or problems that are not explicitly mathematical.

SCHOOL MATHEMATICS		OTHER CURRICULUM CONTEXTS	
Learning the structures, patterns and concepts, ideas and techniques of school mathematics.	Applying the mathematics to other situations, finding situations in which to learn the mathematics, learning to develop mathematical models, finding links to using mathematics in other learning contexts.	Using different learning contexts or integrated settings as arenas for explicitly teaching mathematical ideas and techniques.	Dealing with the mathematical demands inherent in performing tasks, handling information, designing and making things or learning new ideas and understanding concepts.
Example	Example	Example	Example
Students are taught to read, write and understand the meaning, order and relative magnitudes of numbers, and to move flexibly between equivalent forms.	In their mathematics class: Students are asked to convert test scores to percentages, investigate the accuracy of a newspaper account that used a percentage.	A teacher uses a cooking lesson to explicitly ask questions about fractions: students find ¾ of a single pie, ¾ of a package of party pies, share 3 pies between 4 people, find half of ¾ cup of flour and so on.	In a class debate on logging rainforests a student states that only 1% of forests in Malaysia are cut down for timber products as a justification for destruction of rainforest. Another student uses the same information as a reason why rainforests should not be cut. This is a numeracy moment that needs attention.

Mathematics $\longleftrightarrow$ **Numeracy**

One informs and supports the other ...

Figure 2. Mathematics and numeracy in the school context (Hogan 2000)

Each discipline places its own numeracy demands on all learners and makes unique contributions to the development of individuals' general numeracy. Numeracy learning opportunities that arise *within Mathematics* lessons and *within other curriculum contexts* are identified below for each of the eight Queensland Years 1-10 Key Learning Area syllabuses.

Mathematics

In the Mathematics key learning area, students use and enhance numeracy skills as they think, reason and work mathematically. Students engage in numeracy practices when they:

- identify the mathematics in a range and balance of situations from life related to purely mathematical;
- identify opportunities to apply mathematical knowledge, procedures and strategies;
- predict possible outcomes of investigations;
- use mental computation strategies;
- resolve problems with imagination and inventiveness;
- use mathematical knowledge, procedures and strategies to estimate, measure or calculate;
- interpret and use a range of mathematical representations;
- visualise mathematical ideas;
- construct physical models to represent mathematical ideas, thinking and reasoning;
- interpret and follow mathematical instructions and directions;
- make logical generalisations from numerical data;
- represent mathematical information in different ways;
- pose and test conjectures and hypotheses;
- check the reasonableness of conclusions and answers.

The Arts

In this key learning area, students draw on numeracy in representing real or imaginary objects and situations. In particular, the arts employ visual, temporal and kinesthetic concepts of space and numerical patterns. Teachers can develop students' competencies in numeracy through arts activities that:

- develop understandings of concepts shared with mathematics, for example, time, length, symmetry, shape, comparison and their cultural origins;
- enable students to express their competencies in contexts that may not be

seen as overtly numeracy based;

- require the application of mathematical skills to practical activities by planning, counting, measuring, designing, graphing, mapping and calculating;
- make and use patterns and sequences.

English

Numeracy demands in the English key learning area include:

- interpretation and construction of spoken, written, visual and multimodal texts that contain numerical concepts and symbols such as those used in illustrations, diagrams and graphs;
- use interpretation, comparison and design of visual and multimodal texts when considering the spatial features in relation to the purposes of the text;
- critical analysis of the use and presentation of data in texts to develop and demonstrate understandings about the selective construction of information expressed numerically, spatially and diagrammatically.

Health and Physical Education

Teachers in this key learning area can play a key role in developing numeracy skills and understandings by providing students with opportunities to:

- collect, organise and use statistical information about health issues such as nutrition and product use to make comparisons and predict patterns and trends;
- choose and use measurement tools and skills in a range of contexts such as field events and fitness activities;
- create and interpret maps, diagrams and plans and use tools such as a compass when undertaking an orienteering course;
- apply spatial concepts such as direction, pathways, levels, angles and relationship to others when creating movement sequences in dance, games and sports;
- demonstrate understandings of numeracy-related concepts such as space (angles, direction, trajectory, shapes, patterns) and rates (velocity, speed).

Languages other than English (LOTE)

Learning in languages other than English involves learners in real-life applications of, and communication about, key mathematical concepts such as measurement, graphing, statistics and the presentation and interpretation of information in tables and maps, giving and following directions and telling time. Activities that require students to solve communication problems develop skills of pattern reading, analysis and creative thinking, which can potentially reinforce and enhance numeracy.

Science

Numeracy and Science have been traditionally linked through the mathematics that is specific to this key learning area. Numeracy practices in Science include:

- use of mathematical terms in practical contexts;
- use of number and algebra to complete scientific calculations;
- application of measurement skills and concepts;
- construction of representations of objects using spatial sense;
- collation and critique of scientific data.

Studies of Society and Environment (SOSE)

In this key learning area, problems related to the social, built and natural environments provide contexts for the development of numeracy skills. Teachers in this key learning area need to consider how numeracy is used within the environment and society of the students and the society that they are investigating. Numeracy practices in SOSE include:

- use of alphanumeric reference systems, directions, scale and ratio to describe locations and to engage in mapping activities;
- collection, organisation, analysis, critique and synthesis of data.

Technology

The Technology key learning area involves the design and development of products in real-life and lifelike contexts. Design challenges can provide opportunities for students to:

- estimate, count, collect, collate, graph, map and critique technological data and statistics;
- apply numerical terms and concepts in practical situations;
- identify and use patterns and employ spatial concepts;
- visualise and construct three-dimensional structures from two-dimensional plans;
- approximate, measure and calculate time, length and mass;
- use mathematical symbol systems.

SECTION FOUR

Numeracy Achievement of Queensland School Students

This section provides evidence of the current standards of numeracy achievement for students within Queensland as compared with other Australian states and territories. It draws on Australian testing programs that assess aspects of literacy and numeracy in Years 3, 5 and 7 in all states and territories, as well as international comparative studies of mathematics achievement and mathematical literacy. These results need to be interpreted with some caution, however, as assessment of numeracy achievement in Australia has tended to focus on mathematical knowledge and, to some extent, strategic knowledge as it is difficult for pen-and-paper tests to authentically assess contextual aspects of numeracy knowledge.

4.1. Years 3, 5 and 7 testing programs in Australia

States and territories have their own literacy and numeracy monitoring programs. These programs are well established and understood within their educational communities. They allow states and territories to report, publicly and to parents, on the range of performance demonstrated by learners, including benchmark performance. Education Ministers have therefore agreed that assessment against the national benchmarks should occur using the existing state- and territory-based programs.

A nationally agreed procedure was designed to equate state and territory tests with each other and to provide comparable reporting of student achievement data against the benchmarks. At each of Years 3, 5 and 7, equating the state and territory tests is a three-stage process involving the construction of common achievement scales, locating the benchmarks on these scales and finding the equivalent benchmark locations on state and territory achievement scales. Tables 1, 2 and 3 identify differences in relation to the proportion of students achieving the numeracy benchmarks in Years 3, 5 and 7 for 2002 and 2003 (MCEETYA, 2002, 2003).

Table 1. Year 3 Numeracy Results for 2002 and 2003

State	2002		2003	
	Percentage of students reaching benchmark	State rank	Percentage of students reaching benchmark	State rank
NSW	95.3 ± 0.7	2	96.7 ± 0.6	1
Vic	92.0 ± 1.7	4	95.8 ± 0.5	2
Qld	91.8 ± 1.5	5	92.1 ± 1.6	5
SA	91.2 ± 1.2	6	90.1 ± 1.7	6
WA	88.6 ± 2.3	8	89.7 ± 2.7	7
Tas	94.1 ± 1.2	3	93.9 ± 1.4	4
NT	89.1 ± 1.8	7	86.4 ± 2.4	8
ACT	95.4 ± 0.8	1	95.2 ± 1.1	3
Australia	92.8 ± 1.3		94.2 ± 1.1	

Queensland was ranked fifth amongst the eight states and territories for Year 3 numeracy results in 2002 and 2003. In both years, around one in twelve Queensland Year 3 students failed to achieve the benchmark. This proportion did not differ significantly from the Australian average.

Table 2. Year 5 Numeracy Results for 2002 and 2003

State	2002		2003	
	Percentage of students reaching benchmark	State rank	Percentage of students reaching benchmark	State rank
NSW	91.2 ± 0.9	3	91.3 ± 1.1	4
Vic	93.2 ±1.1	1	94.7 ± 0.7	1
Qld	88.7 ± 1.9	5	86.3 ± 1.6	7
SA	85.5 ± 1.3	7	90.7 ± 1.2	5
WA	86.2 ± 1.7	6	90.4 ± 2.0	6
Tas	89.1 ± 1.7	4	92.4 ± 1.2	2
NT	75.6 ± 2.2	8	76.1 ± 2.6	8
ACT	91.3 ± 1.1	2	91.9 ± 1.7	3
Australia	90.0 ± 1.3		90.8 ± 1.2	

In the Year 5 numeracy testing program, Queensland was ranked fifth in 2002 and the proportion of students not reaching the benchmark (around one in nine) did not differ significantly from the Australian average. However, in 2003 Queensland dropped to seventh position and this change in relative position was accompanied by a decline in performance. Around one in 7.5 Queensland Year 5 students failed to achieve the benchmark in 2003, a proportion that was below the Australian average.

Table 3. Year 7 Numeracy Results for 2002 and 2003

State	2002		2003	
	Percentage of students reaching benchmark	State rank	Percentage of students reaching benchmark	State rank
NSW	78.2 ± 0.7	7	73.9 ± 0.8	7
Vic	87.1 ± 1.0	2	85.8 ± 0.7	2
Qld	88.3 ± 0.8	1	85.2 ± 0.6	3
SA	85.6 ± 0.8	4	85.2 ± 0.8	3
WA	85.0 ± 0.9	5	84.3 ± 0.7	5
Tas	84.0 ± 1.1	6	80.6 ± 1.1	6
NT	68.1 ± 3.8	8	68.7 ± 2.1	8
ACT	86.9 ± 1.2	3	86.4 ± 1.6	1
Australia	83.5 ± 0.9		81.3 ± 0.8	

Results of the Year 7 testing program for 2002 placed Queensland in first position amongst the states and territories, with around one in nine students failing to reach the benchmark. This proportion was above the Australian average. In 2003, Queensland dropped to third place and performance also declined so that one in seven students did not achieve the benchmark, a proportion that was nevertheless well above the Australian average.

Differences in performance across states and territories may be related to the age of the students and their number of years of schooling at the time of testing, socioeconomic status and other demographic factors (e.g., geographical location), and the proportion of Indigenous students taking the test. For example, for the results reported here, students in Queensland and Western Australia were several months younger than students in other states and territories at the corresponding year level and had experienced one fewer years of schooling. Also, the generally higher achievement of students in the ACT may be due to their higher socioeconomic backgrounds, while the lower achievement of Northern Territory students may be related to the high proportion of Indigenous students there.

While it is difficult to recognise any trends in the 2002 and 2003 Years 3, 5 and 7 numeracy test results, some conclusions about performance changes over time and performance differences between states and territories can be drawn from results of international comparative studies that have been repeated over a longer period of time.

4.2. International comparative studies of mathematics achievement and mathematical literacy

Australian secondary students' results in international comparative studies of mathematics achievement appear to have declined slightly over a 30 year period of testing encompassing the First IEA Mathematics Study (FIMS), conducted in 1964, the Second International Mathematics Study (SIMS, 1978), and the Third International Mathematics and Science Study (TIMSS, 1994) (Afrassa & Keeves, 1999). More noticeable is the change in Queensland students' performance in terms of the state's ranking in the national context. In 1964, when the only FIMS participants were government schools in New South Wales, Victoria, Queensland, Western Australia and Tasmania (Doig, 2001), Queensland was the best performing state. In the 1978 study (SIMS), non-government schools, the ACT and South Australia also participated, and the mean mathematics scores for Queensland and ACT students were higher than those for other states. By 1994 (TIMMS), when government and non-government schools in all states and territories participated, Western Australia was the top ranked state. These results are consistent with findings of other studies of literacy and numeracy performance in the same time period (Bourke & Keeves, 1977; Masters, 2003). In 1975 Queensland students achieved significantly better than students in other states, but Western Australia has now replaced Queensland as the strongest performing state. However, examination of state differences is complicated by the need to take into account the social, cultural, and demographic factors mentioned in the previous section.

The following sections summarise Australian students' recent performances in two important international testing programs, TIMSS (now known as the Trends in International Mathematics and Science Study) and PISA (Programme for International Student Assessment).

TIMSS (Trends in International Mathematics and Science Study): Mathematics achievement of Year 4 and Year 8 students in 2002-2003

TIMSS 2002-2003 took place in 46 countries, with just over 10,000 Australian students participating. This sample was drawn from all states and territories so as to be representative of the Year 4 and Year 8 populations in Australia. These tests are prepared internationally to reflect the common curriculum features of individual countries to ensure that comparisons between countries are as fair as possible. Note, however, that this is a test of mathematics achievement and not a test of numeracy. Results are reported as average scores, as distributions of scores, and as percentages of students who attain international benchmarks.

At Year 4 the performance of Australian students was not statistically different from the international average, and at Year 8 it was significantly higher than the international average. At both Year levels, performance has not changed significantly since TIMSS 1994-95, but performance relative to other countries has declined as these countries have improved significantly during this period. This means that in 2002-03 there were more countries performing better than Australia than there had been in 1994-95.

Year 4 students in Western Australia performed significantly below the national and international averages and the averages for students in New South Wales, Victoria and the ACT. Queensland's and other states' Year 4 performance was not significantly different from the national or international averages or other state averages. In Year 8, New South Wales students performed significantly better than those in Queensland, Western Australia and the Northern Territory. Students in all states except the Northern Territory achieved average scores significantly above the international average.

The TIMSS 1999 Video Study

Complementing the TIMSS testing program is the TIMSS 1999 Video Study, which aimed to investigate Year 8 mathematics and science teaching practices in participating countries (Australia, the Czech Republic, Hong Kong SAR, Japan, the Netherlands, Switzerland, the USA). In Australia 87 mathematics classes were filmed, with the sample representing all states and territories in proportion to Year 8 enrolment. Schools came from all education sectors and both metropolitan and rural areas. Lesson videotapes were analysed via a rigorous and internationally standardised procedure in order to gain rich and authentic information on mathematics teaching in lower secondary schools.

Although the international results of the TIMSS assessment studies have shown Australian students do reasonably well compared with other international participants, the Video Study painted a less than favourable picture of teaching practices in Australian classrooms (Hollingsworth, Lokan & McCrae, 2003). In particular, mathematics lessons featured much repetition, work on problems rated as low in procedural complexity, an emphasis on low-level procedures rather than higher order thinking, little attention to real-life connections, and little time allowed for discussion of alternative solutions. This ‘shallow teaching syndrome’ was criticised as being insufficient for developing students’ conceptual understanding and problem solving abilities. It was recommended that ‘Australian students would benefit from more exposure to less repetitive, higher-level problems, more discussion of alternative solutions, and more opportunities to explain their thinking’ (Hollingsworth, Lokan & McCrae, 2003, p. xxi). Although this research was concerned with mathematics teaching, the implications for numeracy education are clear in terms of the challenges involved for teachers in developing students’ mathematical, contextual, and strategic know-how.

Programme for International Student Assessment (PISA): Mathematical literacy of 15 -year-old students in 2000 and 2003

PISA is a pen-and-paper survey of the knowledge and skills of 15-year-old students in OECD countries. The domains of assessment were originally reading literacy, scientific literacy, and mathematical literacy, with a fourth domain, problem solving, added in 2003. Because PISA assesses students’ ability to apply their knowledge and skills to real life problems rather than how well they have learned a specific curriculum, it is likely to be a more valid test of numeracy as interpreted in the Australian context than other national and international testing programs.

In 2000, 43 countries participated in PISA. The major domain of assessment was reading literacy, with mathematical and scientific literacy as minor domains. Australia ranked third in mathematical literacy together with five other countries (McGaw, 2004). Marks and Cresswell (2005) used the PISA 2000 data to investigate state differences in mathematical literacy relative to the performance of New South Wales students. Examination of raw score differences between the states showed that the Northern

Territory's performance was significantly different from (and lower than) that of New South Wales; there were no significant differences in performance among the other states. However, a very different picture emerged when statistical methods were used to control for students' socioeconomic status, Indigenous status, geographical region, and Year level (in Queensland and Western Australia, 15-year-old students are evenly divided between Years 10 and 11; in other states, most students of this age are in Year 10): based on these PISA 2000 results, mathematical literacy for New South Wales students was significantly higher than in South Australia, Western Australia, Tasmania, the Northern Territory, and Queensland (which recorded an adjusted score lower than most other states).

Results for PISA 2003 have only recently been released. Australia was ranked fifth in mathematical literacy and fifth in problem solving, and all states and territories performed at or above the OECD average. Queensland students' performance was significantly lower than that of the ACT, significantly better than that of the Northern Territory, and not significantly different from other states. A detailed analysis of state comparisons, controlling for socioeconomic and other factors (see Marks & Cresswell, 2005), has not yet been reported.

When placed in an international context, Australian students' PISA performance is excellent. However, analysis of state and territory results that takes into account factors known to affect performance – socioeconomic and demographic background, Indigenous status, years of schooling – demonstrates that the attainment of Queensland students falls below that of students in other parts of Australia. These results deserve attention as they come from an assessment program that comes closest to evaluating numeracy as application of mathematical, strategic and contextual knowledge and skills.

SECTION FIVE

Effective Numeracy Teaching: The View from Research

This section summarises literature with regard to the current state of play of the teaching and learning of numeracy and mathematics, as within this literature body these ideas are closely intertwined.

The literature suggests that what teachers do in the classroom is the strongest predictor of growth in positive mathematical outcomes for students (DEST, 2004b). Their practices are consistently the most important predictors of student outcomes, and students' perceptions of teacher practices appear to affect students' engagement in mathematics. In the secondary school context mathematics achievements are also strongly influenced by (non-computer) resources in the school, the teacher's educational background and the quality of the professional community in the mathematics department (DEST, 2004a). In the primary school context teachers' beliefs about mathematics and knowledge of mathematics are instrumental in engendering positive student numeracy learning.

From the findings of national and international research projects there appear to be three broad areas that impact on the teaching and learning of mathematics, namely, the theme of elements of effective mathematics teaching with two sub-themes relating to (a) beliefs and attitudes towards the teaching and learning of mathematics, and (b) knowledge about numeracy and mathematics.

5.1. Effective mathematics teaching

There appear to be six core elements that are crucial to enhancing students' numeracy outcomes. These are teachers' mathematical knowledge, teachers' mathematics pedagogical knowledge, teachers' planning (particularly at the unit level), creating active learning environments involving classroom inquiry, continual professional engagement for teachers, and positive parental support (DEST, 2004a). Figure 3 delineates the relationship among these elements.

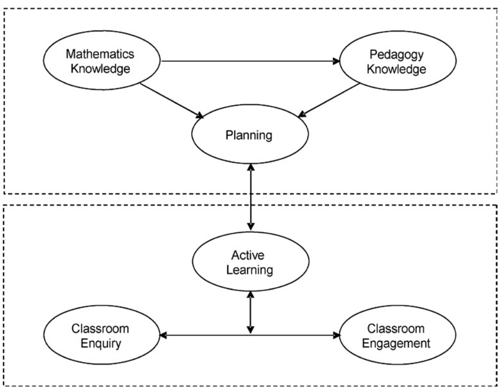

Figure 3. Relationships among the six core elements (DEST, 2004a. p. 71)

External elements that enhance student numeracy outcomes are in situ professional development support, sharing and collaboration within schools and across schools, administrative support in terms of teacher release time and administrators leading curriculum change within the school (DEST, 2004a).

Teacher practices are consistently the most important predictors of student outcomes. Students' perceptions of teacher practices appear to have the strongest effect. This suggests that the strongest predictors of positive mathematical outcomes are the actions of the teacher in the classroom context (DEST, 2004b). In the primary school, effective teaching for numeracy incorporates noticing and dealing with numeracy across the curriculum, paying attention to and understanding students' numeracy issues, giving time to numeracy (across the curriculum) and an ability to reflect on the way mathematics is being taught (DEST, 2004c). Exemplary classroom practice developing numeracy in the middle years of schooling emphasises higher-order thinking about mathematical topics and links mathematical topics to real situations and situations that have relevance to the students (DEST, 2003). Additionally, in secondary schools, the better the learning environment the better the learning that is likely to occur (DEST, 2004b).

In summary, the most effective numeracy teachers challenge pupils to think mathematically, expose and relate to children's existing knowledge, develop significant mathematics, develop connections between mathematical ideas and between mathematics and the real world, stimulate pupils' interest, curiosity and excitement and sustain engagement. They focus on mathematics rather than work, or getting answers, allow sharing of methods and value contributions of children, recognise multiple meanings, focus on reasoning not answers (not cued elicitation), and accept and work with children's errors (Brown & Askew, 2000).

5.2. Beliefs and attitudes towards mathematics

Beliefs about teaching mathematics underpin teachers' effectiveness at teaching mathematics. The three main areas where this seems to have the most profound effect are on teachers in the early years, preservice teachers, and students themselves. For teachers in the early years their beliefs about mathematics impact on their pedagogy to an extent that it is a strong differentiating factor between highly effective teachers and other teachers. Thus while the goals for numeracy in the early years are clear, achievement of these is influenced by the beliefs and attitudes of each early childhood community (DEST, 2003), and in many instances this tends to be non-supportive. As well as teaching quality and confidence, early years teachers' pedagogical content knowledge was recognised as being important for ensuring optimal mathematics learning (Bobis et al., 2005). The literature suggests that making a difference in early years classrooms involves implementing research-based frameworks, with diagnostic interviews at appropriate stages of student learning, and whole-school approaches to professional development. The use of task-based, one-to-one assessment interviews and ongoing reflective professional development are seen to make a difference (Bobis et al., 2005).

In the Queensland context, the results of a large study conducted with Queensland Primary school teachers (Warren and Nisbet, 2001) focusing on beliefs about assessment and teaching practices, indicated that teachers in the lower grades used assessment practices coincidental to learning, whereas upper-grade teachers tended to incorporate practices distinct from instruction, that is, traditional and extended tasks. It also appeared that the main purpose of assessment was to inform teachers about their teaching. Of interest in the results was the relatively low use of assessment to inform the learner about what they do know rather than what they do not know, indicating that many numeracy classrooms in Queensland primary schools continue not to reflect contemporary understandings of teaching or assessment (Nisbet and Warren, 2000).

Many preservice teachers lack confidence in their personal ability to teach mathematics effectively in primary school. Preservice students come to teaching with extensive experiences in mathematics, especially with regard to mathematics at the school level. It is suggested that this has two consequences, namely, (a) 'scarring' that takes visible forms in lower mathematics teaching efficacy, or (b) positive experiences that can predispose students to certain pedagogical preferences at the expense of others (Clarke, 2005). There is also a strong relationship between mathematical anxiety and the apprehension preservice students experience when faced with the prospect of teaching the subject during their initial practicum. This anxiety is related to their experiences with formal mathematics instruction during their own schooling (Brady & Bowd, 2005). Thus teachers' beliefs about mathematics not only have a profound effect on students' learning but on the students who intend to be future teachers.

Students' learning and their capacity to take up the 'role' of being numerate are influenced by their beliefs about mathematics. One way of beginning to address this is to encourage students to work with others. It was found that working with others helps students clarify and solve problems (DEST, 2004c). In the USA context, many students are taught by teachers who are underprepared to teach mathematics, and those poorly prepared teachers are disproportionately working with students from less-advantaged backgrounds and students of colour (RAND, 2003), thus compounding the problem.

5.3. Knowledge about numeracy and mathematics

The knowledge required by teachers encompasses four dimensions, mathematics as substantive content, mathematics as an epistemological perspective, mathematics as a cultural tool and that mathematics learning is influenced by one's disposition to mathematics (DEST, 2004a). Teachers' pedagogical content knowledge as well as teaching quality and confidence were recognised as being important for ensuring optimal mathematics learning (Bobis et al., 2005). Primary school teachers who lacked mathematics knowledge in particular topics tended to avoid teaching that topic altogether (DEST, 2004a).

'Highly effective teachers had knowledge, understanding and awareness of conceptual connections within and between the areas of the primary mathematics curriculum which they taught. However, in this study, being highly effective and displaying this kind of mathematical knowledge were not associated with levels of qualifications in mathematics' (Askew et al., 1997, p.5). Nevertheless, numeracy development can only occur where students' conceptual knowledge of mathematics is firmly established, and for this to happen teachers need to have strong subject-matter knowledge (DEST, 2003).

Teachers' mathematical knowledge for teaching is significantly related to students' achievement in the early years (Hill, Rowan & Ball, 2005). This involves having knowledge of the subject matter as well as knowledge of how to represent mathematical concepts and procedures to students. In other words, it is a teacher's ability to understand and use the subject-matter knowledge required to carry out the tasks of teaching that is paramount. It is suggested that more knowledgeable teachers provide better mathematical explanations, construct better representations, are better able to respond to students' ideas and reasoning and have a clearer understanding of the structures underlying primary mathematics and how they connect (Ball, 1993).

Attracting and retaining effective specialist mathematics teachers is a grave concern in secondary schools. Currently there is a trend to deploy staff prepared in other subjects to teach mathematics. As a result of this trend students may pass through secondary school without encountering mathematics teachers with an enthusiasm for their subject.

In summary, the predominant factors that influence students' numeracy outcomes are:

- teachers' beliefs and attitudes towards mathematics (love of mathematics);
- teachers' own numeracy ability and knowledge of mathematics (educational background);
- the learning environment in which the students are engaged (active, enquiry-based, open-ended tasks, resources in the school);
- students' perceptions of teachers' practices;
- teachers' ability to notice and attend to numeracy across the curriculum;
- teachers' ability to pay attention to and understand students' numeracy issues;
- teachers' giving time to numeracy; and
- ongoing professional support with a focus on those who have weak subject-matter knowledge for teaching and little confidence in teaching mathematics.

5.4. Teaching numeracy across the curriculum

While much of the current debate in Australia about numeracy focuses on school mathematics, it is clear from the description of numeracy endorsed by the national numeracy policy (DETYA, 2000) and adopted for the present report that numeracy is about using mathematics in real contexts where the purpose is more than learning school mathematics (Hogan, 1999). However it can be difficult for schools to address this contextual aspect of numeracy when they are removed from real world problems that demand a numerate response. Similarly, there are challenges in dealing adequately with the 'choosing and using' aspect of numeracy as strategic know-how, when students are obviously expected to use mathematics during mathematics lessons and there is no element of choice invoked. One way of responding to these dilemmas is to recognise that the 'real context' for school students is often the subjects other than mathematics that they do at school. This means it is important to provide opportunities for numeracy development across the whole curriculum and not just in mathematics lessons. This section draws together Australian and international research on teaching numeracy across the curriculum to identify implications for all teachers, including specialist teachers of mathematics and non-mathematics teachers with expertise in other subject areas.

Numeracy across the primary school curriculum

Most of the recent numeracy research and development projects in Australia have been commissioned by the Australian Government in support of the National Literacy and Numeracy Plan. One such project, carried out in Western Australia, aimed to investigate the numeracy demands and opportunities created across the upper primary school curriculum (DEST, 2004d). Its findings shed light on how both students and their teachers deal with these demands.

All three dimensions of numeracy know-how – mathematical, strategic, and contextual – were important for students' learning. Knowing some mathematics and how it can be used in a range of contexts often made students more confident in trying unfamiliar problems; nevertheless, some students had trouble understanding the mathematics whenever they worked on cross-curricular tasks. This means that students still need opportunities to work *within* the mathematics learning area in order to learn mathematical concepts and modes of thinking. Strategic know-how was also important because this helped students adapt mathematical ideas to the context and decide whether the result they obtained made sense. Students who were already familiar with a context could successfully engage with tasks which had mathematical demands, but there is no automatic transfer of knowledge from one context to another.

The project also identified a number of ways in which primary school teachers could help students deal with numeracy demands in learning areas other than mathematics. These included:

- noticing and dealing with numeracy in the moment;
- being explicit with students about numeracy;
- being aware of the possible numeracy demands when planning;
- giving students time and opportunities to work things out for themselves and with peers;
- questioning students about the way they tackled tasks to develop their

strategic thinking;

- listening purposefully to identify numeracy learning problems;
- helping students see the purpose of the task;
- asking other teachers for help in dealing with students' numeracy problems;
- creating situations that allow students to explore similar numeracy issues across different contexts;
- helping students make sense of situations where the mathematics is too unfamiliar or difficult for them to deal with; and
- developing a teaching repertoire that goes beyond demonstration and student practice.

The project provided many examples of tasks from non-mathematics learning areas that required practical and thoughtful use of mathematics. While there was little evidence that participating teachers recognised or exploited these numeracy learning opportunities in their own classrooms, many teachers did become more aware of the complexity of numeracy as a concept and more interested in what their students were doing in numeracy situations. For primary school teachers, then, the demands of numeracy teaching include developing sufficiently rich mathematical knowledge for teaching as well as broad knowledge of contexts for students' numeracy learning offered by other subject areas across the curriculum they teach.

The school curriculum becomes more differentiated and teaching becomes more specialised as students enter the middle and senior secondary years. During these years students usually have different teachers for each subject, an arrangement that presents special challenges for the goal of teaching numeracy across the curriculum. In particular, it is easy to assume that numeracy must be the responsibility of the mathematics teachers in a school rather than being 'everyone's business' (DEETYA, 1997). The literature in this area discusses two approaches that schools might adopt:

- helping all secondary teachers to understand the nature of numeracy and to implement numeracy teaching across the curriculum; and
- drawing on the disciplinary knowledge of specialist mathematics teachers to integrate mathematics with other curriculum areas.

Numeracy across the secondary school curriculum

Groves (2001) reported on a secondary preservice teacher education course, offered by Deakin University, which aimed to help students:

- understand the nature of numeracy and its role in everyday life;
- develop their personal numeracy skills;
- recognise the role of numeracy and the demands and opportunities it presents within their areas of specialisation;

- develop teaching strategies to address their students' numeracy learning needs within these areas.

The course was taught by mathematics education staff members, with input from staff members in other areas during its development. Student evaluations of the course endorsed the importance of these aims and indicated that the first three were addressed to a large extent. (The fourth aim had to be abandoned because of time constraints, and in any case may have been unrealistic in the expectations it embodied.) Overall, however, the student response was described as highly polarised: many enjoyed and valued the course while others disliked it, possibly because of the fears and anxieties they felt towards numeracy in general.

While Groves' (2001) report demonstrated the possibilities for designing a numeracy-across-the-curriculum course for secondary preservice students, it also highlighted the uneven spread of numeracy demands and learning opportunities in non-mathematics subjects across the years of schooling and across the topics being taught. This highlights the need for specialist mathematics teachers to work with teachers who specialise in other subject areas to develop more awareness of the role of numeracy across the secondary curriculum and of the numeracy demands on students.

Numeracy and curriculum integration

Within mathematics education there are moves to reform curricula and teaching methods to make mathematics more meaningful for students by highlighting links among mathematical topics, investigating mathematical applications in the real world, and valuing connections between mathematics and other disciplines. Curriculum integration is often proposed as a means of helping students to develop richly connected knowledge and recognise how this knowledge is used in real world contexts. From a numeracy perspective, efforts to integrate mathematics with other key learning areas, around authentic, real world tasks or problems, may also go some way towards developing strategic and contextual know-how in addition to mathematical know-how.

Approaches to curriculum integration differ according to the type of connections made between subject areas (see Wallace, Rennie, Malone & Venville, 2001). At one extreme is a subject-centred approach, at the other is full curriculum integration where knowledge from relevant disciplines is brought to bear on problem-solving situations. In between lies a variety of interdisciplinary approaches that connects subject areas in different ways; for example, by planning separate subjects around a common theme or problem, or by unifying some subjects into a single course taught by two or more teachers.

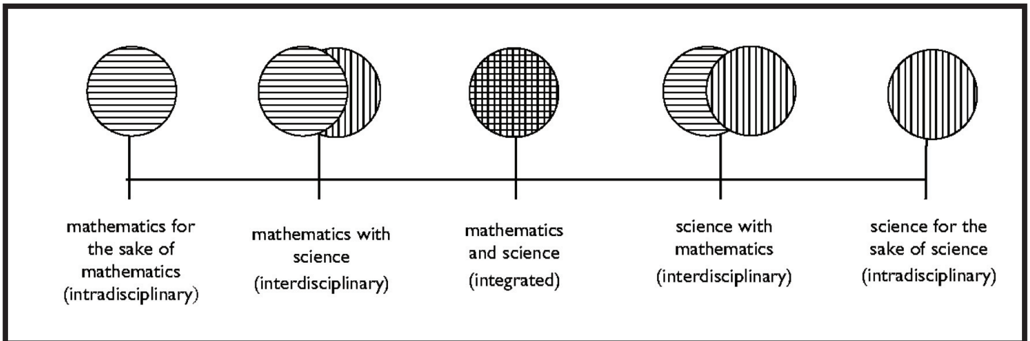

Figure 4. Mathematics/science integration continuum (Huntley, 1998. p. 322)

Considering integration of mathematics and science, Huntley (1998) proposes a continuum to clarify the degree of overlap or coordination between these disciplines during instruction (see Figure 4). For example, she defines a 'mathematics with science' course (interdisciplinary curriculum) as one teaching mathematical topics (represented by the circle filled with horizontal lines) under the cover of a science context (circle filled with vertical lines). On the other hand, in a 'mathematics and science' course (integrated curriculum) the two disciplines interact and support each other in ways that result in students learning more than just the mathematics and science content (circles overlap completely to form a new pattern). The latter approach seems consistent with the idea of numeracy as involving strategic and contextual know-how as well as mathematical content knowledge.

Previous research has identified many barriers to designing and implementing integrated curricula as well as factors that facilitate integration (e.g., see Frykholm & Meyer, 2002; Budgen et al., 2001). These factors operate at several levels of influence, as depicted in Figure 5. Beyond the school, we must consider the influence of education systems on curriculum content and assessment of student achievement, as well as parental and community attitudes. School cultures can inhibit interdisciplinary collaboration, especially in secondary schools where departments are usually organised around subject specialisations. Schools also need to provide administrative support to teachers by allowing adequate time for conceptualising and designing integrated programs and scheduling joint planning time so teachers can work in teams. Inflexible timetabling of teachers and classes and allocation of rooms and other facilities can also make it difficult to offer genuinely integrated learning experiences.

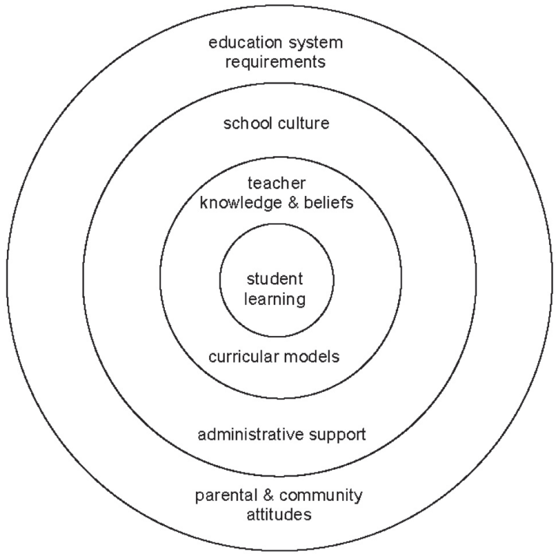

Figure 5. Issues in curriculum integration (Goos & Askin, 2005, p. 128)

However, teachers themselves are the key because teachers' disciplinary knowledge and beliefs, their assumptions about how curricula should be organised, and their knowledge of alternative curriculum models can either facilitate or limit their ability to pursue an integrated approach. Teachers who are committed to curriculum integration must then address important questions about their goals for integration, which disciplines to bring together, how relationships between disciplines are to be coordinated, selection of content, depth of treatment, instructional approaches, and assessment of student learning.

Some of these issues have been investigated by Australian researchers and teachers who are interested in developing numeracy across the curriculum approaches in secondary schools. Goos (2001; see also Goos & Mills, 2001) reports on a project in which prospective teachers of mathematics and history worked together to prepare integrated curriculum units for junior secondary students that would meet learning outcome requirements of both the Mathematics and Studies of Society and Environment (SOSE) syllabuses in Queensland. The project analysed the benefits and difficulties experienced by the preservice teachers and identified implications for collaboration between teachers across different subject areas. These included uncertainty about the extent of integration that was possible and desirable, organisational constraints involving subject timetabling and allocation of resources, and the challenges of working with teacher colleagues who held different pedagogical as well as epistemological beliefs (see Figure 5).

Working with practising teachers, Goos and Askin (2005) describe the design, implementation and evaluation of a problem-based Year 10 course that integrates the disciplines of mathematics and science to help students develop numeracy skills in investigating and explaining their world. Teacher knowledge and beliefs, school culture, and administrative structures interacted to both constrain and support the original intent of the course, although there was evidence that students found the course relevant, real academic learning occurred in the two disciplines of mathematics and science, and the course additionally developed strategic and contextual aspects of numeracy knowledge.

5.5. Implications for ongoing professional learning

The main implication that can be drawn from research on effective numeracy teaching is that professional learning for all teachers of mathematics at all levels of schooling needs to focus on two main dimensions, teachers' knowledge and their beliefs about teaching mathematics. For reform in learning mathematics to be successful attention must be given to existing practices of mathematics teachers. Any attempt to improve the quality of mathematics teaching must begin with an understanding of the conceptions held by teachers and how these are related to instructional practices (Brosnan, Edwards & Erickson, 1996). Teachers' knowledge also needs to be addressed as it is closely linked to students' knowledge (Ma, 1999). In fact it is suggested that the greater the teacher's knowledge of mathematics the greater the likelihood of student success in mathematics. Thus teacher content knowledge in mathematics is a serious issue (Farmer, Gerretson & Lassal, 2003). Both limited teacher knowledge of mathematics and negative beliefs towards mathematics seem more entrenched within primary and early years contexts for this area as compared with others such as literacy. Juxtaposed against this is the hierarchical nature of mathematics, with early numeracy experiences underpinning the development of, and being crucial to future learning in, mathematics.

For fundamental change, teachers need to experiment with new understanding and new behaviour (Loucks-Horsley, Hewson, et al., 1998). Like students, teachers need to learn by being directly engaged and this takes time because new knowledge is not just additive but involves the remodeling of existing knowledge. Teachers will only do something with the ideas from professional development if they have 'ownership' of it. (Farmer, Gerretson, & Lassal, 2003).

With a new Years 1-10 mathematics syllabus being implemented in Queensland in 2007, the lack of engagement of teachers in mathematics at these year levels becomes even more crucial. It is suggested that working as school clusters with appropriate professional and emotional support and curriculum leadership are key components of a framework that enhances teachers as a community of learners of mathematics (Proudford, 2003). For some teachers engaged in professional learning the resistance to change from traditional practices is so ingrained that even evidence that students can create mathematical ideas is not enough for them to overcome prior conceptions about teaching and learning mathematics (Olson & Barrett, 2004). Thus one-off professional learning events can have little impact on the mathematics classroom environment.

One key component absent from professional development models within the Australian context is accreditation (White et al., 2004). Ultimately the success of professional learning depends on teacher commitment and enthusiasm. A more balanced approach within the Australian context would consist of three elements, namely, knowledge about mathematics, knowledge about appropriate ways of teaching mathematics and formal recognition by employers that this knowledge is important to enhancing students' numeracy outcomes.

Significant numbers of Queensland teachers have only a three-year teaching qualification: 24% of pre-school and primary school teachers and 12% of secondary school teachers were in this category in 2004 (Board of Teacher Registration Queensland, 2004), again highlighting the need for ongoing professional learning.

In summary, the professional learning described above needs to be ongoing and to target, in particular, primary classrooms and lower secondary classrooms where teachers may be under-prepared to teach mathematics as a specialist discipline. The experiences need to be classroom focused, developing deep understandings of mathematics and mathematical pedagogy, collaborative with expert input from those who have a deep understanding of mathematics teaching and learning and with an ability to transcribe this into practical, real-world contexts. Figure 6 summarises the interaction between these key elements of the professional development process.

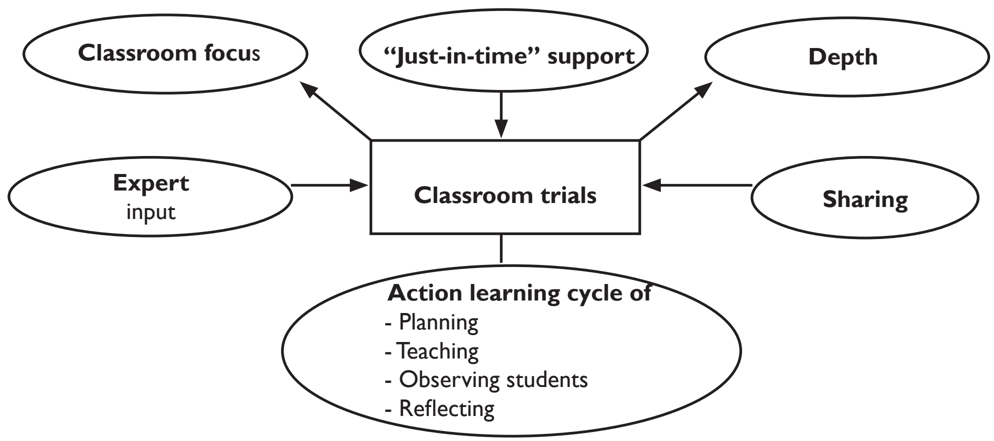

Figure 6. The professional development process (DEST, 2004a, p. 84)

SECTION SIX

Preparing Teachers of Numeracy

Planning for the preparation of teachers of numeracy needs to take into account the nature of numeracy, numeracy learning expectations and opportunities at all levels of schooling and across all key learning areas, data on Queensland school students' numeracy achievements, and research on effective numeracy teaching. It is also important to consider relevant characteristics of Queensland preservice teachers and implications for their ability to engage students effectively in numeracy learning experiences. The next section profiles entry characteristics of candidates for primary and secondary preservice teacher education programs. This is followed by information provided by Queensland universities about approaches they use to develop preservice teachers' personal numeracy competence and prepare them to teach numeracy. Finally, a summary is provided of research findings on teacher education programs for numeracy development, from which implications are drawn for the formulation of numeracy standards for graduate teachers in Queensland.

6.1. Profiles of Queensland preservice teachers

This section reports on the profiles of preservice teachers as reflected in data collected in recent years concerning students who enrolled in Queensland teacher education programs in 2004. The profiles relate to the students' gender, age group, mathematics background, OP Score and mathematics/numeracy skills.

Gender and age

Data published by the Queensland Tertiary Admissions Centre (QTAC) on their website (QTAC, 2004) indicate that the great majority of preservice teachers who commenced undergraduate study in 2004 were females (73%). This was down slightly on the percentage who enrolled in 2003 (74.6%). The majority of preservice teachers who commenced study in 2004 were aged 19 years and under (53.5%); however, the number aged 20 years and over is a significant percentage (46.5%). The data also show that females outnumbered males across the three age groups (19 & under, 20-24, and 25 & over), most noticeably in the '19 & under' group, which is the group of school leavers (see Table 4 and Figure 7).

Table 4. Enrolments in Queensland Teacher Education Programs by Gender and Age, 2004

Gender	Age group: 19 & under	20-24	25 & over	Total
Females	1264	433	558	2255
Males	387	186	259	832
Total	1651	619	817	3087

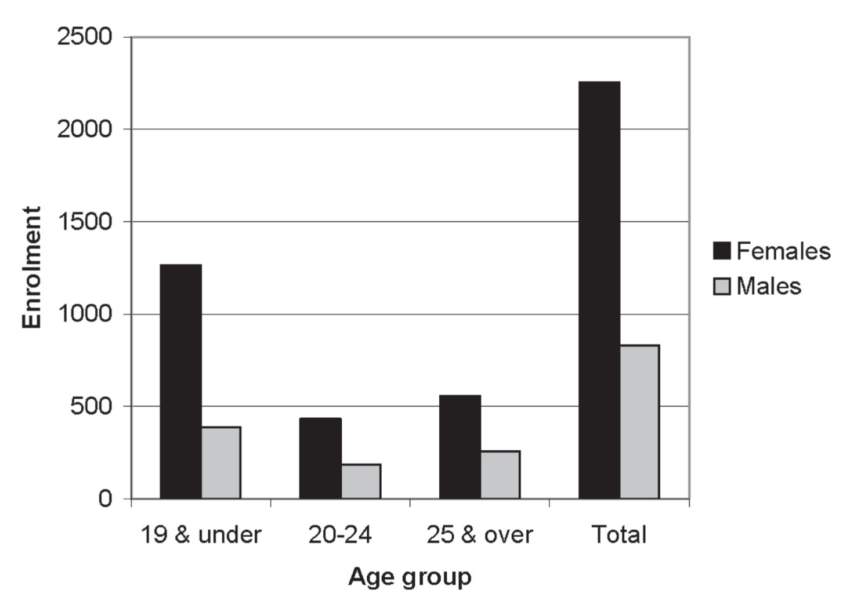

Figure 7. Enrolments in Queensland preservice teacher education programs by gender and age, 2004

The enrolment data include both primary and secondary preservice teachers, although the primary component would be greater, due to higher quotas and the fact that graduate-entry preservice teachers do not all enrol through QTAC. The graduate-entry secondary mathematics profile is different from that exhibited in the overall figures above, as illustrated by the example of enrolment data from the University of Queensland relating to their secondary mathematics intake (see Table 5 and Figure 8). The proportions for the age group 25 & over are higher than those for the overall figures; this is due to the fact that these students have completed an initial degree and because many have been in the workforce for some time as well.

Table 5: Age Profile of Pre-service Mathematics Teachers Enrolled in University of Queensland's Graduate-entry Bachelor of Education (from unpublished UQ enrolment data)

Year	19 & under	20-24	25 & over	Total
2004	0	9	17	26
2005	0	11	12	23

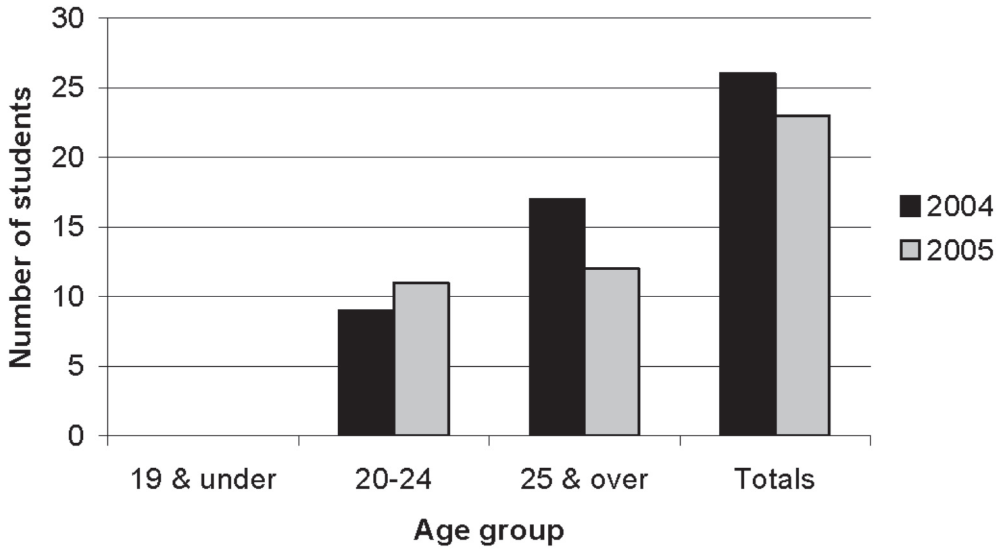

Figure 8. Age profile of pre-service mathematics teachers enrolled in University of Queensland's graduate-entry Bachelor of Education

It appears that there is more of a gender balance in post-graduate education courses. For instance, the percentage of male students in post-graduate education courses at UQ was 36% in 2004 and 35% in 2005, compared to 27% for undergraduate courses in 2004 (see Table 6).

Table 6. Gender Profile of Pre-service Teachers Enrolled in University of Queensland's Graduate-entry Bachelor of Education (from unpublished UQ enrolment data)

GENDER	2004	2005
Female	169	143
Male	96	77
TOTAL	265	220

Mathematics background

Data obtained in a research project conducted in 1998 (Hanbury, 2002) revealed that 91.7% of preservice primary teachers at Griffith University had completed Grade 12 mathematics of some description (Mathematics in Society, Maths I or II, Maths A, B or C). Of those who had not completed Grade 12 mathematics, the majority had completed either Grade 11 or Grade 10 mathematics (see Table 7 and Figure 9).

Table 7. Highest Level of Mathematics Studied by Preservice Primary Teachers at Griffith University (From Research Conducted in 1998, Hanbury, 2002)

HIGHEST LEVEL STUDIED	NO. OF STUDENTS	% OF STUDENTS
Grade 8	1	0.7
Grade 10	8	5.6
Grade 11 – Maths A/ Maths in Society	3	2.1
Grade 12 – Maths A/ Maths in Society	71	49.7
Grade 12 – Maths B / Maths I	50	35.0
Grade 12 – Maths C / Maths II	10	7.0
TOTAL	143	

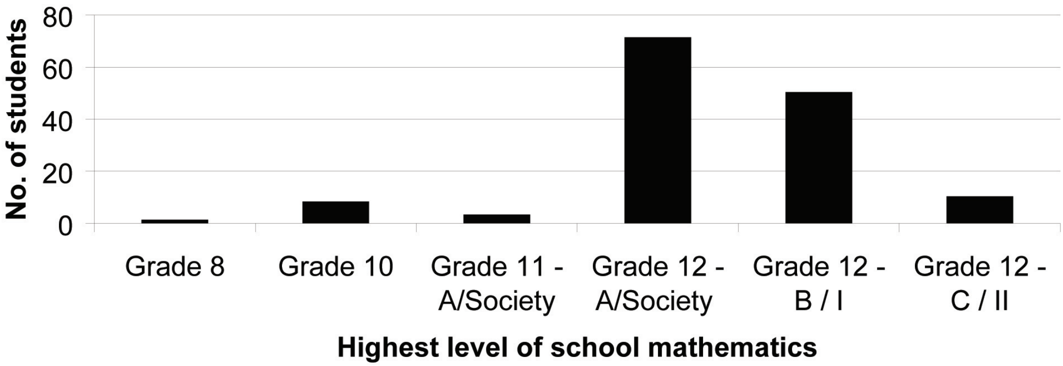

Figure 9. Highest level of mathematics studied by preservice primary teachers at Griffith University (from research conducted in 1998, Hanbury, 2002)

Overall Positions (OPs)

In Queensland, Year 12 school leavers who are eligible are awarded an Overall Position (OP) which indicates their statewide rank order position based on overall achievement. OP scores range from 1 to 25 with 1 being the highest and 25 the lowest.

QTAC figures for 2004 admissions show that the median OP score for Education students was 9.

Thirty-two per cent of students had an OP Score of 7 or better, 85% of students had an OP Score of 13 or better, and 97% had an OP Score of 15 or better (see Figure 10).

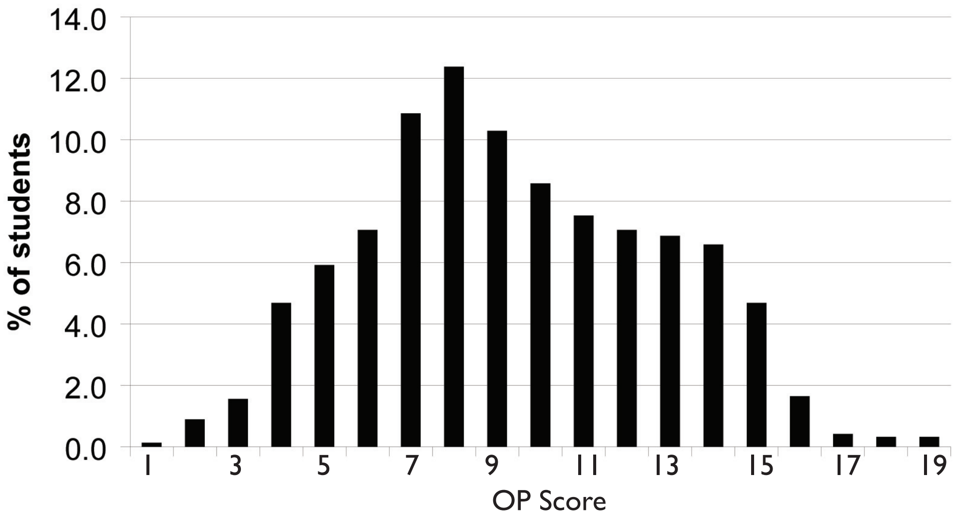

Figure 10. Distribution of OP Scores for Education students (2004 admissions)

However, the distribution of OP Scores varies across institutions. Students who enrol in preservice primary teacher education programs at Brisbane universities, generally have better OP scores (median and cut-off points) than their counterparts in regional universities (see Table 8 and Figure 11).

Table 8. Median and Cut-off OP Scores for Preservice Primary Teacher Education Students (2004 admissions)*

LOCALITY	UNIVERSITY	MEDIAN OP SCORE	OP CUT-OFF - MAJOR ROUND
Brisbane	Griffith University (Gold Coast, Logan, Mount Gravatt)	7	7
	Australian Catholic University	7	8
	Queensland University of Technology	7	8
Regional	Central Queensland University (Pomona)	6	9
	Central Queensland University (Bundaberg)	10	13
	Central Queensland University (Rockhampton)	10	14
	University of Southern Queensland (Toowoomba)	11	12
	Central Queensland University (Emerald)	11	13
	James Cook University (Townsville)	11	13
	Central Queensland University (Gladstone)	11	15
	University of Southern Queensland (Wide Bay)	12	13
	James Cook University (Cairns)	12	14
	Central Queensland University (Mackay)	12	15

* Excluding Christian Heritage College which uses a range of enrolment processes that do not depend on OP.

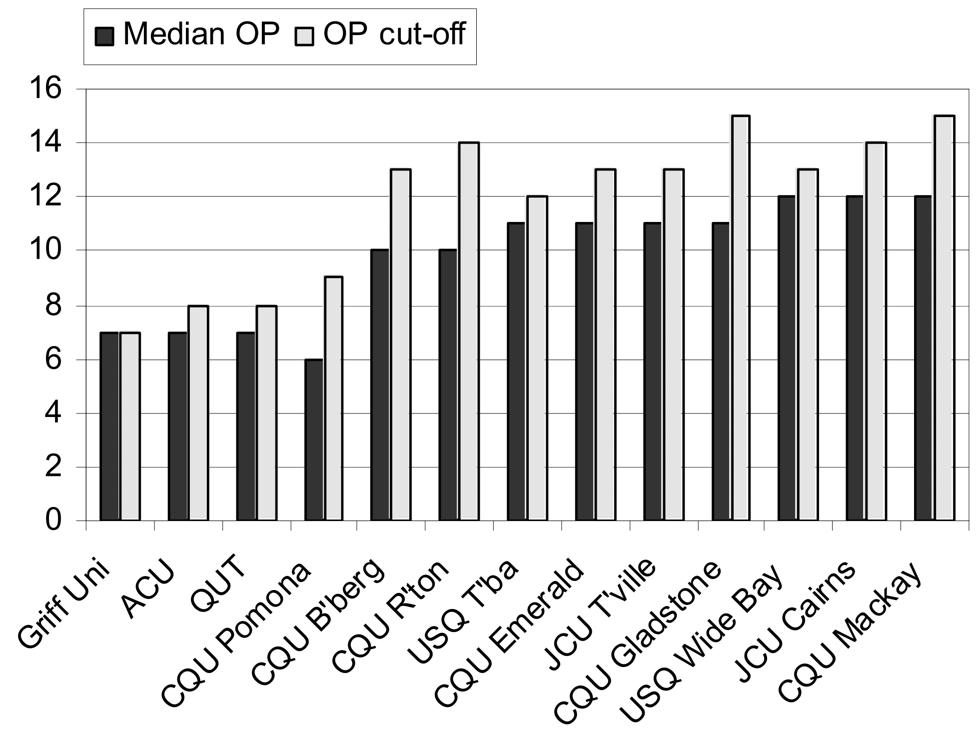

Figure 11. OP Scores of 2004 Entrants into Preservice Primary Education Programs in Queensland *

* Excluding Christian Heritage College which uses a range of enrolment processes that do not depend on OP.

In comparison with students who were admitted to other courses, for example, Creative Arts and Information Technology, Education students showed a more favourable profile of OP Scores, with more students in the upper bands (OP 10 or better) and fewer students in the lower bands (OP 16 or worse) (see Figure 12).

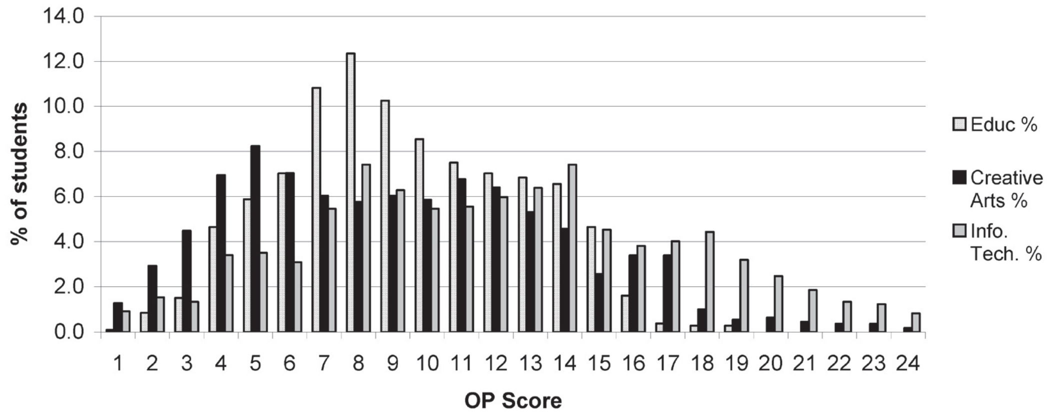

Figure 12. Distribution of OP Scores for students in Education, Creative Arts and Information Technology (2004 admission

However, in comparison with students who were admitted to Science and Health courses, Education students showed a less favourable profile of OP Scores, with fewer students in the upper bands (OP 10 or better), even though there were fewer Education students in the lower bands (OP 16 or worse) (see Figure 13).

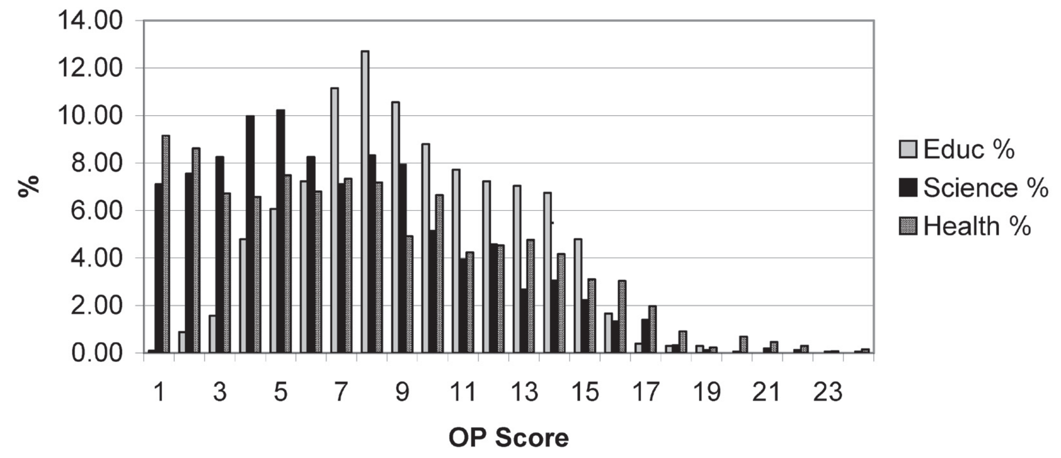

Figure 13: Distribution of OP Scores for students in Education, Science and Health (2004 admissions)

Numeracy/mathematical skills of preservice teachers

Many studies of the numeracy/mathematical skills of preservice teachers have been conducted. Although these studies were conducted outside of Queensland, it seems reasonable to expect that similar patterns may be evident here.

Perry, Way and Southwell (2005) gave 78 preservice teachers in their first mathematics pedagogy course at the University of Western Sydney a test of the primary level mathematics that they would be expected to teach in schools, and found that results overall were 'quite poor'. In a 23-item test, the total marks ranged from 10 to 21 (see Figure 14), with a mean score of 16.1 and a standard deviation of 3.2.

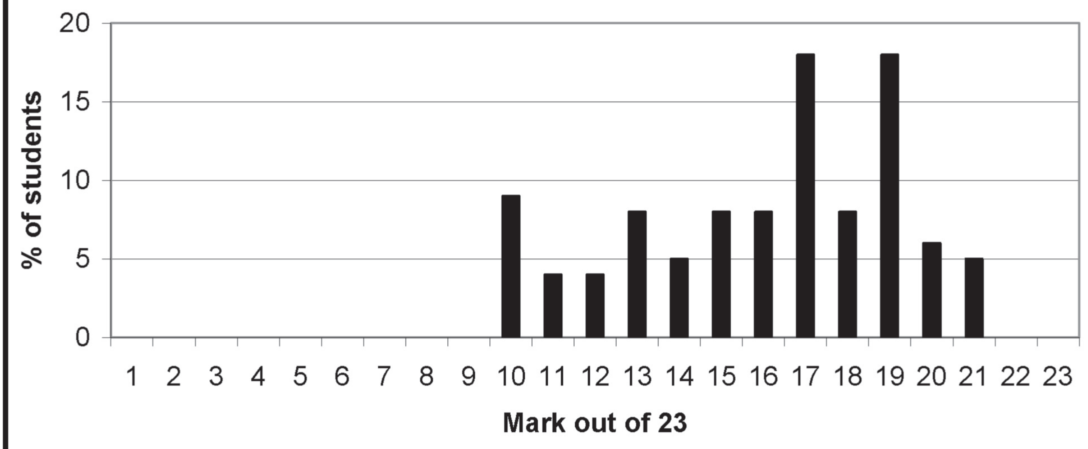

Figure 14: Distribution of marks of preservice teachers in a school-level mathematics test

Sharma (2005) found that preservice teachers demonstrated the same misconceptions in their statistical reasoning about variability as did primary school children. Ryan & McCrae (2005) found that a significant proportion of beginning preservice teachers demonstrated errors and misconceptions in the number, space, and measurement sections of the ACER Teacher Education Mathematics Test. The test produced a profile for each student which was able to be used to identify specific areas for intervention.

In a study conducted 15 years ago, Nisbet (1991) found that preservice primary teachers varied greatly in their levels of confidence, anxiety and motivation to teach mathematics at school. It was also found that these levels improved during the three-year (as it was then) course after completing subjects specifically designed to address these concerns.

Implications

There appears to be an enormous diversity amongst preservice teachers with regard to their ages, mathematical backgrounds, beliefs and attitudes to mathematics, and numeracy skills. It would be expected that this diversity would extend to their learning preferences and styles. This situation presents a great challenge to mathematics educators involved in preservice mathematics education courses, especially in dealing with such diversity, fostering positive attitudes and improving numeracy skills whilst maintaining a constructivist approach to the learning and teaching of mathematics.

There appears to be no research on the numeracy skills of preservice teachers on graduation. It may be considered appropriate to commission some research into this matter in Queensland, relating it also to the preservice teachers' backgrounds.

6.2. Numeracy education in Queensland preservice teacher education programs

One of the Terms of Reference of the Working Party was to examine current approaches to numeracy in Queensland preservice teacher education programs.

Faculties/Schools of Education at Queensland higher education institutions were asked to provide examples of good practice, from the preservice teacher education programs offered by their institution, in the areas of:

- developing personal numeracy competence; and
- preparing teachers to teach numeracy.

Six universities responded. The attention to development of personal numeracy competence and the preparation of preservice teachers to teach numeracy varied greatly from one institution to another and also among programs, with more resources and time being given to this area in undergraduate programs than in graduate-entry programs. The examples provided by universities indicated that in endeavouring to develop preservice teachers' personal numeracy competence and prepare them to teach numeracy they had given attention to practices within the following aspects of their programs: teaching approach; modes of delivery; learning environment; courses specific to numeracy skills; assessment; resources; and attention to preservice teachers' individual needs.

A detailed list provided by universities of examples of good practice in developing teachers' personal numeracy competence and preparing them to teach numeracy can be found in Appendix 2.

6.3. Preservice teacher education programs for numeracy education

High quality professional learning experiences in preservice and in-service teacher education programs are paramount for three reasons. Firstly, optimal knowledge, skills and beliefs about numeracy teaching need to be sufficiently well developed to overcome conflicting perspectives about numeracy teaching that individuals might have experienced in their own schooling or in their own children's schooling or in their previous teaching practice. Secondly, individuals need to have robust knowledge and beliefs about numeracy teaching and be resilient because they are likely to encounter professional inertia in mathematics education (Taylor, 2002). Thirdly, professional learning engages individuals as numeracy learners and also provides models of professional practice for numeracy teaching. If the expectation that students' numeracy development is the responsibility of all teachers is to become a reality, then the scope and nature of preservice and in-service teacher education must be at two levels: (1) for mathematics teachers, to ensure that mathematics classrooms provide the foundation for numeracy; and (2) for teachers of all key learning areas, to ensure that students have opportunities to apply mathematical knowledge in context (DEST, 2003).

Initial teacher preparation is only the beginning of a career-long process of professional growth that is essential for continued effectiveness in a rapidly changing profession (Graham & Fennell, 2001). During their careers, teachers will have to acquire and regularly update their content knowledge and pedagogical tools to enhance student learning (Committee on Science and Mathematics Teachers Preparation, 2001). This requires recognition that numeracy is dynamic and that, as our world changes, what it means to be numerate also changes. For example, in the Information Age numerate individuals require substantial competence with visual representations (e.g., graphs, diagrams, charts and tables) that are commonly used in the organisation and presentation of data (Department for Education and Employment, 1998). However, in addition to all teachers growing professionally in their knowledge of numeracy teaching, some teachers will need opportunities to develop their knowledge of numeracy teaching to a high level in order to provide effective leadership within the profession (Committee on Science and Mathematics Teachers Preparation, 2001).

The general comments above are applicable to the preservice education of all teachers, whether they are specialising in mathematics education or in some other discipline. However, there are additional requirements for programs that prepare teachers of mathematics (including primary school teachers and secondary mathematics teachers). Quality preservice mathematics education programs have four characteristics. Firstly, preservice programs should provide strong exposure to appropriate content and models of pedagogical approaches appropriate for teaching that content (Committee on Science and Mathematics Teachers Preparation, 2001). Thus, throughout their programs, preservice students should experience the strategies that they are expected to implement (i.e., active learning, communication, reflection, building students' confidence and independent thought) (Alsup, 2003). Secondly, preservice programs should focus on worthwhile mathematical tasks and discourse (Graham & Fennell, 2001). Thirdly, case-based materials should be incorporated into preservice programs because they provide students with opportunities to read, view, think, and reflect about mathematics, pedagogy, and student thinking (Graham & Fennell, 2001). Cases that are presented via multimedia offer substantial advantages because they provide students with vicarious experiences that can be shared and analysed by the group, and reviewed. Finally, a quality program should embed elements of effective teaching. According to Graham and Fennell (2001), effective mathematics teaching requires:

- knowing and understanding mathematics, students as learners, and pedagogical strategies;
- a challenging and supportive learning environment;
- an orientation towards continuous improvement.

The latter feature of continuous improvement is fundamental in the seamless transition from teacher preparation to a career in teaching and in the career-long process of professional learning (Committee on Science and Mathematics Teachers Preparation, 2001).

According to Graham and Fennell (2001), the quality of a mathematics education program can be determined by the extent to which it addresses the following four types of knowledge:

1. *Content knowledge* – the type of mathematical content experiences that are most appropriate for mathematics teacher preparation (and continuing professional learning).
2. *Pedagogical-content knowledge* – preservice teachers' understanding of mathematics, the mathematics instructional needs of children, and the appropriate strategies for teaching.
3. *Pedagogical knowledge* – the balance between content and methods; the role of field experiences in a teacher's development; and appropriate types of field experiences.
4. *Pedagogically functional mathematics knowledge* – an awareness that 'It is not what mathematics teachers know, but how they know it and what they are able to mobilise mathematically in the course of teaching' (Ball & Bass, 2000, p. 95 cited in Graham & Fennell, 2001, p. 322).

These various types of knowledge provide clear links to the professional knowledge, professional attributes, and professional practice advocated for high quality mathematics teaching (AAMT, 2002). The Australian Association of Mathematics Teachers (AAMT) Standards for Excellence in Teaching Mathematics in Australian Schools describe 'what teachers who are doing their job well should know and do'. Although these standards were not designed specifically for beginning teachers the three domains they identify, and the elements encompassed by each domain, provide a framework for mathematics teachers' career long professional growth. The AAMT Standards framework (see Table 9) therefore has been used in formulating the standards for graduate teachers presented in Section 7.

Table 9. AAMT Standards for Excellence in Teaching Mathematics in Australian Schools

1: Professional Knowledge	2: Professional Attributes	3: Professional Practice
1.1 Knowledge of students	2.1 Personal attributes	3.1 The learning environment
1.2 Knowledge of mathematics	2.2 Personal professional attributes	3.2 Planning for learning
1.3 Knowledge of students' learning of mathematics	2.3 Community responsibilities	3.3 Teaching in action
		3.4 Assessment

Although the literature provides some guidance on supporting the professional learning of teachers throughout their careers, the Committee on Science and Mathematics Teacher Preparation (2001) advocates strongly that those responsible for teacher education have a corresponding responsibility to undertake research on ways to improve teacher education.

At the time of this report going to print, the report on a Department of Education, Science and Training (DEST) project which investigated the preparation of teachers to teach literacy and numeracy in primary and secondary schools was due for release in December 2005. The report entitled *Prepared to Teach* was expected to become available on the DEST website (http://www.dest.gov.au/) or through the Clearinghouse for National Numeracy and Literacy Research (http://www.griffith.edu.au/school/cls/clearinghouse/).

SECTION SEVEN

Numeracy Standards for Graduates of Preservice Teacher Education Programs

7.1 Formulating Numeracy Standards for Graduate Teachers: Some Key Points

The literature suggests that what teachers do in the classroom is the strongest predictor of growth in positive mathematical and numeracy outcomes for students. Their practices are consistently the most important predictors of student outcomes, and students' perceptions of teacher practices appear to affect students' engagement in mathematics. The predominant factors that influence students' outcomes are:

- Teachers' beliefs and attitudes towards mathematics (love of mathematics);
- Teachers' own numeracy ability and knowledge of mathematics (educational background);
- The learning environment in which the students are engaged (active, enquiry-based, open-ended tasks, resources in the school);
- Students' perceptions of teachers' practices;
- Teachers' ability to notice and attend to numeracy across the curriculum;
- Teachers' ability to pay attention to and understand students' numeracy issues;
- Teachers giving time to numeracy; and
- Ongoing professional support with a focus on those who have weak subject matter knowledge for teaching and little confidence in teaching mathematics.

In the formulation of numeracy standards for graduates these factors were considered along with the following key ideas:

- Numeracy is more than number; its foundations encompass all areas of mathematics;
- Numeracy involves higher order thinking and use of mathematics in context;
- Numeracy is not a stand-alone school subject, but is developed across all curriculum contexts;
- Numeracy education is not just the responsibility of primary school teachers;
- Numeracy education is not just the responsibility of secondary school mathematics teachers;
- Introducing numeracy standards for teacher education does not mean that all teachers are expected to become specialist mathematics teachers, especially in the secondary school; nor does it mean that the mathematics curriculum

will become ‘dumbed down’; and

- Teachers of disciplines other than mathematics can contribute to students’ numeracy education by recognising and exploiting the numeracy demands and learning opportunities within their own subject.

7.2 Overview of the Standards

The standards have been produced to inform the development of programs of preservice teacher education. They are intended to supplement the *Professional Standards for Graduates and Guidelines for Preservice Teacher Education Programs* of the Board of Teacher Registration and the professional standards to be developed in the future by the Queensland College of Teachers*.

The AAMT Standards framework was drawn upon in formulating the numeracy standards for graduate teachers presented in this section. The standards address three domains:

Professional knowledge: incorporating knowledge of students and their numeracy learning needs, knowledge of numeracy appropriate to the year levels and subjects they teach, and knowledge of how to support students’ numeracy learning.

Professional attributes: incorporating personal attributes such as high expectations for students’ numeracy development, a commitment to personal professional development in order to enhance personal numeracy knowledge and teaching strategies, and acceptance of community responsibilities in communicating informed views about numeracy.

Professional practice: incorporating establishment of supportive and challenging numeracy learning environments, planning for numeracy learning in all curriculum areas, demonstrating effective numeracy teaching strategies, and using assessment strategies that allow all students to demonstrate their numeracy knowledge.

The standards have been developed under two broad headings:

Standards for all teachers of mathematics: All teachers in the early years and primary years are included in this (apart from some specialists such as Health and Physical Education, Music or LOTE specialist teachers), as well as mathematics specialist teachers in the middle years and senior years.

Standards for teachers of disciplines other than mathematics: This includes specialist teachers (eg Health and Physical Education, Music or LOTE specialist teachers) in the early years and primary years, as well as teachers of curriculum areas other than mathematics in the middle years and senior years.

* New legislation, the *Education (Queensland College of Teachers) Act 2005*, came into effect on 1 January 2006, establishing the Queensland College of Teachers to replace the Board of Teacher Registration.

7.3 Numeracy Standards for Graduates of Preservice Teacher Education Programs

1 For all teachers of mathematics: this includes non-specialist teachers in the early years and primary years, as well as mathematics specialist teachers in the middle years and senior years.

1.1 Professional Knowledge		
	Graduates will:	
Students	1.1.1	Understand the diversity of mathematical abilities and numeracy needs of learners
Numeracy	1.1.2	Exhibit sound knowledge of mathematics appropriate for teaching their students
	1.1.3	Understand the pervasive nature of numeracy and its role in everyday situations
	1.1.4	Demonstrate relevant knowledge of the central concepts, modes of enquiry and structure of mathematics
	1.1.5	Establish connections between mathematics topics and between mathematics and other disciplines
	1.1.6	Recognise numeracy learning opportunities across the curriculum
Students' Numeracy Learning	1.1.7	Understand contemporary theories of how students learn mathematics
	1.1.8	Possess a repertoire of contemporary, theoretically grounded, student-centred teaching strategies
	1.1.9	Demonstrate knowledge of a range of appropriate resources to support students' numeracy learning
	1.1.10	Integrate Information and Communication Technologies to enhance students' numeracy learning

1 For all teachers of mathematics: this includes non-specialist teachers in the early years and primary years, as well as mathematics specialist teachers in the middle years and senior years.

1.2 Professional Attributes	
	Graduates will:
Personal attributes	1.2.1 Display a positive disposition to mathematics and to teaching mathematics
	1.2.2 Recognise that all students can learn mathematics and be numerate
	1.2.3 Exhibit high expectations for their students' mathematics learning and numeracy development
	1.2.4 Exhibit a satisfactory level of personal numeracy competence for teaching
Personal Professional Development	1.2.5 Demonstrate a commitment to continual enhancement of their personal numeracy knowledge
	1.2.6 Exhibit a commitment to ongoing improvement of their teaching of mathematics
	1.2.7 Demonstrate a commitment to collaborating with teachers of disciplines other than mathematics to enhance numeracy teaching and learning
Community Responsibility	1.2.8 Develop and communicate informed perspectives of numeracy within and beyond the school

1 For all teachers of mathematics: this includes non-specialist teachers in the early years and primary years, as well as mathematics specialist teachers in the middle years and senior years.

1.3 Professional Practice	
	Graduates will:
Learning Environment	1.3.1 Promote active engagement in numeracy learning
	1.3.2 Establish a supportive and challenging numeracy learning environment
	1.3.3 Foster risk taking and critical inquiry in numeracy learning
Planning	1.3.4 Highlight connections between mathematics topics and between mathematics and other disciplines
	1.3.5 Cater for the diversity of mathematical abilities and numeracy needs of learners
	1.3.6 Determine students' learning needs in numeracy to inform planning and implementation of learning experiences
	1.3.7 Embed thinking and working mathematically in numeracy learning experiences
	1.3.8 Plan for a variety of authentic numeracy assessment opportunities
Teaching	1.3.9 Demonstrate a range of effective teaching strategies for numeracy learning
	1.3.10 Utilise multiple representations of mathematical ideas in mathematics and in other curriculum areas
	1.3.11 Sequence mathematical learning experiences appropriately
	1.3.12 Demonstrate an ability to negotiate mathematical meaning and model mathematical thinking and reasoning
Assessment	1.3.13 Provide all students with opportunities to demonstrate their numeracy knowledge
	1.3.14 Collect and use multiple sources of valid evidence to make judgements about students' numeracy learning

2 For teachers of disciplines other than mathematics: this includes specialist teachers in the early years and primary years, as well as teachers of curriculum areas other than mathematics in the middle years and senior years.

2.1 Professional Knowledge	
	Graduates will:
Students	2.1.1 Recognise the numeracy knowledge and experiences that learners bring to their classrooms
	2.1.2 Understand the diversity of numeracy needs of learners
Numeracy	2.1.3 Understand the pervasive nature of numeracy and its role in everyday situations
	2.1.4 Understand the meaning of numeracy within their curriculum area
	2.1.5 Recognise numeracy learning opportunities and demands within their curriculum area
Students' Numeracy Learning	2.1.6 Demonstrate knowledge of a range of appropriate resources and strategies to support students' numeracy learning in their curriculum area

2.2 Professional Attributes	
	Graduates will:
Personal attributes	2.2.1 Display a positive disposition to supporting students' numeracy learning within their curriculum area
	2.2.2 Recognise that all students can be numerate
	2.2.3 Exhibit high expectations of their students' numeracy development
	2.2.4 Exhibit a satisfactory level of personal numeracy competence for teaching
Personal Professional Development	2.2.5 Demonstrate a commitment to continual enhancement of personal numeracy knowledge
	2.2.6 Exhibit a commitment to ongoing improvement of their teaching strategies to support students' numeracy learning
	2.2.7 Demonstrate a commitment to collaborating with specialist teachers of mathematics to enhance their own numeracy learning and numeracy teaching strategies
Community Responsibility	2.2.8 Develop and communicate informed perspectives of numeracy within and beyond the school

2 For teachers of disciplines other than mathematics: this includes specialist teachers in the early years and primary years, as well as teachers of curriculum areas other than mathematics in the middle years and senior years.

2.3 Professional Practice		
	Graduates will:	
Learning Environment	2.3.1	Promote active engagement in numeracy learning within their own curriculum context
	2.3.2	Establish a supportive and challenging learning environment that values numeracy learning
Planning	2.3.3	Take advantage of numeracy learning opportunities when planning within their own curriculum context
	2.3.4	Display willingness to work with specialist teachers of mathematics in planning numeracy learning experiences
	2.3.5	Determine students' learning needs in numeracy to inform planning and implementation of learning experiences
Teaching	2.3.6	Demonstrate effective teaching strategies for integrating numeracy learning within their own curriculum context
	2.3.7	Model ways of dealing with numeracy demands of their curriculum area
Assessment	2.3.8	Provide all students with opportunities to demonstrate numeracy knowledge within their curriculum area

REFERENCES

Alsup, J. K. (2003). New classroom rules to promote preservice elementary teachers' mathematics learning. *Education*, 123, 609-618.

Afrassa, T., & Keeves, J. (1999). Changes in students' mathematics achievement in Australian lower secondary schools over time. *International Education Journal,* 1(1), 1-21.

Arthur, L., Beecher, B., Dockett, S., Farmer, S. & Death, E. (1996). *Programming and Planning in Early Childhood Settings* (2nd Edition). Star Printery, Australia.

Askew, M., Brown, M., Rhodes, V., William, D., Johnson, D. (1997). *Effective Teachers of Numeracy. London*: King's College London, for the Teacher Training Agency.

Australian Association of Mathematics Teachers (2002). *Standards for Excellence in Teaching Mathematics in Australian Schools*. Retrieved June 17, 2005 from http://www.aamt.edu.au/standards/

Ball, D.L. (1993). Halves, pieces, and twoths: Constructing representational contexts in teaching fractions. In Carpenter, T.P., Fennema, E., Ronberg, T.A. (Eds) *Rational numbers: An integration of research*. Hillsdale, NJ: Erlbaum.

Bessot, A. (2000). Geometry and work – Examples from the building industry. In A. Bessot & J. Ridgeway (Eds.), *Education for Mathematics in the Workplace* (pp. 143-158). Dordrrecht, The Netherlands: Kluwer.

Board of Teacher Registration Queensland (2004). *Annual report.* The State of Queensland.

Bobis, J., Clarke, B., Clarke, D., Thomas, G., Wright, R., & Young Loveridge, J. (2005). Supporting teachers in the development of young children's mathematical thinking : three large scale cases. *Mathematics Education Research Journal,* 16(3), 27-57.

Bourke, S. & Keeves, J. (1977). *The mastery of literacy and numeracy: Final report* (Vol. 3). Canberra: AGPS.

Brady, P., & Bowd, A. (2005). Mathematics anxiety, prior experience and confidence to teach mathematics among preservice education students. *Teachers and Teaching: theory and practice*, 11(1), 37-46.

Brosnan, P.A., Edwards, T., Erickson, D. (1996). An exploration of change in teachers' beliefs and practices during implementation of mathematical standards. *Focus on Learning Problems in Mathematics*, 18 (4)

Brown, M., & Askew, M. (2000). What sort of teaching helps children to make progress in numeracy? In '*High expectations, outstanding achievement : early years of schooling P4 conference, Sunday 4 - Monday 5 June 2000*' CD-ROM. Melbourne : Victoria. Department of Education, Employment and Training.

Budgen, F., Wallace, J., Rennie, L. & Malone, J. (2001). *Teaching and learning in integrated settings*. Paper presented at the annual conference of the Australian Association for Research in Education, Fremantle, WA, December 2001.

Clarke, J. (2005). *Preservice Primary Teachers Experiencing Effective Mathematics Communities*. Paper presented at Australian Teacher Education Association 2005 Conference.

Cockcroft Report (1982). *Mathematics counts*. Department of Education and Science. London: HMSO.

Committee on Science and Mathematics Teacher Preparation, Center for Education, National Research Council (2001). *Educating teachers of science, mathematics, and technology: New practices for the new millennium*. Washington, DC: National Academy Press. Retrieved June 17, 2005 from http://books.nap.edu/catalog/9832.html?onpi_newsdoc081600

Crowther Report (1959). *15 to 18: A report of the Central Advisory Council for Education*. London: HMSO.

Department for Education and Employment, UK (1998). *The implementation of the national numeracy strategy. The final report of the numeracy taskforce*. London: DfEE.

Department of Education, Science and Training (2003). *Beyond the middle: A report about literacy and numeracy development of target group students in the middle years of schooling*.

Department of Education, Science and Training (2004a). *Teachers enhancing numeracy*.

Department of Education, Science and Training (2004b). *Investigation of effective mathematics teaching and learning in Australian Secondary Schools*.

Department of Education, Science and Training (2004c). *Assessing numeracy in primary schools*.

Department of Education, Science and Training (2004d). *Numeracy across the curriculum*.

Department of Education, Science and Training (2004e). *Numeracy: Demands and Opportunities Across the Curriculum*.

Department of Education, Training and Youth Affairs (2000). *Numeracy, a priority for all: Challenges for Australian schools*. Canberra: Commonwealth Government of Australia.

Department of Employment, Education, Training and Youth Affairs (1997). *Numeracy = Everyone's Business*. The Report of the Numeracy Education Strategy Development Conference May 1997. Adelaide: Australian Association of Mathematics Teachers.

Doig, B. (2001). *Summing up: Australian numeracy performances, practices, programs and possibilities*. Melbourne: ACER.

Farmer, J. Gerreston, H., & Lassal, M. (2003). What teachers take from professional development: Cases and implications. *Journal of Mathematics Teacher Education*, 6, 331-360.

Frankenstein, M. (2001). Reading the world with math: Goals for a critical mathematical literacy curriculum. Keynote address delivered at the 18th Biennial Conference of the Australian Association of Mathematics Teachers, Canberra, 15-19 January 2001.

Frykholm, J. & Meyer, M. (2002). Integrated instruction: Is it science? Is it mathematics? *Mathematics Teaching in the Middle School*, 7(9), 502.

Goos, M. & Askin, C. (2005). Towards numeracy across the curriculum: Integrating mathematics and science in the middle years. In R. Zevenbergen (Ed.), *Innovations in numeracy teaching in the middle years* (pp. 125-141). Canberra: Australian Curriculum Studies Association.

Goos, M. & Mills, M. (2001). Curriculum integration in the middle school: Mathematics meets history. In *Mathematics Shaping Australia* (Proceedings of the 18th biennial conference of the Australian Association of Mathematics Teachers, Canberra, 15-19 January 2001, pp.65-76). Adelaide: Australian Association of Mathematics Teachers.

Goos, M. (2001). *Numeracy and curriculum integration – The case of mathematics and history.* Paper presented at the Australian Association of Mathematics Teachers Virtual Conference, 18 May – 25 June 2001.

Graham, K. J. & Fennell, F. (2001). Principles and standards for school mathematics and teacher education: Preparing and empowering teachers. *School Science and Mathematics*, 101(6), 319–327.

Groves, S. (2001). Numeracy across the curriculum: Recognising and responding to the demands and numeracy opportunities inherent in secondary teaching. *Mathematics Teacher Education and Development*, 3, 48-61.

Gutstein, E. (2003). Teaching and learning mathematics for social justice in an urban, Latino school. *Journal for Research in Mathematics Education,* 34, 37-73.

Hanbury, L. (2002). An investigation into factors inhibiting test responses designed to elicit student geometric understanding. PhD thesis, University of New England, Armidale, NSW.

Hill, H., Rowan, B., & Loewenberg Ball, D. (2005). Effects of teachers' mathematical knowledge for teaching on student achievement. *American Educational Research Journal*, 42(2), 371-406.

Hoban, G. (2002). *Teacher learning for education changes: A systems thinking approach* Philadelphia: Open University Press.

Hogan, J. (1999). *Numeracy – across the curriculum.* Keynote address from the International Virtual Conference of the Australian Association of Mathematics Teachers.

Hogan, J. & Morony, W. (2000). Classroom teachers doing research in the workplace. In A. Bessot & J. Ridgeway (Eds.), *Education for Mathematics in the Workplace* (pp. 101-114). Dordrrecht, The Netherlands: Kluwer.

Hollingsworth, H., Lokan, J. & McCrae, B. (2003). *Teaching Mathematics in Australia: Results from the TIMSS 1999 Video Study*. Melbourne: Australian Council for Educational Research.

Huntley, M. (1998). Design and implementation of a framework for defining integrated mathematics and science education. *School Science and Mathematics*, 98(6), 320-327.

Johnston, B. (1994). Critical Numeracy, *Fine Print*, 16(4). 32-36.

Kanes, C. (1996). Investigating the use of language and mathematics in the workplace setting. In P. Clarkson (Ed.), *Technology in Mathematics Education* (Proceedings of the 19th annual conference of the Mathematics Education Research Group of Australasia, pp. 314-321). Melbourne: MERGA.

Lave, J., Murtaugh, M. & de la Rocha, O. (1984). The dialectic of arithmetic in grocery shopping. In B. Rogoff & J. Lave (Eds.), *Everyday Cognition: Its Development in Social Context* (pp. 67-94). Cambridge: Cambridge University Press.

Loucks-Horsley, S., Hewson, P., Love, N., & Stiles, K. E., (1998). *Designing professional development for teachers of Science and Mathematics*. California, USA: Corwin Press, Inc.

Ma, L. (1999). *Knowing and teaching elementary mathematics: Teachers' understanding of fundamental mathematics in China and the United States*. New Jersey: Lawrence Erlbaum.

Marks, G. & Cresswell. J. (2005). State differences in achievement among secondary school students in Australia. *Australian Journal of Education*, 49(2), 141-151.

Masters, G. (2003). Challenges in national comparisons. *Professional Educator*, 2(2), 14-16.

McGaw, B. (2004). Australian mathematics learning in an international context. Paper presented at the 27th annual conference of the Mathematics Education Research Group of Australasia, Townsville, 27-30 June.

Ministerial Council on Education, Employment, Training and Youth Affairs (1999). *The Adelaide Declaration on National Goals for Schooling in the Twenty-First Century.* Retrieved 13 October 2005 from http://www.mceetya.edu.au/nationalgoals/

Ministerial Council on Education, Employment, Training and Youth Affairs (2002). *National Report on Schooling in Australia.* Retrieved 24 October 2005 from http://www.mceetya.edu.au/anr/index.html.

Ministerial Council on Education, Employment, Training and Youth Affairs, (2003). *National Report on Schooling in Australia*. Retrieved 24 October 2005 from http://www.mceetya.edu.au/anr/index.html.

Nisbet, S. (1991). A new instrument to measure preservice primary teachers' attitudes to teaching mathematics. *Mathematics Education Research Journal*, 3(2), 34-56.

Nisbet, S., & Warren, E. (2000). Primary school teachers' beliefs relating to mathematics, teaching and assessing mathematics and factors that influence these beliefs. *Mathematics Teacher Education and Development*, 2, 34-47.

Noss, R., Hoyles, C. & Pozzi, S. (2000). Working knowledge: Mathematics in use. In A. Bessot & J. Ridgeway (Eds.), *Education for Mathematics in the Workplace* (pp. 17-35). Dordrrecht, The Netherlands: Kluwer.

Olson, J., & Barrett, J. (2004). Coaching teachers to implement mathematics reform recommendations. *Mathematics Teacher Education & Development*, 6, 73-91.

Organisation for Economic Cooperation and Development (2000). *Programme for International Student Assessment* (PISA). Retrieved 16 September 2005 from http://www.pisa.oecd.org/

Perry, B., Way, J., Southwell, B., White, A. & Pattison, J. (2005). Mathematical beliefs and achievement of preservice primary teachers. In P. Clarkson, A. Dowton, D. Gronn, M. Horne, A. McDonough, R. Pierce & A. Roche (Eds.), *Building connections: Research, theory and practice* (Proceedings of the 28th annual conference of the Mathematics Education Research Group of Australasia, pp. 625-632). Sydney: MERGA.

Proudford, C. (2003). Building professional learning communities for curriculum change. *Curriculum Perspectives*, 23(3).

Queensland Studies Authority (2005). *English Years 1 to 10 Syllabus*. The State of Queensland.

Queensland Studies Authority (2004). *Mathematics Years 1 to 10 Syllabus*. The State of Queensland.

Queensland Tertiary Admissions Centre (2004). Statistical Reports 2003-2004. Retrieved August 2005 from http://www.qtac.edu.au/Statistical_Reports/2003_2004/2003_2004.htm?activeMenuId=Information_About.Statistical_Reports&activeItemId=Information_About.Statistical_Reports.2003-2004

RAND Mathematics Study Panel (2003). *Mathematical proficiency for all students: Towards a strategic research and development program in mathematics education.* Santa Monica, CA: RAND.

Ryan, J. & McCrae, B. (2005). Subject-matter knowledge: Mathematical errors and misconceptions of beginning preservice teachers. P. Clarkson, A. Dowton, D. Gronn, M. Horne, A. McDonough, R. Pierce & A. Roche (Eds.), *Building connections: Research, theory and practice* (Proceedings of the 28th annual conference of the Mathematics Education Research Group of Australasia, pp. 641-648). Sydney: MERGA.

Sharma, S. (2005). Exploring preservice teachers' reasoning about variability. In P. Clarkson, A. Dowton, D. Gronn, M. Horne, A. McDonough, R. Pierce & A. Roche (Eds.), *Building connections: Research, theory and practice* (Proceedings of the 28th annual conference of the Mathematics Education Research Group of Australasia, pp. 672-679). Sydney: MERGA.

Steen, L. (1999). Seeking numeracy. Keynote address delivered at the International Virtual Conference of the Australian Association of Mathematics Teachers.

Steen, L. (2001). The case for quantitative literacy. In *Mathematics and democracy: The case for quantitative literacy* (pp. 1-22). National Council on Education and the Disciplines.

Taylor, P. M. (2002). Implementing the standards: Keys to establishing positive professional inertia in preservice mathematics teachers. *School Science and Mathematics*, 102,(3), 137–142.

The Office of the Queensland School Curriculum Council (2002). *Arts Years 1 to 10 Syllabus*. The State of Queensland.

The Office of the Queensland School Curriculum Council (1999a). *Health and Physical Education Years 1 to 10 Syllabus*. The State of Queensland.

The Office of the Queensland School Curriculum Council (2000a). *Languages other than English Years 1 to 10 French Syllabus*. The State of Queensland.

The Office of the Queensland School Curriculum Council (2001). *Numeracy Position Paper*. The State of Queensland.

The Office of the Queensland School Curriculum Council (1999b). *Science Years 1 to 10 Syllabus*. The State of Queensland.

The Office of the Queensland School Curriculum Council (2000b). *Studies of Society and Environment Years 1 to 10 Syllabus*. The State of Queensland.

The Office of the Queensland Studies Authority (2003). *Technology Years 1 to 10 Syllabus*. The State of Queensland.

Wallace, J., Rennie, L., Malone, J. & Venville, G. (2001). What we know and what we need to know about curriculum integration in science, mathematics and technology. *Curriculum Perspectives*, 21(1), 9-15.

Warren, E., & Nisbet, S. (2001). The assessment of mathematics in the primary school: Belief and practices. *School Science & Mathematics*, 101(7), 348-355.

White, P., Mitchelmore, M., Branca, N., & Maxon, M. (2004). Professional development: Mathematics content versus pedagogy. *Mathematics Teacher Education and Development*, 6, 49-60.

Willis, S. (1990). Numeracy and society: The shifting ground. In S. Willis (Ed.), *Being numerate: What counts?* (pp. 1-23). Hawthorn, Vic: Australian Council for Educational Research.

Willis, S. (1998a). Numeracy for the(ir) future: Rite or right? Paper presented at the National Conference of the Australian College of Education, *Education: Who really counts?* Canberra, 27-30 September.

Willis, S. (1998b). Which numeracy? *Unicorn*, 24(2), 32-42.

Zaslavsky, C. (1994). 'Africa Counts' and ethnomathematics. *For the Learning of Mathematics*, 14(2), 3-8.

Zevenbergen, R. (2004). Technologising numeracy: Intergenerational differences in working mathematically in new times. *Educational Studies in Mathematics*, 56, 97-117.

Zevenbergen, R. & Zevenbergen, K. (2004). Numeracy practices in contemporary work: Changing approaches. In I. Putt, R. Faragher & M. McLean (Eds.), *Mathematics Education for the Third Millennium: Towards 2010* (Proceedings of the 27th annual conference of the Mathematics Education Research Group of Australasia, 605-612). Sydney: MERGA.

APPENDIX 1

Membership of the Numeracy in Preservice Teacher Education Working Party

Chair

Associate Professor Elizabeth Warren
School of Education, Australian Catholic University (McAuley campus)

Members

Ms Eva De Vries
Association of Independent Schools of Queensland

Professor Carmel Diezmann
School of Mathematics, Science & Technology Education, Queensland University of Technology

Associate Professor Merrilyn Goos
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Ms Judy Hartnett
Queensland Catholic Education Commission

Ms Rhonda Horne
Department of Education and the Arts

Dr Steven Nisbet
Faculty of Education, Griffith University

Ms Sue Robertson
Queensland Studies Authority

Ms Leonie Shaw
Acting Director, Board of Teacher Registration

Professional Support

Ms Marilyn Cole, Education Officer, Office of the Board of Teacher Registration
Ms Jill Manitzky, Senior Education Officer, Office of the Board of Teacher Registration

APPENDIX 2

Examples of good practice provided by Faculties/Schools of Education at Queensland higher education institutions from their preservice teacher education programs, in developing personal numeracy competence and numeracy teaching skills

Teaching approach

Using a range of teaching approaches including teacher centred and student centred (model, expert, facilitator)

Promoting the view that numeracy is important/essential

Using a problem-solving approach to practical and theoretical mathematical situations

Encouraging preservice teachers to reflect on the mathematical strategies they themselves use and consider a variety of pathways for problem solving in mathematics

Having an emphasis on building confidence and developing a positive attitude to mathematics

Modelling and engendering enthusiasm towards mathematics and numeracy

Building mathematical skills

Providing continual feedback

Facilitating a self-evaluation process

Promoting the need for continual professional learning

Assisting preservice teachers to link their own understanding of mathematical concepts with their emerging personal and practical theories of teaching mathematics

Developing mathematical language skills

Using practical, activity-based learning experiences

Articulating a clear definition of numeracy

Requiring preservice teachers to consider the numeracy development inherent in cross-curriculum units of work

Modes of delivery

Providing flexible modes of delivery including on-line

Engaging preservice teachers in school-based research related to numeracy

Embedding technology education within courses

Learning environment

Creating a learning environment that encourages mathematical learning through discussion and team work

Promoting a collaborative approach to learning and teaching

Using on-line collaborative learning communities

Courses specific to numeracy

Inclusion of courses that specifically address numeracy

Offering elective courses in numeracy

Assessment

Modelling a variety of assessment techniques

Using numeracy competence tests for preservice teachers which test for expected skill levels in mathematics content and personal numeracy, with tutorial assistance provided for those who need it

Encouraging preservice teachers to view assessment in mathematics as an opportunity to provide structured feedback on mathematical understanding and suggest pathways forward for students, rather than seeing it as a means for focusing on failure

Using assessment tasks that require preservice teachers to consider how mathematics/numeracy can be developed in other disciplines or across several disciplines

Requiring preservice teachers to prepare a unit of work in a discipline other than mathematics which incorporates a number of numeracy outcomes

Resources

Using the Queensland Years 1-10 Mathematics Syllabus as one resource to prepare preservice teachers to teach mathematics

Providing practical ideas and resources for teaching mathematics

Attention to individual needs

Responding to interests, abilities and needs of preservice teachers

Giving individual attention to each preservice teacher’s needs

Reinforcing that the needs of individual students in a classroom will vary

Developing individualised learning plans to assist students to attain competence in the numeracy test