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2000

Improving Numeracy Learning

Research Conference 2000

Proceedings

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Improving Numeracy Learning

Research Conference 2000

Proceedings

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Introduction

ACER's annual national Research Conferences review current research-based knowledge in key areas of educational policy and practice.

The Research Conference 2000 brings together leading numeracy researchers to examine and discuss research evidence relating to the improvement of numeracy learning in schools. The objective of the Conference is to identify major research findings and to study the implications of those findings for improved numeracy teaching and learning. Particular attention is given to research aimed at:

- improving numeracy learning in the early and middle years of school;
- establishing international numeracy benchmarks;
- enhancing children's mental computation skills and number sense;
- improving numeracy outcomes for Indigenous students; and
- mapping and understanding numeracy growth.

An intention of ACER's annual Research Conferences is to provide a forum within which connections can be built between the latest research, educational policies and classroom practices. In pursuing this objective, each conference brings together practitioners, administrators and researchers to share knowledge and to reflect on ways of using research findings to improve student learning.

The focus of the Research Conference 2000 on numeracy is particularly appropriate given the increased national interest in this area of student learning. During the past year, the Commonwealth published the landmark paper *Numeracy: A Priority for All,* which describes Commonwealth numeracy policies for Australian schools, in the context of the National Literacy and Numeracy Plan. The year will also see the publication of the first nationally-agreed numeracy benchmarks for school children at Years 3, 5 and 7, and the Australian Council for Educational Research conducted the first nationwide numeracy tests for 15-year-olds as part of the OECD's Programme for International Student Assessment. These conference proceedings include a valuable summary of Australian numeracy research and development initiatives.

Presentations to the Conference include a keynote address by Professor Margaret Brown from King's College, University of London, reporting British research into factors influencing children's numeracy development. In Britain, as in Australia, the government has placed a priority on raising numeracy standards. The research findings of Professor Brown and her colleagues are likely to be equally relevant to Australian schools.

The papers from this Conference make a valuable contribution to the growing international research literature on numeracy learning. As a set, they contain important insights into ways of supporting and promoting numeracy learning for all.

Geoff N Masters
Executive Director, ACER

1. Summaries of conference papers

This section of the conference proceedings includes summaries of all papers. It should be noted that these are summaries, not the full versions of the papers as presented at the conference. The papers are presented in the order as shown on the conference program. (see pages 76–77.)

What kinds of teaching and what other factors accelerate primary pupils' progress in acquiring numeracy?

Margaret Brown
King's College, University of London

Margaret Brown is Director of the Leverhulme Numeracy Research Programme and Professor of Mathematics Education at King's College, University of London. She has taught in primary and secondary schools in England, and been involved in teacher education. She has directed or co-directed about 18 research projects in mathematics learning, teaching and assessment, ranging from early years to university level. These include both the feasibility study and the evaluation of the national curriculum in mathematics for England and Wales, the pilot study for the national tests at age 14 and an evaluation of the first national assessments at age 7 and 11. She was a member of the National Curriculum Mathematics Working Party, and more recently of the Government Task Force which designed the National Numeracy Strategy. She has been President of the British Educational Research Association and the Mathematical Association, Chair of the Joint Mathematical Council of the UK and is currently the Deputy Chair with responsibility for mathematics of the Royal Society Education Committee.

The Leverhulme Numeracy Research Programme and the UK context

About 15 colleagues at King's, plus a local education authority adviser and two teacher researchers are currently involved with me in the Leverhulme Numeracy Research Programme. The programme aims to develop our understanding of the causes of underachievement in numeracy among pupils of all attainments, and hence assist in a raising of standards. This is a five-year research study funded by the Leverhulme Foundation, a UK educational charity, and we are now just starting the fourth year.

The programme is taking a two-pronged attack, examining both the effectiveness of current practice to see if we can work out which approaches are most successful and why, and also monitoring the effectiveness of carefully designed interventions.

In the third year of the programme the Government decided to implement a National Numeracy Strategy in all English schools starting in September 1999 (following the introduction the previous year of a National Literacy Strategy). The government target was to increase the percentage of children achieving the expected mathematics standard in national tests at age 11 from 58% to 75% by 2002, as well as improving our ranking in international comparisons.

The definition of numeracy adopted by the National Numeracy Strategy is centred on basic skills, i.e. facility in both mental arithmetic and traditional written procedures rather than application of numbers to real life problems. However because the broad UK national curriculum is statutory, the strategy has had to encompass all aspects of primary mathematics.

The key characteristics of the National Numeracy Strategy are:

- emphasis on mental calculation throughout, and de-emphasis in the early years on 'vertical' written methods and calculator use;
- daily three-part lessons with each part of a specified length (mental/oral warm-up, direct teaching of the whole class or groups, plenary review) to significantly increase the amount of whole class teaching;
- a national framework of detailed and exemplified objectives specified for each group of lessons throughout each year of primary school; and
- a systematic national programme to train teachers.

This is supported by packages of training materials for each school, including videos illustrating recommended teaching equipment and approaches, and the appointment of local numeracy consultants to support all schools but with special emphasis on those with low results.

Although not designed as an evaluation project, the Leverhulme programme is gathering data which can be used to monitor some effects of the National Numeracy Strategy.

The Leverhulme Numeracy Research Programme

The Leverhulme programme includes a large-scale *Core* project together with five *Focus* projects, which are small-scale projects each focusing on a particular factor. Only the Core and Focus 1 projects span five years; other projects begin and end at different points in the programme.

- *Core: Tracking Numeracy* – a large-scale survey of the knowledge and gains of two cohorts of 1700 pupils in 40 schools, with a variety of observational, interview and other data which is being used to investigate the contributions to progress of different factors.
- *Focus 1: Case Studies of Pupils' Progress* – a parallel project to the Core, but gathering a larger quantity of classroom data about the teaching and learning of a sample of 30 pupils in each cohort from within the larger Core sample.

- *Focus 2: Teachers' Knowledge, Beliefs and Practices and Pupils' Numeracy Learning* – case studies of changes in three teachers in each of the four schools selected to attend a five-day National Numeracy Strategy training course, focusing on mathematical content, and supported by consultant visits to their schools.
- *Focus 3: Whole School Action on Numeracy* – an investigation of the preparation for and the response to inspections in six schools, to see what actions appear to facilitate or inhibit the development of effective whole school strategies for raising numeracy standards.
- *Focus 4: Community Context and Interpretations of Numeracy* – a study of the similarities and differences between home and school in numeracy, following a small group of Reception-level children in three schools which have different socio-economic intakes.
- *Focus 5: Cognitive Acceleration in Mathematics Education (CAME Primary)* – a collaborative intervention project designing and piloting materials to investigate whether stimulating pupils' thinking through challenging tasks and verbal interactions in the classroom can help to raise standards (as in the CAME Secondary project).

The programme design enables us to examine the importance of various factors on pupils' progress, including teachers, teaching methods, schools and homes, by drawing data from more than one project.

The Leverhulme Longitudinal Studies

Because of time limitations I will concentrate on the Core and Focus 1 projects, which are the two studies monitoring pupils' progress longitudinally, in an attempt to discover which factors are most significant in raising standards.

The sample for the Core project was drawn from two cohorts of primary pupils: one group as they progressed from Reception (ages 4/5) to Year 4 (Grade 3, ages 8/9), and the other from Year 4 to Year 6 (Grade 3 to Grade 5) and into the first year of secondary school (Year 7, Grade 6). This involved 40 schools, 10 in each of four Local Education Authorities (LEA) in different and varied regions of the UK, chosen to represent a variety of socio-economic circumstances (inner-city, urban, suburban, rural), levels of prosperity and ethnic characteristics. Within each LEA the 10 schools were selected to give a balance in relation to school-size, religious affiliation (if any), attainment in national tests, and effectiveness in numeracy teaching as judged by LEA advisers. Altogether the sample involves in each cohort about 1700 children in about 75 classes.

Data is collected in six ways:

- Pupils are assessed towards the beginning and end of each school year (October and June), except at the Reception stage, using a linked series of numeracy assessments.
- Data is collected from each participating school and/or their LEA, detailing pupils' postcode of home address, details of performance in baseline and national tests, etc.
- Each teacher completes a questionnaire, adapted from the TIMSS questionnaire, which provides data about their beliefs and practices in teaching mathematics, and teacher characteristics such as age, gender, qualifications.
- Each class is visited for one mathematics lesson each year; the visiting researcher observes and records notes about the lesson.
- The class teacher is interviewed by the researcher who has observed the lesson, exploring the teacher's views on the lesson, the pupils and the mathematics as well as teacher characteristics and preferences.
- Both the head teacher and mathematics co-ordinator in each school are interviewed in the first year of the study, with updates in subsequent years.

The assessments were adapted from previous assessments undertaken at King's for the *Effective Teachers of Numeracy project* (Askew et al. 1997) which were, in turn, based on a carefully developed diagnostic numeracy test (Denvir & Brown 1987). They are orally administered by teachers and include contextual as well as purely numerical items. The same test is used at the start and end of the year, and there are many common items across the tests for adjacent year groups. They are designed so that equal gains can be made by pupils at different attainment levels.

The children in the Focus 1 case study sample are a subsample of the Core sample; they are drawn from one class in each of the two cohorts in each of five schools. The schools, from three different LEAs, were chosen after our first visits to the Core schools so as to cover a range of intakes, teaching organisations and methods.

In each class, teachers were initially asked to select three high-attaining, three low-attaining and three average pupils, each group comprising at least one pupil of each sex. After the first year we narrowed the sample down to only six children per class, two from each attainment band. This gives 30 pupils in each cohort.

Two researchers are allocated to each school and observe between them a week of lessons in the first term and a week of lessons in the third term for each of the two cohorts, talking to case study pupils and gathering completed work. Finally each teacher is interviewed about the pupils and their progress, and at the end of Year 6, before leaving primary school, each pupil is interviewed.

Tentative Findings

There is much data still to be analysed and hence findings are only slowly and tentatively emerging. However some of the findings so far from the Core and Focus 1 projects are given below. (Although there is not enough space in this summary, both quantitative and qualitative evidence will be given in the presentation to support some of these findings.)

1. Our data suggests that there is no association between some measurable aspects of pedagogy and pupils' gains, e.g. frequency of lessons with substantial amounts of whole class teaching, frequency of use of calculators, frequency of homework. This means that if, as seems likely, the National Numeracy Strategy has a clear effect in raising standards in our tests, it is more likely to be due to the change in curriculum emphasis than to the change in pedagogy. The change in pedagogy has been considerable: the proportion of teachers who whole class teach in every lesson has increased from 11% in 1994 to 60% in 1998/9 and almost 100% in 1999/2000. There is some indication that more whole class teaching is associated with both higher and lower gains.
2. Similarly, easily measurable teacher characteristics seem to have little association with pupils' gains. These include age, experience, appointment as mathematics co-ordinator, mathematical qualifications or attendance at in-service courses.
3. While most classes have similar gains there are some that have unusually large or small gains (and sometimes even losses) during the year. The lowest gains are not surprisingly often associated with many changes of teacher, teachers who find control difficult, or with a group of older children in a mixed-age class.
4. The range of attainment within each class is generally much larger than the differences between classes, pointing to the secondary effect of the teacher.
5. In the earlier study *Effective Teachers of Numeracy* (Askew et al. 1997), in a small sample there were clear-cut results where relatively high mean gains were associated with teachers with *connectionist* orientations and relatively low mean gains with *transmission* and *discovery* orientations. *Connectionist* teachers emphasised connections within mathematics and between mathematics and the real world, and were able to relate their teaching to children's thinking. While transmission teachers emphasised the mathematics and the learning of techniques, discovery teachers prioritised children's needs, interests and readiness, and often the use of manipulatives. Classes taught by teachers with orientations between these extremes generally had average gains.
6. In the Leverhulme study we have found some of the same features as before in many of the teachers with high and low gains, but the picture is more complex, especially when trying to predict gains from features observed in lessons rather than teacher beliefs. We initially evolved a quite complex framework based loosely on Saxe (1991) which focused on the quality of tasks, talk, tools and norms/relationships, but are now trying out a simpler framework based on the relations between the teacher and the mathematics, the teacher and the pupils, and the pupils and the mathematics. We are still not confident that we will be particularly successful in predicting from classroom observation which teachers will have the greatest and least gains (which makes us wary of inspectors' judgements of teaching quality).
7. Some of our case study schools seem to be consistently successful, with children achieving high gains in each year and classes moving steadily up the attainment ranking. At the moment we think that this might be because teachers in those schools have a shared commitment to focusing on children's mathematical learning rather than on provision of pleasant classroom experiences, on providing a challenging rather than a comforting curriculum, and on having high expectations of initially lower attaining pupils. These may be more important than other differences in teaching style. However we are not yet sure whether such gains will be sustained, nor whether they are always associated with confident and positive attitudes.
8. Case study children change their ranking within their class (just as classes change ranking within the sample) over time, sometimes to a surprising extent. In some cases this seems likely to be due to home pressure or home problems, and there are signs that such associations may not necessarily have a long-term effect. Children have an accurate perception of which teachers have best helped them to progress.

These findings are in line with much but not all international research, and generally warn against policies which produce simple solutions.

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Some insights from the first year of the Early Numeracy Research Project

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Doug Clarke is an Associate Professor at the Australian Catholic University (Victoria), where he directs the Mathematics Teaching and Learning Centre. He was formally joint coordinator of the Australian Mathematics Curriculum and Teaching Program (MCTP: K-10). In 1991 and 1992, he studied in Wisconsin USA, and coordinated teacher materials for the Mathematics In Context Project, an NSF-funded curriculum and professional development program for Years 5-8. His PhD focused on the changing role of the mathematics teacher in a 'problem solving classroom'. Doug's professional interests include using mathematics to explore current events and students' interests, problem solving and investigations, manageable and meaningful assessment, and the professional growth of mathematics teachers. Doug is Director of the Early Numeracy Research Project, exploring effective approaches to numeracy learning in the early years in 70 Victorian primary schools.

Jill Cheeseman comes from a background of primary teaching. She has also taught in a range of settings from early childhood to adult education. One of Jill's ongoing interests is professional development. This has involved lecturing in pre-service and postgraduate teacher education courses in mathematics education. She has been active in professional associations and thoroughly enjoys working with in-service teachers. Her interest in the development of children's mathematical thinking led to her work in state-wide assessment and monitoring and the National Numeracy Benchmarks for Years 3 and 5. Jill's research interests include: the role of calculators in primary mathematics education, young children's acquisition of number concepts, innovative practice in primary mathematics and teacher change. Her current work with the Early Numeracy Research Project draws together aspects of previous work as the research centres on developing the mathematical thinking of young children through the professional development of their teachers. It also involves developing assessment protocols and working closely with teachers in classrooms.

The Early Numeracy Research Project is researching effective approaches to numeracy learning in the first three years of school. Seventy Victorian schools (35 'trial schools' and 35 'reference schools') are participating in the project. An early focus of the project was on the development of a framework of 'growth points' of early numeracy learning and a task-based interview designed for one-to-one use by classroom teachers. Professional development at school, region and statewide levels provides the opportunity for teachers in trial schools to use what they learn from such interviews, and other ongoing assessment, to inform their practice. In this paper, data will be shared on student understanding and early data on changes in teaching practice that teachers believe have led to promising growth in understanding.*

In Victoria, the Early Literacy Research Project (Hill & Crevola 1998) worked with 27 disadvantaged primary schools to bring about substantial improvements in early literacy outcomes. The Early Numeracy Research Project (ENRP) was established in 1999 by the (then) Victorian Department of Education, with similar aims to those of the Early Literacy Research Project, but with a numeracy focus. The ENRP is now a collaborative venture between the Australian Catholic University, Monash University, the Victorian Department of Employment, Education and Training, the Catholic Education Office (Melbourne), and the Association of Independent Schools Victoria. The project is funded to the end of 2001 in 35 'trial' schools and 35 'reference' schools (for details see Clarke, D. M. 1999, 2000; Clarke, D. M., Sullivan, Cheeseman & Clarke, B. A. 2000). The ENRP has a major professional development component involving teachers meeting with project staff for statewide, regional and local in-service programs.

Important differences from the literacy project included the need for development of a comprehensive and appropriate learning and assessment framework for early numeracy (such frameworks were well established for reading), and the need to address the personal confidence with, and understanding of, mathematics of many primary teachers.

Measuring mathematics learning

The impetus for the project was a desire to improve mathematics learning and so it was necessary to quantify such improvement. It would not have been adequate to describe, for example, the effectiveness of the professional development in terms of teachers' professional growth, or the children's engagement, or even to produce some success stories. Instead it was decided to create a framework of key 'growth points' in numeracy learning.

The research team first came across the term 'growth points' in the work of O'Toole, Rubino, Parker & Fitzpatrick (1998), and discussions with members of that team from the Catholic Education Office (Adelaide) were most helpful in considering aspects of the Measurement domains of the framework.

The project team studied available research on key 'stages' or 'levels' in young children's numeracy learning (e.g. Boulton-Lewis 1996; Fuson 1992; McIntosh, Bana & Farrell 1995; Mulligan & Mitchelmore 1995, 1996; Pearn & Merrifield 1992), as well as some frameworks developed by other authors and groups to describe learning (e.g. Bobis & Gould 1999; Wright 1998).

In developing the ENRP framework it was intended the framework would:

- reflect the findings of relevant research in mathematics education from Australia and overseas;
- emphasise the 'big ideas' of early numeracy in a form and language readily understood by teachers;
- reflect, where possible, the structure of mathematics;
- give a sense of a possible order in which strategies are likely to emerge and be used by children;
- allow description of the mathematical knowledge and understanding of individuals and groups;
- form the basis of planning and teaching;
- provide a basis for task construction for interviews, and the recording and coding process that follows;
- allow the identification and description of improvement where it exists;
- enable consideration of those students who may benefit from additional assistance;
- have sufficient 'ceiling' to describe the knowledge and understanding of all children in the first three years of school; and
- build on the work of other successful, similar projects such as *Count Me in Too* (Bobis & Gould 1998; Stewart, Wright & Gould 1998).

These principles informed the process of developing and refining the framework as is outlined in the next section.

The development of the framework

For 1999, the decision was taken to focus upon the strands of Number (incorporating the domains of counting, place value, addition and subtraction strategies, and multiplication and division strategies) and Measurement (incorporating the domains of length, mass and time). In 2000, the strand of Space (incorporating properties of shapes and visualisation and orientation) was added to the framework.

Within each mathematical domain, growth points were stated with brief descriptors in each case. There were typically five or six growth points in each domain. To illustrate the notion of a growth point, consider the child who is asked to find the total of two collections of objects (say nine objects and another four objects). Many young children will 'count all' to find the total ('1, 2, 3,…11, 12, 13') even once they are aware that there are nine objects in one set and four in the other. Other children will realise that by starting at 9 and counting on ('10, 11, 12, 13') they can solve the problem in an easier way. *Counting All* and *Counting On* are therefore two important growth points in children's developing understanding of Addition.

The ENRP growth points for Addition and Subtraction Strategies are shown in Figure 1.

0. Not apparent
   Unable to combine and count two collections of objects.
1. Count all (two collections)
   Counts all to find the total of two collections.
2. Count on
   Counts on from one number to find the total of two collections.
3. Count back / count down to / count up from
   Given a subtraction situation, chooses appropriately from strategies including count back, count down to and count up from.
4. Basic strategies (doubles, commutativity, adding 10, tens facts, other known facts)
   Given an addition or subtraction problem, strategies such as doubles, commutativity, adding 10, tens facts, and other known facts are evident.
5. Derived strategies (near doubles, adding 9, build to next ten, fact families, intuitive strategies)
   Given an addition or subtraction problem, strategies such as near doubles, adding 9, build to next ten, fact families and intuitive strategies are evident.
6. Extending and applying addition and subtraction using basic, derived and intuitive strategies
   Given a range of tasks (including multi-digit numbers), can solve them mentally, using the appropriate strategies and a clear understanding of key concepts.

Figure 1. ENRP growth points for Addition and Subtraction strategies

These growth points informed the creation of assessment items and the recording, scoring and subsequent analysis as discussed below.

Growth points, levels and stages

The growth points are clearly a key element of this framework. In discussions with teachers we have come to describe them as key 'stepping stones' along the path to mathematical understanding. However, we do not claim that all growth points are passed by every student along the way. For example, one of our growth points in addition and subtraction involves 'counting back', 'counting down to' and 'counting up from' in subtraction situations, as appropriate. But there appears to be a number of children who view a subtraction situation (say, 12 minus 9) as 'What do I need to add to 9 to give 12?' and do not appear to ever use one of these three strategies.

The interpretation of these growth points reflects the description by Owens and Gould (1999) in the *Count Me In Too* project: 'The order is more or less the order in which strategies are likely to emerge and be used by children…intuitive and incidental learning can influence these strategies in unexpected ways' (p. 4). In discussing 'higher' level growth points in a given domain, the comments of Clements, Swaminathan, Hannibal and Sarama (1999) in a geometrical context are helpful: 'The adjective *higher* should be understood as a higher level of abstraction and generality, without implying either inherent superiority or the abandonment of lower levels as a consequence of the development of higher levels of thinking' (p. 208).

Also, the growth points should not be regarded as necessarily discrete. As with Wright's (1998) framework, the extent of the overlap is likely to vary widely across young children, and 'it is insufficient to think that all children's early arithmetical knowledge develops along a common developmental path' (p. 702).

In concluding this section, it is probably important to state briefly some of the things that the framework is *not:*

- It is not a statement of development stages in the sense of children being locked into certain growth points according to age, or in the sense of all children moving along the same developmental path.
- It is not a document written specifically for the research community but rather a framework for teachers with the intention of use and eventual 'ownership' by teachers.
- It is not a learning hierarchy in the 1970s sense of that term; a helpful distinction is that the focus of the growth points derive more from the child's mathematics than the structure of mathematics.

The development of the interview

Once the early drafts of the framework were developed, assessment tasks were created to match the framework. A major feature of the project is a one-to-one interview with every child in trial schools and a random sample of around 40 children from each reference school at the beginning and end of the school year (February / March and November respectively), over a 30 to 40-minute period.

Although the full text of the interview involves around 50 tasks (with several sub-tasks in many cases), no child moves through all of these. The interview is of the 'choose your own ending' form in that the interviewer makes one of three decisions after each task. Given success with the task, the interviewer continues with the next task in that mathematical domain as far as the child can go with success. Given difficulty with the task, the interviewer either abandons that section of the interview and moves on to the next domain or moves into a detour, designed to elaborate more clearly the difficulty a child might be having with a particular content area.

All tasks were piloted with children aged five to eight in non-project schools in order to gain a sense of their clarity and their capacity to reveal a wide range of levels of understanding in children. This was followed by a process of refining tasks, further piloting and refinement, and where necessary, adjusting the framework, as shown in Figure 2.

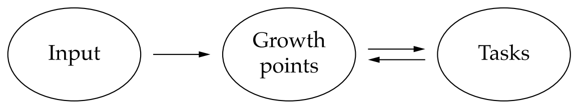

Figure 2. The process of developing the ENRP framework and the interview

The growth points for which they are intended to provide evidence influence the form and wording of the tasks. The consideration of student responses to a given task can lead to a refining of the wording of a given growth point.

The interview provides information about those growth points achieved by a child in each of the seven domains. Our aim in the interview is to gather information on the most sophisticated strategies that a child accesses in a particular domain.

It is important to stress that the growth points are 'big mathematical ideas or concepts', with many possible 'forms of progress' between them. As a result, a child may have learned several important ideas or skills necessary for moving to the next growth point, but perhaps not of themselves sufficient to move there. Also, to achieve many of the growth points requires success on several tasks, not just one or some.

Of course, decisions on assigning particular growth points to children are based on a *single* interview on a *single* day, and a teacher's knowledge of a child's learning is informed by a wider range of information, including observations during everyday interactions in classrooms. However, teachers agree that the data from the interviews are revealing of student mathematical understanding and development in a way that would not be possible without that special opportunity for one-to-one interaction. It appeared that the children also enjoy that special time having the teacher 'all to themselves'. Teachers report that children appreciated the opportunity to show what they knew and could do.

Data collection and results

As well as moving carefully through the 16-page interview schedule, the interviewer completed a four-page Student Record Sheet. The information on this record sheet is then used by a trained team of coders together with a scoring algorithm to assign 'achieved growth points' to each child for each content area. The rating of an individual child at a particular growth point is based on his or her responses to a number of different interview tasks. These raters demonstrated extremely high levels (all greater than 90%) of inter-rater reliability, as detailed in Rowley, Horne & Clarke (forthcoming).

A key criterion for the framework to be successful is the extent to which it reports on the spread and development of children's learning. Table 1 presents the percentages of children at each growth point in the March 2000 interview for addition and subtraction, for each grade level, for reference schools. Reference school data is chosen in this instance because it can be argued that students in these schools typify children across the state.

		Prep *n*=503	Grade 1 *n*=418	Grade 2 *n*=365	Total *n*=1286
0.	Not apparent	55.2	12.4	3.0	26.7
1.	Count all	38.0	51.2	22.7	38.0
2.	Count on	6.2	31.3	46.8	25.9
3.	Count back/count down/count up from	0.2	4.3	13.7	5.4
4.	Basic strategies	0	0.2	10.4	3.0
5.	Derived strategies	0	0.5	3.3	1.1
6.	Extending and applying	0	0	0	0

Table 1. Percentage of children at each Addition and Subtraction growth point, by grade level (%)

Data collected in March and November 1999 and March 2000 from approximately 5000 children informed the refinement of the framework and interview in preparation for the assessment period in March 2000. Changes were also made in light of the perceived need to increase the focus on applying understandings in 'practical' contexts. The major change to the framework was the incorporation of two domains for the Space strand (properties of shape and visualisation and orientation). There were also a number of word and phrase changes, to increase consistency and clarity for teachers and interested others.

Comparative data so far

As explained earlier, student assessment in trial and reference schools enables the research team to decide whether the improvement over the year in student understanding would have happened anyway, or whether it has been enhanced by the involvement of trial schools in the project.

There was clear and positive growth in both trial and reference schools. However, looking at the data overall, children in trial schools outperformed those in the reference schools at *every grade level* and in *all of the mathematical domains studied.* Further information on comparisons will appear in Clarke, Rowley, Horne, Sullivan & Gervasoni (forthcoming).

Teachers' stated professional growth

Given the clearly successful efforts of trial school teachers in developing children's mathematical skills and understandings in 1999, it becomes increasingly important for the research project to start to look at successful teachers' practice to try to discern those aspects of 'what the teacher does' that make a difference. After slightly more than one year's involvement in the project, teachers were asked to identify changes in their teaching practice (if any). There were several common themes:

- more focused teaching (in relation to growth points);
- greater use of open-ended questions;
- giving children more time to explore concepts;
- providing more chance for children to share strategies used in solving problems;
- offering greater challenges to children as a consequence of higher expectations;
- greater emphasis on 'pulling it together' at the end of a lesson;
- more emphasis on links and connections between mathematical ideas, and between classroom mathematics and 'real life mathematics'; and
- less emphasis on formal recording and algorithms; allowing a variety of recording styles.

Several of these themes are evident in the following quote from a teacher:

> The assessment interview has given focus to my teaching. Constantly at the back of my mind I have the growth points there and I have a clear idea of where I'm heading and can match activities to the needs of the children. But I also try to make it challenging enough to make them stretch.

Teachers were also asked to comment on aspects of children's growth that were not necessarily reflected in movement through the growth points. Common themes were the following:

- children are better at explaining their reasoning and strategies;

- children enjoy mathematics more, look forward to mathematics time and expect to be challenged;
- the development of a 'give it a go' mentality is evident, with greater overall persistence;
- children are thinking more about what they have learned and are learning;
- all children are experiencing a level of success.

Conclusion

Although the ENRP is just over half-way through its three-year life, already we have seen the power of the carefully-developed, research-based, one-to-one interview in building an understanding of children's mathematical learning and in informing practice. Detailed case studies of particularly effective teachers and school communities (in relation to numeracy learning) will be undertaken in 2001. Data from these case studies will help to flesh out what it is that schools and teachers can do to achieve positive growth in student mathematical knowledge, understanding and confidence.

Endnotes

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Language implications for numeracy: A study of language use of disadvantaged students

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Robyn Zevenbergen is a senior lecturer at Griffith University where she works in mathematics education. Her research is focused on issues of equity and social justice in mathematics education, particularly in the areas of social class and indigenous education. The work is largely from a sociological perspective in which she critically examines the role of practice in the construction of social disadvantage. Her work is mainly in the area of primary schooling but also extends in the compulsory years of secondary school. She has been involved in many school-based projects both for research and professional development. She has been involved in a number of professional organisations nationally and internationally, including secretary of MERGA. She is currently a member of the Queensland School Curriculum Council's Syllabus Advisory Committee for Mathematics.

While once mathematics was considered a discipline that could transgress linguistic and cultural boundaries, it is now acknowledged that language has a considerable role in mathematics. Increasingly language is recognised as causing difficulties for students when they come to learn mathematics. Many different levels and aspects of language can be seen to create such difficulties for students. The implications of language on learning mathematics or developing a sense of numeracy is central to this paper.

The impact of language on numeracy has been more evident in recent times where there have been attempts to ensure that mathematics makes links to the real worlds of students. This approach, while attempting to embed mathematical concepts into contexts that seek to make mathematics meaningful and relevant, brings with it significant barriers to success. In part, this is due to the application of mathematics to 'real world' problems whereby such embedding needs to be couched in language. While the intentions of the approach are to embed problems into contexts thereby creating an aura of relevance, and hence accessibility, it creates a new set of difficulties for students that are becoming recognised. How such issues are framed is dependent on the ideological orientation of the researcher and/or educator.

Within the work on numeracy/mathematics and language, there are two distinct branches that have fundamental assumptions built into them. The first seeks to identify barriers to learning but without any social or political understanding of the issue, whereas a second branch identifies the issues within a socio-political perspective. This second approach recognises and sees as central, that the issues of language and numeracy have a strong correlation with the background of students, suggesting that the barriers to effective numeracy learning are related to student background. However, this is not to suggest a deterministic reading of success in numeracy, only that it is necessary to recognise that success can be enhanced or hindered as a consequence of socio-cultural background. The fundamental tenet of this approach is that mathematics teaching and learning is a political process through which students have differential access to knowledge and power. Language is one means through which such power is exercised. It is this approach that is central to this paper since it offers insights into the barriers to numeracy learning for many students from disadvantaged backgrounds. It allows educators to critically examine numeracy education and policy for the ways in which it can be implicated in the marginalisation and legitimation of failure for these students. This approach seeks to challenge the alternative (and dominant) approaches of education where it is seen that students from such backgrounds are lacking in some ways or other.

Language, underachievement and numeracy

In the following sections, I provide a very brief overview of a theoretical understanding of the issue and provide some examples of how such a theory provides us with a model for understanding how language impacts on numeracy teaching and learning. For the purposes of this paper, I align myself with those discourses on numeracy where numeracy is seen to be the application of, and capacity to use, basic mathematics in everyday and applied contexts. For ease of communication, this means that topics such as algebra and calculus are likely to be absent from discussions on numeracy. However, basic skills such as operations, calculating percentages, and using basic statistics with contexts commonly encountered by a significant section of the community is what can be seen to be numerate. In such a working definition, language is integral to numeracy. Thinking in a numerate way does not equate with thinking in a linguistic way, rather, in terms of being numerate; being able to speak or communicate mathematically is a key aspect of numeracy. Hence to be numerate includes being able to work and communicate effectively.

When students enter formal school contexts, they will have had very different experiences based on their social and cultural backgrounds. One such experience will be in the field of language. The work of Basil Bernstein (Bernstein 1990) and Pierre Bourdieu (Bourdieu, Passerson & de saint Martin 1994; Greenfell 1998) alerts us to the impact of language on school success. This paper takes as central their notions of language as political. Bourdieu et al. (1994) summarise this position in their statement 'The more distant the social group from the scholastic language, the higher the rate of scholastic mortality' (p. 41). While providing strong framing for considering aspects of language and learning on the outcomes of schooling, they do not explicitly or systematically explore the implications that their theories have in the study of numeracy.

Language, texts and success

Hardcastle (1985) and Walkerdine (1982) argue that situating problems in familiar contexts can result in students making mistakes when replying since they select the wrong discourse within which to locate the problem. Walkerdine (1982, p.141) argues: 'That children will search for a discourse in which to situate a task is amply supported by the fact that children will interpret...tests...by picking up a feature of the task and making it the object of a familiar discourse'. Bernstein (1996) is more explicit with his pedagogic theory and proposes that students need to be conversant in the unspoken, or invisible, aspects of pedagogy. One aspect of pedagogy is the rules through which students come to participate in interactions – with the teachers, texts and so forth. He refers to such rules as recognition and realisation rules. Recognition and realisation rules occur at the level of the individual: recognition rules are the means by 'which individuals are able to recognise the specialty of the context that they are in' (Bernstein 1996, p. 31) whereas realisation rules allow the student to make what are seen as legitimate responses within a particular context. If students are not able to recognise the 'power relations in which they are involved and their position in them, [and] they do not possess the realisation rule, they cannot speak the legitimate text' (Bernstein 1996, p. 32). For example, within the context of the classroom and an interview situation, students recognise that the teacher has power and that they should conform with expectations. However, when the teacher asks questions or has particular expectations of the students, students must be able to respond in a manner that is seen as appropriate in the classroom.

Consider a task such as the following:

> Suppose you had a garden this shape and you were in a helicopter right above your garden looking down on it. Which of the following shapes would be like yours?

The mathematics embedded in the task is a recognition task whereby the students are expected to identify the oblong shapes that have been placed in different orientations to the original. In considering the responses made by students to the task, it was apparent that fewer mistakes were made by students from middle-class backgrounds than their peers from working-class backgrounds. Consider the two responses following from students when questioned further as to their incorrect responses where it was not the mathematics that was problematic, but rather the selection of the incorrect discourse within which they needed to embed the task:

Girl

R: Why did you take that shape [the square]?

G: Because it looks like the shape of my garden.

R: Is your garden at home like that?

G: Yes.

Boy

B: None of those.

R: Why aren't any of them the same?

B: My garden goes like that [draws a semi-circle in the air].

In these tasks the students have been able to offer a response in the ways desired by a testing situation; that is they have selected an answer, albeit incorrect, but the inappropriateness of the response is due to a misrecognition of the recognition rule. The students failed to recognise the context of the question – the question is not asking about their personal gardens, but rather some abstract garden that has nothing to do with them personally. Students need to recognise that mathematics education is rarely a personalised game, but something that is often abstracted from the personal. Where questions may be embedded in discourses that suggest, or even encourage, a personification of mathematics, this is not the case. Indeed, mathematics increasingly becomes depersonalised as the students move through to higher levels of content. For these students (and others), the incorrect responses indicated a misrecognition of the context of the problem rather than seeing it as mathematical task requiring shape identification.

Unlike other discourses in mathematics education where the interpretation of such incorrect responses may be based on Piagetian notions of cognitive development where the students are caught in the concrete/abstract divide, Bernstein's theory offers considerably more potential to understand the social basis to such differences. Bernstein (1996) found that middle-class students, as young as seven years, are able to privilege official pedagogic codes over local or home pedagogic codes. In his work, he uses the example of classifying foods and found that middle-class students were more likely to classify them according to food groups (a school-based classification system) whereas working-class students were more likely to offer local classification systems, such as what would be offered as Sunday lunch. Moreover, he notes that middle-class students are able to switch between codes when asked to offer different classifications, whereas this was not the case with working-class students who tended to rely on local pedagogic codes. Within a language framework, what becomes critical when working with students is to recognise whether or not they identify realisation and recognition rules, rather than within a restrictive 'numeracy' framework. Students need to be able to recognise that the teacher is embedding mathematical tasks in particular discourses and that these discourses may or may not be relevant to the task.

In their extensive work on UK testing regimes, Cooper and Dunne (1999) have appropriated Bernstein's work to demonstrate the effects of social class on performance and report that where questions are embedded in clearly recognisable mathematical contexts, students from working-class and middle-class backgrounds are likely to respond in similar ways. That is, there is little difference in performance on such tasks – tasks that they refer to as 'esoteric'. What is concerning is that where tasks are embedded in 'realistic' contexts, differences emerge in performance. They argue that the embedding of tasks in 'realistic' contexts distracts students from the demands of the tasks whereby students from working-class backgrounds are less likely to identify the recognition rules and so fail to recognise the specificity of the mathematical tasks. In contrast, middle-class students are more likely to identify the recognition rules and so respond appropriately. That is, they are able to realise legitimate responses to the tasks posed. Whereas, once it was commonly assumed that working-class students were more likely to be concrete thinkers due to their perceived slower cognitive development, and hence more likely to perform better on concrete tasks, Cooper and Dunne challenge such assumptions. Their analysis has shown that working-class students may perform equally as well (as a group) as their middle-class peers on esoteric tasks (mathematical ones) but perform less well than their middle-class peers on realistic (or contextualised) tasks due to what Bernstein (1996) identifies as recognition and realisation rules. When students fail to identify the recognition rule – in this case the task posed was shape identification – they are unable to respond appropriately.

The work of Walkerdine (1992) has also been useful in alerting educators to the effects of the different codes used by families. She notes that within working-class families, the numeracy practices and language are somewhat restricted in comparison to their middle-class peers. For example, she notes that whereas middle-class parents use both terms in binary oppositional terms (such as more and less), working-class parents tend to use only more. This exposure to language has the potential to impact on students' capacity to make sense of teacher interactions when comparisons of number or size are being undertaken: Which is more, 2 or 5? What number is 3 less than 6?, and so on. These are common teaching strategies in the early years of schooling and integral to the development of number sense. Yet, when students are not exposed to the taken-for-granted language of instruction, there is potential for students to have greater or lesser access to the concepts as a consequence of their language.

Frequently cited studies in the Number strand have shown the effects of contexts and outcomes. For example, Ruesser (1986, cited in Schoenfeld 1992) posed nonsensical word problems to primary school students such as 'There are 125 sheep and 5 dogs in a flock. How old is the captain?' to which almost 75% gave a numerical response. Students toyed with the numbers until they were able to arrive at an answer that seemed to produce a sensible response to the question: 125+5 = 130; 125-5 = 120; 125/5 = 25; so that 25 seemed to be a reasonable age for a shepherd as the others were too high. While this research fell into the apolitical category of research, questions need to be asked as to whether or not some students respond differently in relation to their social and/or cultural background. It may well be that some students have greater or lesser opportunity to unpack the question for the hidden mathematics as a result of their social and/or cultural background that predisposes them to analyse the task within particular frameworks, some of which are more or less aligned with the official pedagogic discourses of school.

Conclusion

When considering students' numeracy learning, it becomes necessary to consider aspects of language as being integral to the teaching and learning process. Not only is language the vehicle through which students come to make sense of concepts via the teaching process, but also how they realise their understandings though their responses to teachers and through assessment schemes. Language is a political process through which some students have greater or lesser access depending on their language background. In cases where there are extreme differences between the language of instruction and language background, there is greater chance for error not due to some innate ability but due to differences between the formal language of school and the language of the home. It must be recognised that even in the case of English-as-a-first language, there are aspects of language that will hinder or enhance students' capacity to make sense and to make meaningful numeracy constructions. This is particularly the case for working-class students, and some indigenous students who speak different forms of English to that of the formal school context. Bernstein and Bourdieu have been particularly useful in alerting educators to such distinctions and their potential impact on learning outcomes. What becomes clear is the need for teachers, educators and researchers to explore this gap more thoroughly and identify the disjunctions between the home language and the formal language of instruction. The impact of language on numeracy development needs to have further exploration since little is known in any systematic form.

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International perspectives on numeracy learning: PISA and TIMSS

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Jan Lokan is Deputy Head of Measurement at the Australian Council for Educational Research (ACER) in Melbourne. Her undergraduate degree and teacher training were in pure mathematics and she has taught mathematics at both upper secondary and undergraduate levels in Australia, England and Canada. While in Canada she completed a PhD in Educational Measurement at the University of Ottawa.
Jan left the classroom to take up a career in educational research, first with the Ottawa Board of Education in Canada and later with ACER. She began her research life developing mathematics assessment materials for the Ontario Ministry of Education and for research projects in Ontario schools. Since joining ACER Jan has undertaken program evaluation studies, test and questionnaire development, and has managed several large-scale surveys and assessment projects. Recent ACER projects she has directed include a major survey of the implementation of curriculum statements and profiles in Australian schools and the Australian component of the Third International Mathematics and Science Study (TIMSS). She was a member of the Expert Group for the recently-developed Australian numeracy benchmarks. Currently Jan is directing the TIMSS-Repeat Video Study of mathematics and science teaching in Australian schools and the national component of the OECD Programme for International Student Assessment (PISA).

This paper examines implications for numeracy education in Australia arising from three international studies.

Although I cannot report any results as yet, I will describe the most recent study first, given that it has aimed to measure aspects of mathematics that would probably come closest to the collective understanding of 'numeracy' held by the people at this conference. I am assuming that this collective understanding will reflect various initiatives to define 'numeracy' in Australia over the past decade or so, particularly the 1997 conference which produced the definition that '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' (AAMT 1997). The study is the Programme for International Student Assessment (PISA), a new international survey of student learning outcomes in three key learning domains, one of them mathematics.

Programme for International Student Assessment (PISA)

PISA is a project of the Organisation for Economic Cooperation and Development (OECD) in Paris. A consortium led by the Australian Council for Educational Research (ACER) won the contract for developing and implementing this project internationally, and, in addition, ACER was also successful in its bid to run the national component. Testing for PISA in Australia took place very recently, from mid July to the end of August 2000, and involved over 6000 students from more than 230 schools. The sample, which came from all states, territories and education sectors, was selected to be nationally representative. The students selected in all countries were aged between 15 years, three months and 16 years, two months. Altogether, students from 31 countries have participated in the inaugural PISA testing, being all but one of the OECD member countries plus Brazil, Latvia and Russia. Several more countries are likely to do the survey in an extension of PISA next year.

Each student participating in PISA does a two-hour test, containing a mixture of reading, mathematics and science questions, plus a questionnaire to collect information about their background, educational experiences and attitudes. All test and questionnaire items are standard for all countries, with much effort invested in ensuring uniformity of translation and cultural fairness. Countries may add additional material to either the test or the questionnaire as national options if they wish. The year 2000 assessment is the first cycle, with testing planned to occur every three years. Each of the three key areas is the major area once and a minor area twice over the nine-year span. Mathematics will be the major area in 2003.

PISA's definition of 'mathematics'

PISA's definition of mathematics has arisen directly from the framework constructed in the first year of the project (1998) to guide the development of the tests. The framework covers all three domains and was developed by world leaders in the assessment of reading, mathematics and science. One of PISA's main goals is to find out how well prepared the students are for their lives beyond school; the assessment framework therefore has a forward-looking orientation towards life skills rather than a retrospective view at students' curriculum knowledge. In keeping with this focus for PISA, the three domains are referred to as 'reading literacy', 'mathematical literacy' and 'scientific literacy'. PISA is fortunate to have Professor Jan de Lange, of the Freudenthal Institute at the University of Utrecht, as chair of its mathematics expert group.

'Mathematical literacy' is defined as: the capacity to identify, to understand and to engage in mathematics and make well-founded judgements about the role that mathematics plays, as needed for an individual's current and future life as a constructive, concerned and reflective citizen.

> In keeping with this orientation, the assessment is broad, focusing on 'students' capacities to analyse, reason and communicate ideas effectively by posing, formulating and solving mathematical problems in a variety of situations' (de Lange 1999, p. 41).

The PISA assessment tasks have three main aspects: content, processes and the situations in which mathematics is used. *Content* is defined in broad concepts underlying mathematical thinking, for example 'change and growth', 'space and shape', 'uncertainty' and 'dependency relationships'. These broad concepts allow wide coverage of more familiar areas such as number, estimation, probability, functions, and so on. *Processes* are embodied in mathematical competencies such as:

- mathematical thinking;
- mathematical argumentation;
- mathematical modelling;
- problem posing and solving;
- representation;
- manipulation of symbols;
- understanding and correct use of terminology;
- knowing about and appropriate use of aids and tools; and
- communication.

These competencies can be grouped into three classes:

- Class 1 – reproduction, definitions and computations;
- Class 2 – connections and integration for problem solving;
- Class 3 – mathematisation, mathematical thinking, generalisation and insight.

An important aspect of mathematical literacy in PISA is use of mathematics in a variety of *situations*, from personal life and school life to sports, work and the broader community.

Some sample items will be shown to illustrate their innovative nature, broadness of coverage and range of skills required to answer them successfully.

PISA and numeracy

A book that is a decade old now, but still very relevant to discussions of numeracy education, presents the following points (among others) about numeracy skills:

> An appropriate curriculum to develop numeracy in all students would focus on developing: the attitude that mathematics is relevant to me personally and to my community; the learning skills (listening, reading, talking and writing) and fundamental mathematical concepts needed to access personally new mathematical ideas; and the confidence and competence to make sense of mathematical and scientific arguments in decision-making situations (Willis 1990, p. 22);

and

> In order for a mathematics curriculum to build real numeracy, it needs to develop:
> - the ability to make sensible choices about which method to use;
> - the ability to recognize major problem types and how to deal with them efficiently;
> - confidence in one's ability to carry out the procedure properly; and
> - sufficient general problem-solving skills so that students can get the problem into a state where their algorithmic and procedural knowledge is of some use. (Stacey 1990, p. 76).

In its overall aims, variety of applied situations for tasks and innovative problems posed, PISA has readily recognised overlap with many of the aspects of numeracy listed here.

Third International Mathematics and Science Study (TIMSS)

Another recent international survey was the Third International Mathematics and Science Study (TIMSS), more conventional than PISA in its coverage but nevertheless able to offer useful insights into Australian students' numeracy skills in relation to those of students from many other countries.

TIMSS was different from PISA in that it attempted to identify curriculum areas and topics that were common across many countries, and to assess knowledge and skills in those areas. Thus the TIMSS mathematics items reflected traditional strands such as Number, Geometry, Algebra, Data representation and analysis etc, and featured processes such as recall of basic knowledge, routine operations, complex operations and problem solving/investigating.

The TIMSS testing was carried out in 1994–95 at three schooling levels: mid-primary (Years 3 to 5); lower secondary (Years 7 to 9) and upper secondary (Year 12). Our students in the national random samples selected for TIMSS acquitted themselves relatively well. At mid-primary level, Australia outperformed half of the countries and fewer than a quarter outperformed us. At lower secondary level, we outperformed almost half of the countries and only a fifth achieved better results than we did. At upper secondary, in the specialist advanced mathematics and physics tests, Australia was among the highest achieving countries, though we did less well in the more general TIMSS mathematics and science literacy tests. Of some concern to our federal education minister was that the countries outperforming us at primary and lower secondary levels included our Asian trading partners of Singapore, Japan, Korea and Hong Kong (these countries did not participate in the Year 12 testing).

Analysis of the Australian TIMSS results within strands and processes have enabled us to see where our strengths and weaknesses lie in an international context. For example, at mid-primary level our students achieved relatively best in geometry and in measurement, estimation and number sense, but relatively weakest in understanding and use of whole numbers. At lower secondary level they performed relatively best in algebra and data representation / analysis / probability, and relatively weakest in geometry and fractions and number sense.

The reversal of the latter two areas between mid-primary level and lower secondary level provides food for thought. For both areas, the change may reflect differing curriculum emphasis. This certainly seems likely for geometry, which receives a lot of emphasis at primary level in the Space strand of our curricula. For number sense the situation seems less clear. Among the fractions items are some requiring conceptual understanding, others requiring manipulation, and still others requiring a combination of these aspects. In the main, our students showed reasonable levels of conceptual understanding of fractions, but very poor ability to manipulate even straightforward fractions. (Those who support use of calculators may think that this is not something to be concerned about, but I throw my hat into the ring to say that easy computations, such as dividing 14 by 2, should be able to be done by 13-year-olds without the aid of a calculator.)

TIMSS and Australia's numeracy benchmarks

Further analyses were undertaken to see if there were mathematics questions in TIMSS that constituted good or reasonable matches to Australia's numeracy benchmark statements for Years 3, 5 and 7. Many of these were identified, and useful information derived about Australian and other countries' achievement on them. Illustrative examples will be shown as part of the conference presentation.

Repeat of TIMSS (TIMSS-R)

A repeat of TIMSS, using questions that had been kept secure from the first study together with some new material, was carried out in 1998–99, but only at lower secondary level. Results from that testing are due for release in December this year. I have mentioned TIMSS-R because I now want to describe the exciting video study that Australia is taking part in as an extension of TIMSS-R.

An objective of TIMSS is to identify classroom practices that enhance mathematics and science learning, which has been attempted mostly through having the TIMSS students' teachers complete specially developed questionnaires. But the TIMSS researchers knew that written questionnaires for this purpose are a poor substitute for watching what teachers do, and so some of them set up a pilot study in the USA, Japan and Germany in which many mathematics classrooms were videotaped. Analyses of the tapes revealed significant, and in some cases, striking, differences in teaching styles across these three countries (Stigler & Hiebert 1997).

Encouraged by the pilot study results, the researchers, led by Professor Jim Stigler from UCLA, set up a study in science as well as mathematics teaching in a wider group of countries. Australia was fortunate to receive some financial support from the US National Center for Education Statistics (NCES), supplemented by funds from the Commonwealth, State and Territory Governments, to enable us to be a participant in this extension of TIMSS-R.

The video study

So far, the video study in Australia has involved selecting a national random sample of 100 secondary schools, and then selecting a Year 8 mathematics teacher at random from all such teachers in the school to have a lesson filmed at an unannounced time. A daunting prospect for teachers, I would say, and we did have some schools pull out of the study for this reason (in most circumstances it was not permitted to substitute an alternative teacher). In those cases we approached schools that had been selected as replacement schools when the sampling was done.

There were standard videotaping procedures for the study, and specially trained videographers were sent to schools all around the country to film the selected lessons. The filming was intentionally spread over several months, to get away from any lock-step teaching of similar content at similar times of the year (not a problem in Australia, but a problem in Japan, for example). Altogether in Australia 88 randomly-selected mathematics classes were filmed, and also 88 science classes occurring on the same or the next day in the same schools as the mathematics classes. The teachers whose lessons were filmed each completed a questionnaire about the goals of the lesson and where it fitted in a teaching sequence, and the students in the filmed classes completed a short questionnaire and a mathematics or science test. The data collection was completed in June 2000.

Processing the video study data

How does one go about studying teaching practices from videotaped lessons? This is a very complex undertaking, as anyone who is or has been a teacher will realise. A basic unit of time needs to be decided, beginning and ending of lessons need to be specified, transitions between activities need to be recognised and documented, and the activities themselves have to be described. A coding scheme has to be devised that can capture all of these things (and much more), and has to be specified precisely enough that people coding the lessons can do so in a highly reliable way. Some extracts of the coding scheme developed for the TIMSS-R video study will be included in the presentation, and will be illustrated by short lesson excerpts where the teaching appears likely to enhance students' numeracy development (provided that the teachers grant permission for these to be shown).

Conclusion

In the short time available, a presentation such as this can only skim the surface of some examples of large-scale studies that have already provided useful information about Australian students' numeracy learning. The potential of the PISA survey is greater than that of the TIMSS projects because of the closer match of PISA's framework and assessment tasks to Australian conceptions of what constitutes 'numeracy'. The TIMSS-R video study offers the additional potential of being able to identify teaching practices that seem more likely than others to enhance students' numeracy learning.

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Researching numeracy in the middle years: The experience of the Middle Years Numeracy Research Project

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Numeracy in the Middle Years

One of the major challenges confronting any attempt to improve numeracy outcomes concerns the notion of numeracy itself. In 1997, the National Numeracy Benchmarks Taskforce defined numeracy as

> the effective use of mathematics to meet the general demands of life at home, in paid work, and for participation in community and civic life.

State and Territory curriculum documents refer to numeracy in a similar vein. In some cases, they link numeracy with a capacity for critical thinking and/or effective communication:

> Numeracy involves abilities which include interpreting, applying and communicating mathematical information in commonly encountered situations to enable full, critical and effective participation in a wide range of life roles (Queensland Department of Education, 1994, cited in AAMT/DEETYA, 1997).

> NUMERACY is an ability to cope mathematically with the demands of everyday life. Numerate and literate persons in mathematics are those who can appropriate mathematics as a tool to guide their reasoning, help them to solve problems in their everyday lives, communicate and justify their ideas, as well as to understand the ideas of others (ACT Curriculum Frameworks, 1996, cited in AAMT/DEETYA, 1997).

In *Numeracy = Everybody's Business,* the Report of Numeracy Education Strategy Development Conference, jointly published by AAMT/DEETYA in May 1997, numeracy is seen as

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

More recently, in *Numeracy A Priority For All: Challenges For Australian Schools* (DETYA, May 2000), numeracy is represented as follows.

> Numeracy like literacy provides key enabling skills for individuals to participate successfully in schooling. Furthermore, numeracy equips students for life beyond school in providing access to further study or training, to personal pursuits, and to participation in the world of work and in the wider community (DETYA, 2000).

The OECD's view of mathematical literacy is reported in the same document.

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

What each of these views encapsulates to varying degrees are the three foci identified by Willis (1998), that is, the underpinning nature of core mathematical understandings and skills (mathematical knowledge), the capacity to critically apply one's mathematical knowledge and skills in a particular context for some purpose (contextual knowledge), and the actual processes and strategies needed to connect and communicate one's mathematical knowledge to every-day problems and events (strategic knowledge).

This suggests that the development of numeracy will necessarily involve a consideration of each of these aspects in different ways and proportions at different ages and stages of schooling. While this is relatively straightforward in the early years where the focus is primarily on the development of the key mathematical ideas, skills and strategies that underpin numeracy, it is arguably more problematic in the middle and upper years of schooling where prior knowledge and experience, issues of identity, and a range of complex social, emotional and physical factors impact student's capacity to learn. For more general background information see the work of the *Middle Years Research and Development* project at www.sofweb.vic.gov.au/mys.

The particular challenges confronting the teaching and learning of numeracy in the middle years of schooling include the following.

- The enormous range in student ability and motivation, and the significant number of students whose experience of failure or sense of disconnectedness make them reluctant learners.
- The perceived demands of ‘the mathematics curriculum’ – too much, too soon, for too many, inhibiting attempts to cater for the learning needs of all.
- Limited time, resources and availability of qualified mathematics teachers particularly in Years 7 to 9 and/or additional, appropriately trained staff to support strategic intervention.
- The relatively sterile, transitory, learning environments of most junior secondary classes which do not facilitate the display of artefacts that celebrate and record prior learning.
- Procedural, ‘surface’ based approaches to learning mathematics, where there is little inclination to search for meaning and the primary focus is on ‘getting the answer’.
- Little or no culture of communication which values explanations, justification and the elaboration of student reasoning and strategies.

Clearly, attempts to improve numeracy in the middle years will need to consider not only the contribution that school mathematics might make (that is, essential underpinnings as well as new knowledge, skills and strategies), but also how to impact entrenched classroom cultures, scaffold discourse elements, and engage learners more effectively. The Victorian *Middle Years Numeracy Research Project* is attempting to do this using an action research methodology with 20 trial schools. While it is too early to comment on the effectiveness of the approaches and strategies being trialed, it is possible to share some of the outcomes and observations derived from the initial data collection.

The Middle Years Numeracy Research Project (MYNRP)

The *Middle Years Numeracy Research Project* is one of a number of current research projects on literacy, numeracy and/or the middle years of schooling commissioned by the Victorian Department of Education Employment and Training (DEET), in partnership with the Catholic Education Commission of Victoria (CECV) and the Association of Independent Schools of Victoria (AISV).

The aims of the *Middle Years Numeracy Research Project* are:

- to provide advice to DEET, CECV and AISV which will lead to the development of a coordinated and strategic plan for numeracy improvement;
- trial and evaluate the proposed approaches in selected Victorian schools; and
- identify and document what works and does not work in numeracy teaching particularly in relation to those students who fall behind.

The project is essentially an ascertaining study involving the collection of quantitative and qualitative data and the implementation, trial and evaluation of a *Draft Numeracy Strategy.* A more detailed explanation of the research methodology can be found in the 2000 MERGA Conference proceedings (Siemon & Griffin, 2000).

Base-line data on the numeracy performance of a structured sample of Grade 5 to 9 students from 27 primary and 20 secondary schools in Victoria was collected in November, 1999. This involved a 5-6 item written test of approximately 45 minutes and an extended classroom task (also of 45-50 minutes duration). The extended classroom task, known as *Street Party,* was sourced from the INISSS Project in Tasmania (see Callingham, 1999). This task caters for a range of abilities and is aimed at assessing higher order cognitive knowledge and skills related to pattern recognition and generalisation. The short assessment tasks were largely derived from *Effective Assessment in Mathematics Levels 4 to 6* (Board of Studies, 1998) to meet the following criteria.

- The tasks assessed numeracy performance of students in Years 5 to 9 (that is, mathematical, contextual and strategic knowledge (see Willis, 1998).
- The tasks were broadly representative of the three aspects of numeracy, ie, number sense, measurement and data sense and space sense 9 (the *draft National Numeracy Benchmarks for Years 5 and 7* were used a guideline).
- Opportunities were provided for students to demonstrate what numeracy-related mathematics they did know or could do (referenced to *Levels 3 to 6, Victorian Curriculum & Standards Framework).*
- Content as well as process outcomes were assessed, that is, conceptual as well as procedural knowledge and strategy usage.
- The tasks modelled best practice (see Clarke et al, 1996) and facilitated performance assessment, that is, the use of scoring rubrics which evaluated student’s performance including the capacity to choose, use and apply relevant knowledge, skills and strategies in context.

- They were relatively straightforward and cost-efficient to administer.
- The tasks could be locally assessed with some confidence and globally assessed using computer-readable score sheets.

Both tasks were assessed by the teachers concerned using previously trialed scoring rubrics and pre-printed scannable score sheets. The overall assessment procedure was referred to as the SNP or *Student Numeracy Performance* package.

The Phase 1 data was analysed using SPSS and Quest, a Rasch modelling tool developed by Adams & Khoo (1993). Of all the short assessment tasks used, only one task, *How Far to Walk,* lay outside the boundaries set by the Rasch item fit analysis suggesting that all the others were measuring a similar construct. This outcome is heartening as it suggests it is possible to measure a complex construct such as numeracy using rich assessment tasks that incorporate performance measures of content knowledge and process (general thinking skills and strategies) across a range of topic areas. It also suggests that the use of teachers-as assessors is a valid measurement procedure. Another encouraging feature of the overall item analysis is that the degree of difficulty of the tasks chosen appears to be appropriate for the cohort tested (see Siemon & Griffin, 2000).

'Hotspots' identified by the initial data collection, indicate that a significant number of students in Years 5 to 9 have difficulty with some or all of the following.

- Explaining and justifying their mathematical thinking
- Reading, renaming, ordering, interpreting and applying common fractions, particularly those greater than 1.
- Reading, renaming, ordering, interpreting and applying decimal fractions.
- Recognising the applicability of ratio and proportion and justifying this mathematically in terms of fractions, percentage or written ratios.
- Generalising a simple pattern and applying the generalisation to solve a related problem.
- Working with formula and solving multiple steps problems.
- Writing mathematically correct statements using recognised symbols and conventions.
- Connecting the results of calculations to the realities of the situation, interpreting results in context, and checking the meaningfulness of conclusions.
- Maintaining their levels of performance over the transition years.

One of the most promising outcomes of the initial data collection has been the development of an *Emergent Numeracy Profile* with rich descriptions of distinct developmental levels of numeracy performance based on the content and process analysis of the items included in the Phase 1 data collection (see below). This has important implications for the design of structured, numeracy-specific teaching and learning materials which not only support students to acquire the necessary content knowledge and skills but also scaffold a hierarchy of skills, strategies and dispositions concerned with mathematical thinking and problem solving (Siemon, 1993). Callingham (1999) has reported a similar developmental pattern for the *Street Party* task which she has described using the SOLO taxomony.

While the *Emergent Numeracy Profile* will be informed by further trialing of the SNP, it will be used in the Trial phase as a framework to guide the design and implementation of school-based teaching materials and assessment tasks. During the Trial phase it is also planned to collect data to help frame advice concerning the design elements under consideration. That is, structured mainstream classroom programs, additional assistance, the role of parents, mentors and peer support, and the role of professional development in improving numeracy outcomes.

Feedback on the implementation of the assessment tasks in Phase 1 schools indicated that although the assessment took place at a very difficult time of the year, it was generally viewed as a worthwhile exercise. Teacher journal entries from the Trial Phase suggest that teachers are more likely to accept the outcomes of assessment if they have been involved in the assessment themselves. For instance, there appears to be a greater acceptance of the importance of students' explaining and justifying their mathematical thinking and/or conclusions, even though this message has been part of the reform agenda for some time (eg, see the *Victorian Curriculum Standards Framework*). This in turn appears to have led to a greater willingness to use the data to inform future teaching (evident in Trial School Action Plans). In some cases, actually prompting discussions on task-specific solution strategies (eg, 'rotators' or 'left/righters' approaches to the Bird's Eye view task).

To date, the work of the MYNRP suggests that it is possible to measure a complex construct such as numeracy using rich assessment tasks incorporating performance measures of content knowledge and process (general thinking skills and strategies) and teachers-as-assessors. While it appears that the *Emergent Numeracy Profile* represents an important first step in helping teachers plan more effective instruction, it must be stressed that the profile represents work in progress that needs to be elaborated by further data collection and analysis. The research team would welcome any comments and/or feedback on the work so far.

Emergent MYNRP Numeracy Profile

H Well established in the use of fractions/ratio. Able to generalise and apply number relationships to solve problems. Monitors cognitive actions and goals (ie, almost always evaluates what they are doing for meaning and relevance to problem solution).

G Established in using and interpreting data and/or information appropriate to context, fraction representations, and in describing patterns and relationships. Able to explain solutions to problems.

F Consolidating use of data and information appropriate to context. Established in recognising 2D representations of simple 3D space. Beginning to monitor cognitive goals as well as actions (ie, evaluates what they are doing for sense and relevance).

E Consolidating fraction and % knowledge. Monitors cognitive actions (for 1-2 step problems). Little/no monitoring of cognitive goals (ie, checks procedures but not their meaningfulness and/or appropriateness to problem context and/or conditions).

D Beginning to understand and represent simple fraction situations. Generally solves one-step problems involving 3-digit whole numbers, ones and tenths. Describes simple patterns.

C Able to use a number pattern to solve a problem. Monitors cognitive actions and/or goals some of the time (eg, recognises relevant information but unable to use it effectively).

B Recognises a number pattern and represents it in one way. Makes judgements about data more on the basis of perception than analysis. Little evidence of cognitive monitoring, eg, estimates or calculates without regard for meaning or applicability.

A Uses make-all, count-all strategies to solve a simple number pattern problem

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Count Me In Too: Creating a choir in the swamp

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Peter Gould is the Chief Education Officer in Mathematics with the NSW Department of Education and Training. His primary responsibilities are in the design and development of effective mathematics curriculum support from Kindergarten to Year 12. He has a strong interest in developing interactive research projects that enable research-based knowledge to improve, and be improved by, teaching practice. Peter considers himself fortunate to have been able to work with a range of talented researchers from within Australia and overseas with similar interests.

The Count Me In Too early numeracy program has been bringing together research and teaching practice in NSW primary schools since 1996. It is now operating in over 500 schools in NSW as well as in schools in Tasmania, the Australian Capital Territory and New Zealand. The program brings together a synthesis of research in early number learning with research into professional development.

Over a decade ago, Donald Schön used a powerful analogy that captured the challenges of educational research. He described a high, hard hill of research-based knowledge overlooking the soft, slimy swamp of real-life problems. Up on the hill, simpler problems respond to the techniques of basic science whereas down in the swampy lowland, messy, confusing problems defy technical solution. Should the researcher 'remain on the high ground where he can solve relatively unimportant problems according to prevailing standards of rigor, or shall he descend to the swamp of important problems and non-rigorous inquiry?' (Schön 1987, p. 3) As Schön noted, the irony of the situation is that the problems of the high ground tend to be relatively unimportant to individuals or society at large, however great their technical interest may be, while in the swamp lie the problems of greatest human concern.

The *Count Me In Too* early numeracy program (Bobis & Gould 1998; Stewart, Wright & Gould 1998) was developed to address the challenge of teaching and learning mathematics in the 'swamp of real classrooms'. The focus of the program is the advancement of children's mathematical solution strategies, particularly in number. This is an area of need that has long been recognised in research.

At first glance, the issue of instruction failing to match or even recognise students' solution strategies appears significant. It would by itself, however, hardly rate as a problem of great human concern. When combined with Gray's (1991) identification of the dominance of strategies of counting by ones in use by less able students, the failure to recognise students' solution strategies grows in significance. In a study of mixed ability children aged seven to 12, Gray comments on the dominant use of counting by ones and concludes that in '…one sense *they make things more difficult for themselves* and as a consequence *become less able'* (1991, p. 570).

The problems of the swamp are problems of both process and product. Combined with the 'invisibility' of students' solution strategies is the challenge of traditional teaching. Tradition in teaching is formed by the accumulated series of stories that illuminate and fashion our fundamental meanings. Within the *Count Me In Too* project, new teaching stories are formed. These stories have been shaped by the following principles:

> What I hear in isolation from the classroom is only theory. What I see in practice in the classroom I believe as 'teaching reality'.

The *Count Me In Too* professional development model builds upon these principles. It creates a climate for learning for four linked groups within the project: academic facilitators, consultants, teachers and students (Figure 1).

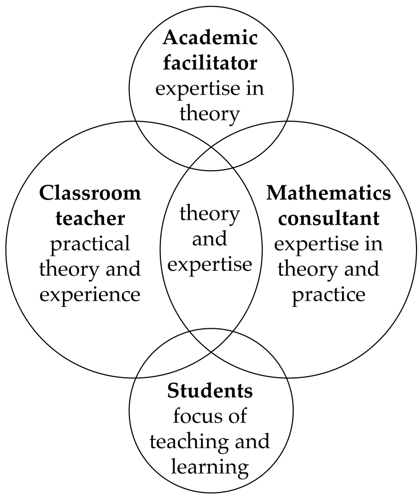

Figure 1. Interactive curriculum change

The professional development model engages teachers in classroom-based learning through observation, diagnostic interviews and reflection, using videos of students' classroom activities as a reflective tool. The focus on the learning framework enables its adoption as a personal theoretical model to be facilitated by being grounded in the teacher's classroom experiences. The teacher's classroom practice is modified to accommodate the change in personal theories on how children learn, which in turn impacts on teaching and on student outcomes. Consequently, the learning framework takes on the function of a *viewing frame* to guide assessment and instruction in early number strategies.

Stages in number development: tonal scale

Fuson (1992), in summarising research on whole number addition and subtraction, states:

> Children in the United States display a progression of successively more complex, abstract, efficient and general conceptual structures for addition and subtraction. Each successive level demonstrates cognitive advances and requires new conceptual understandings.

The progression of successively more efficient and general conceptual structures which children use has been described by a research-based Learning Framework in Number (Wright 1998; Wright & Gould 2000). This Learning Framework in Number is a synthesis of multiple research projects. The study reported here draws on a major component of the framework which outlines the learning stages in the construction of the number sequence (Steffe 1992).

Simplified descriptions can provide an important starting point for understanding complex activities. At the risk of over-simplifying the description of some of the stages of students' use of strategies, as outlined within the Learning Framework in Number, they are, in brief, as follows:

- *Emergent* – A child who is an emergent counter may have some number knowledge but it is generally made up of discrete pieces of information. For example, a child may know some of the sequence of number words and be able to identify some numerals while still being an emergent counter.
- *Perceptual* – A child who is a perceptual counter can count perceived items, matching the number word sequence to the items. A perceptual counter is limited by his or her knowledge of the forward sequence of number words.
- *Figurative* – A child at the figurative stage can determine the total in two concealed collections of items but typically counts from one to do so. The numbers now exist as independent entities.
- *Counting on* – A child at the counting on stage uses advanced count-by-one strategies to solve addition or missing addend tasks. A number takes the place of a completed count and a child can count on or back to solve problems.
- *Facile* – A child at the facile number sequence stage can use a range of strategies other than counting by one. This includes a part-whole knowledge of numbers that enables children to draw on doubles or known combinations to five or ten.

The stages outline a progression of increasing sophistication in the conceptual use of number. For example, to solve 8 plus 3 a child can count out 8 objects, then 3 objects, before combining and counting them all, starting again from one. This approach is typical of a perceptual counter. Alternatively, a child can start with the 8 and treat it as a completed count before counting on the 3, saying '8,…9, 10, 11'. This is a more advanced strategy that still employs counting by ones and is typical of the counting on stage.

Of the many things that teachers have learnt by focusing on students' solution strategies, perhaps the most striking is the insidious nature of inefficient strategies. Inefficient strategies are persistent because they work. That is, although counting from one three times to find the total of two numbers is quite slow, it will still result in the correct answer eventually.

Building resonance

Over 360 primary or central schools in New South Wales were involved in the *Count Me In Too* project in 1999. During 1999, the project had a strong Kindergarten to Year 2 focus. Information on students' arithmetical thinking was collected from a sample of 162 schools. The 15,176 children were in Kindergarten, Year 1, Year 2 and Year 3 and ranged in age from four years five months to eight years eight months.

One-to-one clinical interviews were carried out using a Schedule for Early Number Assessment (SENA; NSW Department of Education and Training 1998). The SENA has a series of questions that address numeral identification, the student's ability to produce sequences of number words from different starting places (both forwards and backwards), addition and subtraction using screened and partially screened collections of counters, knowledge of tens and ones, and subitising. Glasersfeld (1982) describes subitising as the immediate correct assignment of number words to small collections of perceptual items.

All of the students were interviewed twice – at the start and end of the project. The time between the initial and final assessment varied between schools and ranged from two months to eight months, with most schools separating the assessments by three to four months. The classroom teachers carried out the interviews. Each of the school teams was assisted in the analysis by a district mathematics consultant.

At least three students from each class had their interviews video-taped. These tapes were used in professional development meetings to discuss the nature of children's solution strategies. The meetings also created a forum for collaborative planning of ways to provide specific learning opportunities to enable students to develop more sophisticated solution methods.

The *Count Me In Too* project recognises that students frequently use strategies that are less sophisticated than those of which they are capable. This is addressed in the design of the Schedule for Early Number Assessment used within the project. Children's performance is recorded as the highest level that the child is able to demonstrate through the interview.

Chorus

Data on students' performances from the initial and final assessment were used to produce a subset of matched information. Any records that were incomplete because the student's age or initial or final interview results had not been recorded were excluded. From the total data collection on 15,176 children, this left 10,105 children. This information was then organised by stage of strategy use and age at the initial interview as in Table 1.

	4.0 – 4.9 years	5.0 – 5.9 years	6.0 – 6.9 years	7.0 – 7.9 years	8.0 – 8.9 years
Emergent	582	1556	445	4	0
Perceptual	342	2347	1888	39	4
Figurative	18	469	1198	51	10
Counting on	8	133	757	70	13
Facile	0	9	147	12	3
Totals	950	4514	4435	176	30

Table 1. Stages of early arithmetical strategies by age (initial interview)

The stages of strategy use are clearly dependent upon age. Excluding the 8.0 – 8.9 years column, as the category numbers are too small, produces

$\chi^2_{12} = 2549$ ($> \chi^2_{exp} = 26.2$, $\alpha = 0.01$).

Masters and Doig (1992) used data from the Carpenter and Moser (1984) longitudinal study of 88 children from Grades 1 through 3 in creating a response map for single-digit addition. The underpinning assumption in creating such a response map was that there had to be a relationship between school grade and the type of strategy used. Indeed, the response map was designed to display the different ways in which students respond to a task and to show '…how these responses change with increasing age or mathematics ability' (Masters & Doig 1992, p. 264). The analysis of the results from 10,075 students' interviews demonstrate there is a statistically significant relationship between the stages of early arithmetical strategies in the Learning Framework in Number and students' ages. This relationship is evident in the initial interview, before any teaching focusing on students' solution strategies has taken place.

Comparison of strategy use in the initial interview and the final interview shows significant change. For example, the initial assessment showed that the proportion of emergent counters appeared to decrease steadily from 61% (students less than five years) to 10% of students between six and seven years of age. The final interview showed the proportion to decline from 16% (students less than five years on initial interview) to 2% of students between six and seven years of age on initial interview. Clearly many of the students who had started school as emergent counters had progressed to perceptual counting or beyond. This change, however, is far greater than can be reasonably accounted for by traditional growth in strategy use within this population.

Using the initial interview as a predictor of the final interview would suggest that the 61% of students less than five years old and emergent counters would reduce to 34% of students in the five to six-year-old group. At the time of the second interview only 16% of this group were still emergent counters. The rate of progression through the stages of strategy use was greater than the 'natural' progression rate, as mapped in the initial assessment of this population.

Recapitulation

Evaluating the impact of a large-scale professional development program on students' cognitive outcomes is rarely a simple matter. This is certainly the case when the program is located in the 'swamp' of important problems. There are always problems associated with what is measured and how it is measured.

As the focus of the *Count Me In Too* program is the advancement of children's mathematical solution strategies, what needed to be measured was a given. Yet this measurement is not a simple thing. One of the features of assessment within the *Count Me In Too* project is that it recognises that children are not always consistent in their choice of strategy. Consequently, the assessment tasks have been designed to elicit the most advanced strategy that children can demonstrate. The Schedule for Early Number Assessment is also constructed with consideration given to the impact of number size on the type of strategy elicited.

The comparison of the rates of change of strategy between the initial and final assessments suggests that the *Count Me In Too* project has progressed students' development of solution strategies from less efficient to more efficient ahead of expectations.

Teachers' beliefs, knowledge, judgements and thoughts have a profound effect on the decisions they make, which in turn determine to a large extent what students learn in their classrooms. The research in action within the 'swamp' has created a choir that impacts on both the professional knowledge of teachers (Bobis & Gould 1998) and the curriculum outcomes of students.

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Numeracy development of Indigenous students: An introduction to research

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In presenting a paper on research into numeracy development of indigenous students to a conference focussing on numeracy research, two points need to be established. Firstly, the definition of numeracy which underpins both this paper and the work described herein relates closely to the AAMT (1998) numeracy policy definition:

> 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.

Secondly, there has been relatively little formal research in the field of numeracy development of indigenous students and, as yet, no large-scale research projects. To date, most of the efforts in this field have been in materials development with varying degrees of uptake, and, hence, success. With factors such as massive staff turnover and limited access to resources and professional development in most remote localities, the impact of a wide range of materials on enhancing student outcomes has been limited, despite the investment of a great deal of well-intentioned time and money.

The Northern Territory Numeracy in Schools Project (NISP) was not established as a formal research project. The NISP outcomes, which have remained fairly consistent since the project commenced in 1998, relate strongly to the improvement of numeracy outcomes for all NT students. The main vehicle for this is site-based professional development of all (teachers and support) staff using long-term, whole-school approaches.

Consequently, from a limited field of research, this paper attempts to synthesise the findings of the small but research-rigorous Indigenous Students Achieving Numeracy (ISAN) project and the far less formal but much larger scale Numeracy in Schools Project (NISP) in order to inform current and future thinking in relation to indigenous students' numeracy development.

The ISAN Project

Overview

The Indigenous Students Achieving Numeracy Project was a collaborative venture between the Australian Association of Mathematics Teachers and five school sites during 1998. The schools were Marree Aboriginal School (SA), Alice Springs High School (NT), Manmoyi Outstation School of Gunbalanya CEC (NT), Shepherdson College (NT) and Kununurra District High School (WA).

As part of the Indigenous Education Strategic Initiatives Programme – Strategic Results Programme (IESIP–SRP), the project aimed to demonstrate that improved learning outcomes for indigenous students can be achieved quickly. ISAN was based on a commitment to supporting the wisdom and capability of teachers in the field – this is central to the belief and operational framework of the AAMT as the national professional association of teachers of mathematics. Each school designed and implemented a unique project that built on understanding of the local context and needs. Student achievement was measured against 'mainstream' assessment and reporting frameworks.

The ISAN project was not internally conceptualised as a research project, but there are at least two levels on which it is, in fact, a small but significant contribution to the research base in relation to indigenous students' numeracy development. The overall project involved rigorous pre and post assessment of student learning. Hence, project results are evidence of the sorts of learning gains that can be achieved by indigenous students. Within each school, the day-to-day operation of the project had an orientation towards 'action research' methodologies. Continuing cycles of planning-action-reflection-planning…occurred during the year. These were fed by networking and sharing among the schools, and by input from others on request. As a result of this orientation towards reflection, in particular, the project the team – key people from each site – were able to distil some common factors that contributed to successful numeracy development for indigenous students in the schools.

The results

In relation to student learning, four of the five schools met their goals, or were within one student of doing so (IESIP–SRP National Coordination and Evaluation Team 2000, p. 308). It should be noted that the targets here were at least as demanding as would be placed on typical 'mainstream' classes, even though the students selected to be involved were, in some cases, deemed to be 'at risk' in their numeracy development. In other words, some schools selected students whose backgrounds made the achievement of substantial progress even more problematic.

While this mapping of student progress was the goal of the project, the most valuable (and more broadly applicable) lessons relate to processes and strategies identified by staff involved at the conclusion of the project. At that time there was a pooling of understanding of those factors found to be important to success at each of the schools. Please note that the strategies associated with the factors varied

Emergent factors	Message
Person(s) established and resourced to attend to students' numeracy development as a special responsibility, subject to: • time (release); • money (purchase resources and materials); • external support (consultants, critical friends).	Numeracy seen as being 'taken seriously' within the school context.
Explicit involvement of para-professionals such as: • team teachers; • part-time instructors; • parents; • community members.	Empowerment of para-professionals to take an ongoing, collaborative and pro-active role in students' numeracy development.
Community involvement /empowerment/ ownership of teaching strategies to ensure it is: • best practice; • appropriate to context; • based on knowledge of students' experiences.	Engagement of staff, students and community members in long-term and substantial changes. Explicit recognition that all contexts are different.
Ensuring understanding of appropriate concepts in students' first language through: • formal bilingual programs; • informal bilingual programs; • indigenous Languages, Creole, Aboriginal English; • community members.	Focus on conceptual knowledge and what is known rather than what is not known.
Attention to the development of students' understanding and use of the language of mathematics in English through: • a wide range of strategies (ESL in particular); • links with literacy strategies; • links with first language development.	Acknowledgement of the importance of language in mathematics & conceptual rather than procedural knowledge.
Use of new or different teaching materials and resources. Best practices included: • number sense approaches; • using maths within meaningful, real and realistic contexts; • hands-on, activity based experiences.	Opportunities to hear of, adapt trial & use best practice strategies within individual contexts.

Table 1: Summary of ISAN findings

enormously from school to school, and that not all factors were relevant in all schools. These two seem almost inevitable given the commitment to local autonomy within the project.

Some emergent over-arching issues have subsequently been identified. These may be considered as something of an overall analysis of the project among key personnel at the AAMT. The issues include:

- the important role of language;
- making connections with students' life (relevance and context dependent including employment opportunities and other life choices);
- care in relation to affective (emotional) issues;
- maximising 'redeemability' through programs which allow students to recommence their numeracy development if there are breaks in their education; and
- setting high and consistent expectations for student learning and maintaining positive beliefs that students can achieve.

The Northern Territory Numeracy in Schools Project (NISP)

Background

The NISP was established in order to improve numeracy outcomes for all NT students, largely by addressing and providing localised professional support for the needs of teachers and other school-based personnel.

From the beginning, in order to be involved in the NISP, schools had to present an extensive, well thought out application to the project Steering Committee. Many of the remote indigenous schools had been heavily accountable to the NT Department of Education through their bilingual education programs. Hence, these schools had well-developed 'action plans' and where numeracy had been targeted as an area of need within the school, these 'action plans' were easily converted into successful NISP proposals. Table 2 shows the large percentage of indigenous community schools successfully nominating for involvement in the NISP in each of the project years.

	1998		**1999**		**2000**	
	No of schools	**% of total**	**No of schools**	**% of total**	**No of schools**	**% of total**
Remote indigenous	7	87.5%	19	54 %	31	57 %
Urban mainstream	1	12.5%	16	46 %	23	43 %

Table 2: Remote indigenous and urban mainstream schools in NISP (1998–2000)

The NISP in action

Until the middle of 1999 there was only one project officer; after that another three were appointed such that there are now three officers based in Darwin and one in Alice Springs. The effectiveness of the project ensured that its messages were spread throughout all NT schools. This factor combined with the availability of extra project officers led to many more schools applying for involvement during 2000. At this stage at least another ten remote schools are on the waiting list.

The contextualised nature of numeracy as described in the AAMT definition highlights the need to develop numeracy appropriate to the contexts which students will experience within their lives. While this may not vary dramatically from school to school or town to town within most parts of Australia, the diversity of communities, life circumstances and hence numeracy needs of different groups is significant in the Northern Territory. Additionally, due to the localised need-based proposals, NISP 'looks', 'feels' and 'sounds' different in every school. In this way, NISP is structurally and conceptually very similar to ISAN.

Projects vary greatly and include development and implementation of what could be considered very 'mainstream' numeracy development programs. Other schools are developing programs for formal and informal bilingual settings – where both conceptual development in first language and ESL strategies are critical to maximising numeracy development for the students. One project also involves the development of a truly bicultural numeracy / mathematics program where a large amount of the material is based on indigenous knowledge systems.

Despite catering to such diverse school and student populations, there is a common element to all NISP school projects. This involves the development of:

- positive attitudes;
- use of appropriate contexts;
- understanding of the language associated with mathematics; and
- inclusion of 'best practice' strategies in numeracy and mathematics education such as use of open-ended, multi-level tasks and number sense strategies.

Links to the ISAN project are not limited to the locally-based and highly variable nature of each sub-project in the NISP. In fact, experiences in NISP are able to substantiate every emergent factor from ISAN as detailed in Table 1 above. In addition, all of the over-arching emergent issues are also able to be substantiated by the work in all indigenous community schools within NISP. Hence, although not part of the ISAN research, NISP schools provide extensive evidence of how the ISAN factors are generalisable across a substantial number of schools. This adds greatly to the power of the ISAN data and experiences, underlining the importance of the identified factors to successful indigenous numeracy programs.

An additional and emerging element within NISP is the need for numeracy development for many teachers, both indigenous and non-indigenous. Increasingly, as teachers are implementing different teaching strategies and relying less on a textbook and stencils approach, many are expressing an urgent need to further develop their own mathematical understandings and skills.

Although NISP is not a formal research project, the manner in which individual school proposals are submitted, implemented and evaluated, coupled with the capacity for large-scale substantiation of the 'emergent factors' of the ISAN project, ensures that the work of the NISP officers over the past three years has much to offer the field of 'numeracy development of indigenous students'. It is on this basis that the following recommendations are detailed.

Ways forward and recommendations

Both the NISP and ISAN projects have shown that ongoing work in the field of indigenous numeracy (in both research and practice) needs to be local and rigorous – but not hurried. Time has to be dedicated to numeracy development, and the professional development required to bring about the necessary changes in teaching practice that will ultimately result in enhanced student learning outcomes. To this end, investment in professional development for local indigenous staff and community members is recommended as these people are a 'constant' within the communities and have a wealth of local understanding that is invaluable when maximising student learning.

In addition, both projects show that assessment needs to be meaningful; revealing what students do know rather than what they don't. Such meaningful assessment better enables constructive learning programs to be planned. This is particularly evident in remote areas where students commence school with vast personal collections of conceptual understandings which are inextricably linked to their culture and first language. There is a need for the development of 'tools' to assess these understandings in first language and then base learning programs on an appropriate combination of first language, ESL and English-only experiences.

Conclusion

The work reported in this paper consists of the results of some practically oriented, small scale research and the subsequent validation and extension of these insights through a wider scale professional and curriculum development project. It represents a few signposts and general directions only, and these appear to have some currency.

That there appear to be no more major projects with clear research intentions in relation to indigenous numeracy development is a telling observation in itself. It is clear to those working in the field that there is great scope for significant and informative research in this area, yet the apparent lack of effort is striking. Research without clear articulation into practice is not what is needed, however, and the ISAN and NISP projects serve to illustrate that teachers, schools and communities can and should be integral to future research efforts.

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Strengthening Numeracy: Reducing Risk

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I start from the premise that all students have the right to leave school with high levels of numeracy, the conviction that all but a very small minority are capable of doing so and the faith that teachers and schools are committed to enabling this. And yet too many students continue to leave school ill equipped to exercise 'intelligent practical mathematical action in context' (Willis 1998a), numeracy remains socially distributed and too many of us are really not surprised by when many children, and certain children, do not succeed.

And so I applaud the focus on raising levels of numeracy and accountability for ensuring that all children become numerate. And of course this means, at the very least, that we identify children who are risk of not 'becoming numerate' and that we do something about it. This is, however, easier said than done.

Many people consider that we know what needs to be done and that we should provide the carrots and sticks, and the teacher education, to ensure that teachers do it – now. And, clearly, we do know quite a lot and, in any case, we cannot wait around until we have all the answers. Nevertheless, if we are to improve numeracy outcomes we have to be prepared to ask the 'hard questions ... regarding what needs to change' and 'to make the changes necessary' (Linda Darling Hammond 1993, p 760) even if, or especially when, they go against the grain.

Some of those hard questions relate to the very nature of numeracy (Willis 1998b), others to teacher practice (Willis 1998c). Here, however, I want to focus on what we mean by being 'at risk' and where the real risk lies. I will do so by drawing on just two examples of the most 'basic' levels of numeracy.

We know where the risk lies and it is out there

In everyday use, 'to count' has two meanings. It can mean to recite the number names in their right order beginning at 1 *(I can count to 10: one, two, three, four, ...).* It can also mean to check over a collection one by one in order to say how many are in it *(I counted and found there were 7 birds).* We have known for a long time that some children may recite the number names correctly up to 40 or 50 or even more and yet not be able to reliably count a collection of 8 or 9 things unassisted. Such children need to learn the counting process, that is, how to use the number names one-to-one to decide 'how many'. Other children may only remember the number names to ten or twelve but be able to use these numbers one-to-one to work out how many there are in a collection of 10 or 12 items. Such children do not need to learn *how* to count a collection, they need help to *remember* more of the number sequence in order to extend the repertoire to which they can apply their understanding of the counting process. We understand that neither is the right order and that good pedagogy will accommodate such differences. We also understand, however, that if you can only count to say 6 in the first sense, then logically you cannot count collections bigger than 6 or distinguish a collection of eight from a collection of seven or nine. You need the number names in order *and* one to one correspondence to reliably say how many are in a collection. Don't you?

It seems not! In a project commissioned by the Education Department of Western Australia to investigate children's learning in key areas of mathematics *(First Steps in Mathematics)*, we found that some Aboriginal children who would typically be regarded as 'non-counters' were, in fact, able to say how many were in particular collections. That is, children who could not 'count to six' could say that there were seven pencils or eight rocks. Others could tell at a glance when one or two items were removed from scattered collections of 8 or 9 – a skill that eludes many adults. When we investigated further, we found that these skills were also present amongst some non-Indigenous children who 'couldn't count'.

It was mainly luck that we noticed. Our test items were carefully structured so that we first found out how far children could count in the first sense, and then we gave them collections no bigger than that to see if they could use the sequence in one to one correspondence with the items to count how many there were. Because we are SNATs (sensitive new age teachers), because we care, we did not want to put the children in a failure situation and so we imposed a limit on the size of the collections we presented. But one day, one of the teachers working with us asked, in a tentative tone, whether it was *possible* that a child who could not count to four or five, even when assisted, could consistently tell you that there were seven lollies on the plate or eight birds in the sky. She had noticed some of her students doing just that. How could it be?

Some of our initial explanations were rather fanciful. Since then, we have found that in some Aboriginal communities social activities may help children recognise 'how many' are in a scattered collection just by looking. Subitizing (seeing how many 'at a glance') is the focus of informal playful activities. These activities are different from, but parallel, the counting oriented activities that many majority culture children experience.

Why were we so taken aback? Most of us are familiar with the process of subitizing (if not the word). Even quite young children seem to be able to distinguish two from three things, at a glance, without counting and many familiar rhymes and stories promote just this skill. Many of us also recognise 5 items or 9 items at a glance so long as they are presented in familiar arrangements such as on cards. We, and the children with whom we are most familiar, however, cannot tell 'at a glance' whether there are 7 or 8 in a scattered collection, and so we did not understand that others could and we did not know enough to ask.

What is the point of this story?

Implicit in much of the way we talk about children at educational risk is the view that 'risk', even 'educational risk', is something that children bring with them to school, that it lies out there, with the children's families and communities, or with their own personal characteristics. Witness the following principle from the Commonwealth's Literacy Policy for Schools.

> **All students will be given an equal opportunity to learn**
>
> If schooling fails to overcome educational disadvantage ... . The major factors which are usually seen as placing educational outcomes at risk include socioeconomic disadvantage, poverty, low parental expectation, disability, language background other than English, family or personal difficulties, geographic isolation, Indigenous background and gender. (p 6)

Membership of certain social groups is seen as the explanation of success and failure rather than the connection between the two being seen as the thing to be explained. Schools and teachers may need to do things differently and better in order to overcome disadvantage, but the 'factors ... placing educational outcomes at risk' come from without. The curriculum is innocent and schools and teachers are the solution to the 'problem' of differences between children.

At this stage our research is inconclusive. We do not know how widespread these subitizing skills are or even how easy or hard they will be to identify in classrooms. We have only tentative ideas about what changes in pedagogy are needed, what we might do differently, when children come to school subitizing rather than counting. We *are* sure, however, that differences between children in their learning of mathematics can neither be explained nor accommodated simply by variations in the pace at which they develop certain mathematical concepts. Rather, there may often be differences in the very nature and sequence of their development of mathematical ideas. We simply cannot assume that the same early indicators and sequencing are equally appropriate for all children.

Our 'subitizing' children may well be put at risk if curriculum practice assumes that learning should 'normally' proceed in the way and order it does for many non-Indigenous Australian children, since such practice is unlikely to recognise that the children can tell how many, define them as 'behind', and move them through learning experiences which do not build on their existing strategies and may actually undermine them. Their teachers, with the best will in the world, might feel that they have an uphill battle and not really be too surprised when such children 'at risk' have learned to fail in mathematics. The challenge this provides us with is to ensure that the familiar developmental sequences (and the associated benchmarks) of majority culture children do not dominate and thus become the mechanism by which certain children are *put* at educational risk. Certainly, when you are different there is a risk that you will not progress, but the risk factor may not be out there!

It's what you do that matters not why you did it

Annie in year 1, knows that 4 + 2 is 6 and 3 + 3 is also 6. So does her friend Sam. Is that good? Perhaps, we do not yet know enough to say. Annie and Sam might simply remember by rote and have no idea what either expression means. If this were the case I would consider them to be at risk of not progressing unless something was done about it.

As it turns out, Annie and Sam each knew what + meant and could use their fingers to work out that 4 + 2 equals 6 and that 3 + 3 equals 6. Annie went on to say:

> They both equal 6 because if you take one off the four and give it to the two, to make it three, then it is 3

add 3 or you could take one off the three and give it to the other three and make 4 + 2. That's why both have to be the same.

It became clear that Annie *knows* that if 4 + 2 is 6, then 3 + 3 *must* also be 6, she did not need to check. It is a logical necessity following from what numbers are and what addition means. These are not simply two unconnected 'empirical' facts. Annie has the kind of connected knowing, the *nous* required for intelligent mathematical action.

For Sam, however, these were simply two pieces of information, empirical facts, perhaps useful in their own right but little more than that – unconnected to each other or much of anything else. Sam needed to calculate to know that they were the same and even knowing that they were the same did not help him link them. He did not really understand why they were the same.

Are Annie and Sam to be judged 'the same'? I hope not. Not understanding is alright – for a while – but if we leave Sam simply knowing the two separate facts then we do him a disservice and place him at risk. And if you do not believe me, then think about this: What is 473 + 398?

Either 473 + 398 = 471 + 400 = 871 (Annie in Year 3?)

Or
```
   1 1
   473
 + 398
   871
```
(Sam in Year 3?)

What the Annies and Sams need to understand is the nature of the operation itself, so that it is indeed obvious that you can shift that 2 around. This is the basis of number sense. It is also, by the way, the very essence of algebraic thinking! It is what is needed to reduce the risk in learning. It is what Annie and Sam need for next week and the week after, next year and the year after. It is sustainable learning. It is the only kind worth spending their time on – anything less than understanding isn't worth the risk.

Unless *we* take the risk of distinguishing between Annie and Sam as early as Year 1, and certainly by year 3, we place Sam at risk. He may get by during the middle primary years by carefully lining up the digits and adding columns – slowly but surely. But I think we should be worried indeed for children like Sam and not only because they are more likely to get it wrong! If our strategies for diagnosing the risk of not progressing do not identify this as a problem, then they need rethinking.

Of course, it isn't as simple as that. Which is why it is one of the hard questions. Surely it wouldn't be fair to judge Annie and Sam in Year 1, or indeed in Year 3, differently. They can both get the right answers. They both have a reliable method.

But is it fair to have apparently succeeded and yet be unable to exercise 'intelligent mathematical action' (even if you do not know what you are missing!). And is it fair to believe in your present success and hence believe that you are well positioned for success in future and then find you've been misled. Who will bear the responsibility if Sam falls through the crack. Of course, the problem for Sam may not become obvious until he reaches algebra when we can reassure ourselves with the common sense understanding that many children 'go off' when the mathematics becomes abstract. 'Going off' is a familiar phenomenon in mathematics. The risk for Sam was not that he did not really understand in year 1, he's got time. It isn't even that he still did not understand in Year 3, although that is more worrying. The risk for Sam is when we do not think it matters, when we interpret Sam's capacity to get the expected answers in year 1 or year 3, as a sign that he is not at risk.

Conclusion

What we mean by being 'at risk' and where the real risk lies are two of the 'hard questions' we have to ask if we are going to be genuinely accountable for children's progress. Whether or not children are 'at risk' relates to whether their long term progress or mathematical growth is at risk, it is not simply a description of their current performance nor is it a description of the social grouping to which they belong.

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Number sense and mental computation: Implications for numeracy

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Introduction

Numeracy in Australia, though not universally, is taken to cover more than number. For example, the National Numeracy Benchmarks have three strands: Number Sense, Measurement and Data Sense, and Spatial Sense. However, numeracy is generally agreed to incorporate two elements: flexible understanding and usability. The results of our research, which in this paper are confined to number, wholeheartedly support the importance of these two elements.

Our separate and joint research projects have been directed towards very practical classroom results: we want to provide a research basis for approaches to numeracy in classrooms. In particular our separate and joint research has been directed towards providing a sound basis for moves away from the teaching of inflexible algorithms and towards approaches to number, and operations with number, based on the development of number sense. Far from seeing skills and understanding as separate and opposed, our research shows again and again the effectiveness of approaching each through the other. A unifying theme however is the necessity to build skills on conceptual understanding.

We describe here briefly each of our relevant projects, and draw conclusions relevant to numeracy in schools.

Past research

1. *Identifying and Developing the Mental Arithmetic Abilities of Primary School Children* (Edith Cowan University 1989–1993).

The project had two major goals: to discover, describe and analyse the mental arithmetic strategies of primary age students; and to devise and trial classroom practices which might lead to more awareness of these strategies among teachers and more proficiency and facility in flexible mental computation by students. Only that part of the project directed toward the first goal is described here. Material designed to achieve the second goal is described in McIntosh, De Nardi & Swan (1994), which also includes the full strategy classification system developed by the researchers.

Individual clinical interviews were conducted by a team of three researchers with 72 students of primary age (12 students at each grade level from Grade 2 to Grade 7) from three primary schools. Each student was interviewed three times, during which a total of 45 mental computation calculations involving whole numbers were given orally. The same 45 calculations were used for all children in all year levels. After each calculation the student was asked to describe how the calculation had been performed. All interviews were audiotaped, transcribed and analysed using a classification system devised and refined by the researchers during the study.

Four items were included as an indicator of the students' short term or working memory (STM). A three-, four-, five- and six-digit number was presented orally to the student, who was then asked to repeat the number backwards. The longest string correctly answered was taken as a measure of the student's STM.

Some conclusions:

- Short term memory does not appear to be a decisive factor in mental computation ability.
- Less competent students make more use, and for longer, of primitive strategies, in particular counting forward and back in ones.
- More competent students develop strategies based on place value.
- Very few children learned their mental computation strategies through deliberate classroom teaching: the only strategy that many children remembered being 'taught' related to the removal of zeros; this was also the strategy which was most frequently mis-used.

2. *Mental Computation Abilities of Children in Japan, the United States and Australia* (Edith Cowan University 1992–1994).

This study was designed to provide three different perspectives on the mental computation of comparable students at ages eight, 10, 12 and 14 in the three countries. It involved a measure of attitude towards mental and written computation, a survey of the kinds of computations which they preferred to do mentally, and an assessment of their performance on mental computation items (McIntosh, Nohda, Reys & Reys 1995; McIntosh, Bana & Farrell 1995).

Three different survey instruments were developed for the study: a Preference Survey (PS), an Attitude Survey (AS), and a Mental Computation Test (MCT). The MCT consisted of two parts: a set of items presented orally (items read individually by the administrator) and a set of items presented visually (items presented individually using an overhead projector).

Some conclusions:

- Mental computation can be tested at system level.
- Seeing the calculations usually, but not always, has a positive effect on performance.
- Early emphasis on 'basics' is not necessarily productive.
- Students think they do more written computation in schools, but do more mental computation out of school.
- Mental computation performance is often an indicator of number sense or lack of it.

3. *Number Sense of Children in the United States and Australia* (Edith Cowan University 1994–1996).

This project had two main aims: to investigate the possibility of assessing number sense by written tests, and to gain some information regarding the number sense of students at ages eight, 10, 12 and 14 (McIntosh, Bana & Farrell 1997).

Four group-tests of number sense were compiled, one for each of the four age levels (eight, 10, 12 and 14), and were administered to the same cohorts of students as were the Mental Computation Tests described earlier. Some questions were common to two or more age levels. The majority of the questions used a multiple choice format, but others asked for open answers, written explanations or marks to be placed on number lines or other displays. All items were scored either 'correct' or 'incorrect'. No time limit was placed on the test.

During the project, Swedish researchers from the University of Gothenburg used adapted versions of the test on similar cohorts of students. In addition, a doctoral student adapted some of the items to assess the number sense of Taiwanese students.

Some conclusions:

- Number sense (particularly of older students) can be assessed by written tests, but individual interviews are needed to reveal students' thinking.
- Conceptual understanding of decimals is generally weak, and conceptual understanding of fractions is very weak.
- Written questions testing number sense as opposed to skill acquisition or instrumental understanding are difficult to devise.

4. *Enhancing Numeracy Outcomes (ENOS) Project* (University of Tasmania 2000).

In this project, involving four primary schools in Tasmania and two primary schools in the ACT, teachers are developing a variety of individual classroom strategies for developing children's numeracy through an emphasis on mental computation and oral communication. This is still in progress.

At the beginning of the year all children in each class from Prep to Grade 6 sat a mental computation test. The conclusions are based on analysis of the results of these pre-tests.

Some conclusions:

- There appears to be a constant 20% of children at every grade level from Grade 3 to 6 who gave incorrect answers to the addition or subtraction of two single-digit numbers. This was the only case where performance did not improve from grade level to grade level.
- By far the most common error in addition and subtraction was an answer which was wrong by one or two. It is conjectured that these errors are overwhelmingly the result of counting on and back by ones.
- In multiplication and division, many answers were wrong by one multiple. It is conjectured that most of these were the result of skip-counting allied to inaccurate counting.

Current research

5. *Baseline Standards in Mental Computation: A Preliminary Study* (ARC Small Grant, University of Tasmania 2000).

All students from Grade 3 to Grade 10 in one district high school and one high school, together with their associated primary schools, will sit written mental computation tests. At each grade level there are three versions of the test, with items overlapping between the three tests and across grade levels. The aim is to provide more detailed information covering more items in order to provide a reliable picture of the general range of competency and the range of ability at each grade level and across grades. It is thought that this will provide the first picture of the range of mental calculations which students at these levels can process, and will provide a basis on which more appropriate decisions can be made as to the range of mental calculations which can be attempted at successive grade levels. All students are being tested during October 2000.

6. *Mental Computation, Number Sense and General Mathematics Ability – Are They Linked?* (University of Tasmania 2000).

This study (McIntosh & Dole 2000) was based on the perception that number sense is regarded as an important aspect of general mathematics knowledge, and that mental computation performance is frequently thought to link to number sense ability.

Separate pencil-and-paper tests of Mental Computation (MC), Number Sense (NS) and general mathematics (MA) were given to a total of 58 Year 3 and 60 Year 5 students in two Tasmanian primary schools. Analysis of test results suggested that the three tests were testing somewhat different things. From interview data, it was apparent that students with good mental strategies were not always the students that performed the highest on mental computation, but that often they had a good understanding or 'sense' of numbers and their relationships. In all cases, good conceptual understanding of particular mathematics topics was seen to contribute to high scores on the general mathematics test, and good conceptual knowledge assisted in accessing meaning for particular number sense and mental computation items (particularly fraction items).

Some conclusions:

- Students who score highly on mental computation tests and general mathematics tests may not be developing a 'sense' of numbers.
- Students who do not score highly on written tests of mental computation, number sense and general mathematics may still have quite good strategies for mental computation and a lot of 'sense' about numbers.
- Mental computation and number sense need to become integral components of curriculum and assessment procedures at class, school and system levels. If this does not happen, curriculum may be distorted by playing down the importance of number sense and mental computation, and students may be either advantaged or disadvantaged if there is failure to assess important aspects of mathematics.

7. *Numeracy and Number Sense Associated with Percent in Grades 8–10* (Queensland University of Technology, 1997–1999; University of Tasmania 2000).

Percent is one topic within the mathematics curriculum that is frequently used and applied in other subject areas as well as beyond the classroom and, as such, knowledge and understanding of percent can be regarded as an integral component of numeracy. However, research has indicated that percent calculations are difficult for students, and that little conceptual understanding is applied in such cases (Dole 1999). Alarmingly, research into students' percent performance has also indicated that as a consequence of formal instruction in percent, students' intuitive percent understandings and flexibility in thinking about percent gives way to mindless application of rules and procedures.

In the research study conducted by Dole et al. (1997), one class each of Grade 8, 9 and students 10 (90 in total) were given a pen-and-paper percent test containing items relating to percent use in the real world, percent conversions and percent word problems and calculations. From test results, six students (two each with high, middle and low test scores) from each grade level (18 students in total) were selected for an individual interview to probe their thinking strategies for test items.

Results of this research suggested similarities between the three categories of students selected for interview across the three grade levels. High performing students demonstrated strong number sense and flexibility of approach when performing percent calculations rather than rely on any percent formula. Middle performing students were seen to rely on a formula approach, although they were happy to use trial and error if they forgot the formula. They used flexible strategies, usually as a checking mechanism at the end of the solution rather than as an aid in solving the problem. They were able to realise when an answer did not make sense, but were unable to construct alternative strategies to correct their mistakes or overcome difficulties. Low performing students tended to try to solve problems by using the formula or key word approaches rather than examine the question as a whole; they looked for 'of' for multiplication and 'is' for division. They had little idea if an answer was sensible or if they had used the formula correctly. If they forgot the formula (their main strategy), they were unable to access another strategy and consequently were unable to solve the problem.

Some conclusions:

- Low performing students tended to focus on key words and to discontinue solution attempts if they could not determine an appropriate formula.
- Middle performing students showed more use of estimation and trial and error.
- Middle and low perfomers were inflexible and formula driven.
- Very few students in this study could be categorised as high performing.
- Although high performers did translate their knowledge into effective procedures, they did not translate their knowledge into efficient solution procedures (ie, their number sense enabled them to access the correct solution, but this was through trial and error rather than percent schema knowledge.
- Instruction in percent must focus on building upon number sense, but also increasing students' knowledge of the breadth and complexity of percent and its many uses and applications in the real world.

The focus of current research by Dole (in progress) is upon the development of mental computation of percent quantities (eg, find 25%, 10%, 1%, 33 1/3%, and so on) and conceptual knowledge of percent as a proportion, as well as the multiplicative and additive nature of percent change situations, through the use of visual representations. Dole is currently undertaking a teaching experiment with Grade 8 students in a Tasmanian school.

Future research

We have two projects planned to extend our research: we have a SPIRT application for 2001-2003 to provide a developmental sequence of mental computation competency incorporating both computational ability and strategy acquisition, together with a coherent approach to the development of flexible mental strategies linked to practical classroom assessment processes; and a strategic research and development project looking at the interface between the development of mental and written computation skills in Grades 2 to 4.

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Constructing scales for reporting growth in numeracy: the ACER Longitudinal Literacy and Numeracy Study

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Andrew Stephanou is a researcher at the Australian Council for Educational Research. He has taught physics for 17 years at secondary and tertiary levels. He has extensive experience in large scale testing programs (HSC/VCE Physics and literacy/numeracy statewide testing in Australia) and research in higher education (at the University of Melbourne). Currently his main interest is in educational assessment and psychometrics, more precisely using Rasch Measurement in the construction and description of educational variables. His work includes the construction of phenomenographic categories calibrated with Rasch Measurement on a single scale for the preparation of an instrument for measuring conceptual understanding in physics.

Marion Meiers came to ACER in 1998 with wide-ranging professional experience at all levels of education, particularly in the professional fields of literacy and the teaching of English. She has played leadership roles in the contexts of teaching, professional development, curriculum and assessment, and policy implementation. At ACER she is project director of the ACER Longitudinal Literacy and Numeracy Study. She also directed the DETYA-funded cross–sectoral project, the *Successful Interventions Literacy Research.* She has played a major role in coordinating the 1999 and 2000 ACER Research Conferences, *Improving Literacy Learning* (1999) and *Improving Numeracy Learning,* (2000). Prior to joining the ACER, she was consultant to the Literacy Section in DEETYA, Canberra, in 1997; and Executive Liaison Officer of the Australian Literacy Federation from 1993 - 1997.She was a member of the Expert Group for the development of the national literacy benchmarks. She has a particular interest in curriculum development and assessment of Year 12 English, and chaired the accreditation panel for the new VCE English Language Study. She has been State Reviewer for VCE English since 1992. She also teaches the third year B Ed program in Secondary English Method at RMIT University.

Margaret Forster is a Senior Research Fellow at ACER. Prior to joining ACER, while undertaking post graduate studies in special education, she worked as a special resource teacher. Since 1989 she has been a member of the humanities item writing team, working on a number of testing programs including the NSW Basic Skills Testing Program, the Queensland Core Skills Testing Program, the Victorian General Achievement Test and the Western Australian Monitoring Standards in Education Program. Ms Forster conceptualised and co-authored the first *Developmental Assessment Resource for Teachers – DART English* (upper primary), and supervised the development of the DART middle primary English and DART upper primary mathematics kits. She also supervised the development of materials for use in the 1996 National School English Literacy Survey (NSELS). Margaret is co-author of the NSELS report *Mapping Literacy Achievement* and of the *Assessment Resource Kit* (ARK) materials. From 1995 – March 2000 she led the Humanities (Primary) test development team. She directs the research area, Assessment and Reporting, within the ACER core program. At present on study leave in the USA, Margaret contributed to the initial work on this paper.

Assessing and reporting students' numeracy growth

The ACER Longitudinal Literacy and Numeracy Study is set within the conceptual framework of developmental assessment. The feature of developmental assessment which distinguishes it from other forms of assessment is:

> that the intention of developmental assessment is to obtain an estimate of a student's current location on a progress map as a guide to the kinds of learning experiences likely to be most useful at that stage in the student's learning and as a basis for monitoring growth over time (Masters & Forster 1997, pp. 1–2).

In a paper presented to the 1999 ACER Research Conference, *Improving Literacy Learning,* the early stages of work on the development of a literacy scale were described (Meiers & Forster 1999). The present paper will describe the work which has been done since then on the development of a numeracy scale, and will demonstrate how the progressive achievement of the LLANS cohort of students can be reported on that scale and subscales.

Central to developmental assessment is the use of progress maps, or continua describing increasing levels of achievement. These progress maps or continua provide frames of reference for monitoring the development of individuals or groups. At different points in time, estimates can be made of a student's location on the continuum, and changes in location provide measures of growth over time.

The LLANS will provide the empirical evidence for constructing a numeracy scale, that is:

> a scale based on a measure of each participating student's achievement. Each student's responses to LLANS tasks [will be] used to construct the scale so that the location of [numeracy] skills [will be] based on students' observed performances on the [numeracy] tasks. The method used to construct the scale allows achievement measures to be interpreted in terms of the skills typical of students at various levels of achievement (Meiers & Forster 1999).

Once the LLANS numeracy scales have been developed, it will then be possible to map the achievement of the whole cohort of participating students, subgroups, or individuals at several points in time.

The Longitudinal Literacy and Numeracy Study

The key research question to be investigated in the LLANS is: What is the nature of literacy and numeracy development amongst Australian school children? One way of responding to this question is to develop a set of scales describing growth in literacy and numeracy. As a national longitudinal study, the LLANS creates an opportunity to develop achievement scales which will describe growth from the first year of schooling through to the stage when students make the transition to secondary school.

A national sample of students was selected from an Australia-wide sample of 100 schools. Ten students were randomly selected from class lists provided at the beginning of the 1999 school year by the 100 schools in the project, creating a total initial sample of 1000 students. As far as possible, students who have changed schools have been retained in the study. Where students have moved to other schools, their continuation in the study has been negotiated with the principal of the new school. Around 900 students from some 140 schools are now participating in the study.

Comprehensive data on the literacy and numeracy growth of the students is being collected each year from two sources: common tasks developed at ACER and work samples selected from the students' normal classroom work. A range of background data on the school, teachers and student variables is also collected annually from a set of questionnaires. This will enable analyses to be made in relation to various subgroups including gender, ESL learners, language background other than English, time spent reading, watching television and using computers at home, and so on.

An important aspect of the methodology is the role of teachers as partners in the study. In these first years of the study, the students' own teachers have worked in a one-to-one interview-like context to administer and record students' oral responses to the common tasks. The item writers faced the challenge of designing tasks to be administered easily by teachers working one-to-one with students. Each set of instructions was carefully worded to make the requirements absolutely clear to both teacher and student, thus ensuring the reliability of the assessments. In designing the common tasks it was also essential to take account of time, acknowledging the practicalities of managing one-to-one assessments in the classroom. Therefore, the focus was on essential aspects of emerging literacy and numeracy.

The LLANS numeracy assessment tasks

Three sets of common tasks have now been completed by students at three key stages of schooling: in the first and final terms of the first year at school (1999) and in the first term of their second year of school (2000). A fourth set of common tasks will be administered in the last term of the 2000 school year.

Four broad aspects of numeracy have been investigated in each of the sets of common tasks:

- number
- space
- measurement
- chance and data

The tasks designed for the first two years of primary school have required students to answer questions orally, while teachers assess and record their responses. Wherever possible, hands-on aids such as rods, counters, shapes, coloured stars, pipe cleaners and match sticks have been provided to support students in responding to the tasks.

The item writers have designed tasks of various difficulties in each of the four broad aspects. For example, in the space strand, the tasks included:

Start of school (Term 1, 1999)

- placing an object upside down, on top of, in front of, behind, under etc;
- identifying shared and different attributes of shapes;
- identifying shapes with same colour and different attributes; and
- naming a geometric figure (square, circle, triangle).

End of first year at school (Term 4, 1999)

- dentifying the first, third and last object in a line;
- naming the fourth position and placing an object between the second and third position;
- counting objects; and
- naming a rectangle.

Start of second year at school (Term 1, 2000)

- reading a simple map to locate adjacent animals and counting animals on the map;
- using arrows to determine direction of a path;
- identifying the first stopping point on a path and identifying animals missed by path;
- using tiles to copy map onto a grid;
- making a square (using match sticks) then making a larger square;
- making a triangle then making a larger triangle; and
- indicating where to cut shapes in half (kite, fish shapes).

The marking guide (categorisation of children's responses) is included with the tasks, and the teacher judges the child's responses against the marking guide. Precise instructions have been provided for teachers to follow so that the tasks are, as far as possible, administered under standard conditions.

Counting (end of first year at school)

Equipment	Instructions and questions	Marking guide	Record
18 counters	Tip out all counters in front of child. Count these and tell me how many there are.	Eighteen Seventeen or nineteen Any other number No attempt	

Pet Shop (start of second year at school)

Equipment	Instructions and questions	Marking guide	Record
Pet shop map and yellow tiles	Tip the tiles out of the bag near the child. One of these tiles fits exactly on a small cage, put a tile on the dog cage. How many tiles do you need to fit exactly on the snake's cage? Don't do it yet. What do you think? *Tell the child to use the tiles if they don't know or guess incorrectly.*	Two, answered without putting tiles on grid. Two, answered after putting tiles on grid. Other No attempt	

The marking guide is coded for data entry, and the entered data is then analysed.

Constructing the LLANS scales: the process

Rasch measurement allows us to display the performance of children and the difficulty of tasks on the same interval scale, in the same units of measurement. High on the scale we see the best performances and the most difficult tasks. Low on the scale we find the poor performances and the easiest tasks.

The three LLANS surveys completed so far contain common items that allow the calibration of all tasks used so far to be displayed on the same scale. The difficulty of a task for which responses have been marked either correct or incorrect is represented by the position of its threshold on the scale. Children above the threshold are more likely to be correct and children below are more likely to be incorrect. A similar explanation is given for tasks rated in more than two categories.

The calibration of the tasks on the scale is followed by an analysis of fit to check the extent to which these tasks target the same latent trait. Misfits in Rasch measurement are a source of information on the performance of children. All misfits are considered and explanations sought. In examining the result of the analysis of fit, some collapsing of the categories in which children's responses had been assigned becomes necessary either because there is insufficient data available for a sufficiently accurate calibration, or because adjacent categories are not clearly and meaningfully discerned. For example, two categories may be too close along the continuum and the location of their thresholds overlap considering the error of measurement.

In figure 2, four of the LLANS early numeracy scale items are used to illustrate our methodology for describing the variable constructed with the tasks from the first three surveys. The relative positions of the thresholds on the interval scale are those calibrated with the data. Item 2PPC is more difficult than item 1PT3, as indicated by their threshold values. Children's responses for item 3RP2, and also item 1OU, have been classified into three categories, therefore their difficulty is shown by two thresholds. The calibration takes into account the different abilities of the children to whom the items have been administered. If, for example, an item has been answered correctly by 60% of the children at Survey 1 and another item by 60% of the children at Survey 3, then the second item must be more difficult because the same percentage of better performing children can answer it correctly. The relative difficulty of the items applies to children anywhere on the scale.

It can be seen that children find more difficulty in recognising that there are three more fish than butterflies in a set of six fish and three butterflies (2PPC) than in creating their own pattern after having been shown an example of a repetitive pattern (1PT3).

The description of the measured variable is a lengthy process in which common features in the categories of items belonging to the same part of the scale are identified. Regions of the scale, partly overlapping, with qualitatively different and meaningful description are formed. The description of these regions constitutes the description of the measured variable. The process would be similar to a verbal description of the temperature scale. The region around 0ºC would be described differently from the region around 15ºC degrees, etc.

Reporting growth on the LLANS numeracy scales

The construction and description of suitable variables for showing the variation in the skills children develop during their early years at school makes it possible to show the rate at which children develop various skills.

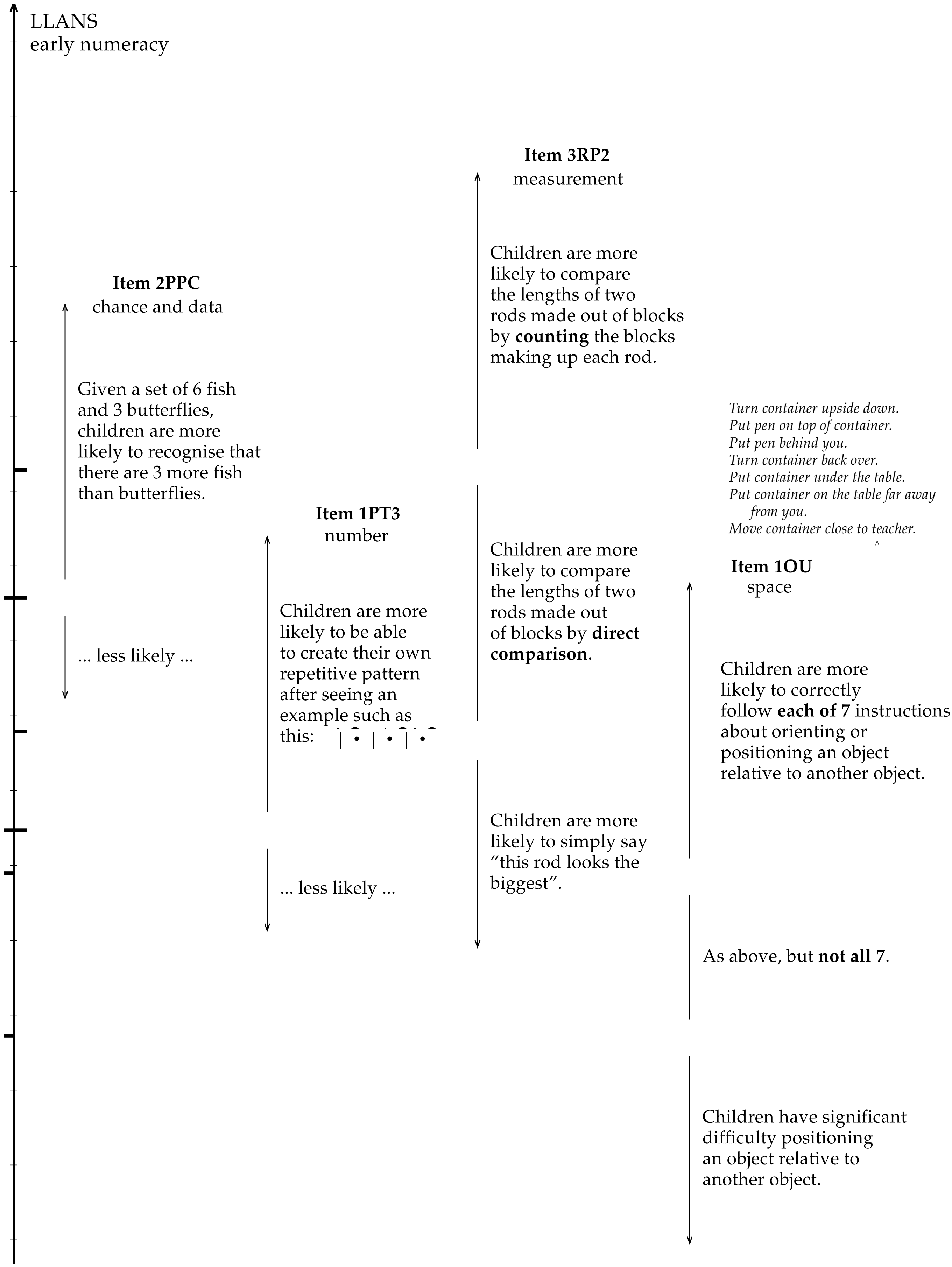

Figure 1. The LLANS early numeracy scale and four of the tasks used to describe it. The two items on the left are dichotomous and the two on the right are polytomous (three categories).

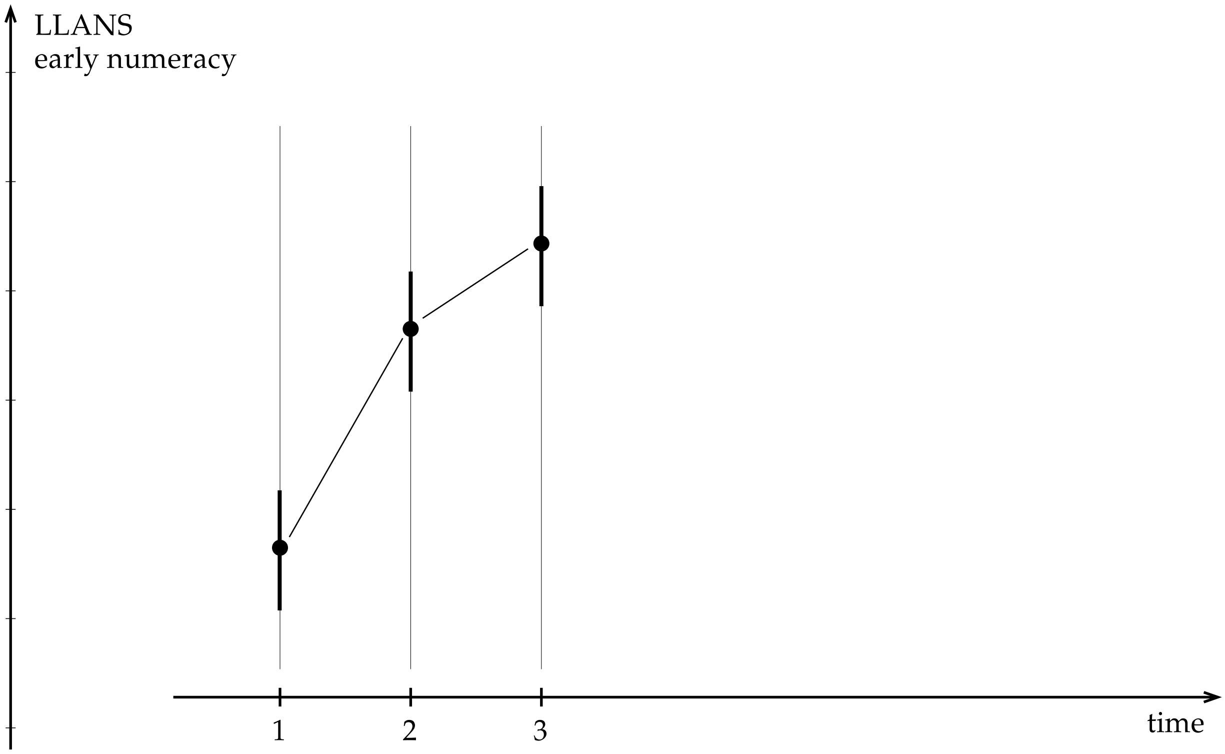

Figure 2. The LLANS Early Numeracy scale and an example of a growth path

Figure 2 shows how rate of growth over time can be reported at the individual child level and for selected groups of children. It can be shown how rate of growth depends on prior achievement through real examples.

Multilevel modelling of the measures of children's performance on the LLANS scales will allow the identification of factors affecting growth.

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Computational numeracy

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Joy Cumming is Associate Professor in the Faculty of Education and Head of School, Cognition, Language and Special Education at Griffith University. Her research interests include literacy and numeracy curriculum, cognitive processing and assessment of student achievement. Her PhD research was on computational fluency and she has undertaken a number of research studies on child and adult numeracy. She was invited to write a chapter on the Quantitative Literacy outcomes for the 1996 Australian Bureau of Statistics Survey of Aspects of Literacy. Recent major studies include a two-year national DETYA funded study titled The *literacy demands of the curriculum in post-compulsory schooling,* with a book from the study to be published by the Australian Council for Educational Research in 2000. She is a nominee of the Institutes of Educational Research on ACER Council and the Board of Directors.

Introduction

As Hiebert (1999) has noted in a discussion of the relationships between research and the National Council of Teachers of Mathematics standards for American students, 'researchers are called upon to resolve issues that really are about values and priorities, and, on the other hand, research is ignored when empirical evidence is essential'. While research cannot set the standards or make the decisions for policy-makers, a considerable body of valuable information is available to assist.

A critical issue in knowing what the research can tell us for improving numeracy learning is to know what questions to ask the research. Even more critically, I would like to suggest, is to draw on research from a range of perspectives to inform decision-making in teaching and learning, and to have a good sense of the complementarity of different research outcomes. Too often in education, we read too narrowly.

This session will draw together research from a range of theoretical perspectives – research in street mathematics and the social cultural mathematical development of the workplace, research in memory formation and instruction, and research from just one specific workplace – to try to frame both a rationale for the significance of, and effective instructional approaches in, the development of computational fluency.

This paper provides an overview of the research that will be considered and the nature of the discussion. The ideas will be elaborated on in the conference session; the references are provided here as a permanent resource for participants.

The topics to be addressed in the session encompass research and writings on:

- numeracy, mathematics education and changing directions;
- the significance of sufficient numeracy for personal life and employability;
- the importance of number or computational fluency as an aspect of numeracy both culturally and in mathematics curriculum;
- the importance of computational fluency as shown by workplace research;
- the importance of computational fluency in one specific work area: health care;
- the importance of computational fluency in further mathematics achievement, possible gender differences in mathematics achievement, and the new technological society;
- current performance data on computational fluency for Australian school children and adults and some overseas data; and
- how to teach to improve computational fluency.

Numeracy, mathematics education and changing directions

This section will draw on recent Australian policy documents (DETYA 2000) to discuss briefly definitions of numeracy, such as from the report of the Numeracy Education Strategy Development Conference (AAMT 1997).

> *This project identifies the following elements as central to any description of numeracy:*
>
> … *numeracy involves*
>
> … *using*
>
> … *some mathematics*
>
> … *to achieve some purpose*
>
> … *in a particular context.*

and their relationships to mathematics education. New goals for mathematics education such as 'mathematical power' (NCTM 1995), contrasted with ancient Chinese goals such as 'pragmatics' (Wang, cited in Leung 1998). Extensions of numeracy to include critical numeracy (Johnston 1994), following work in literacy (Freebody & Luke 1990), will be discussed.

The significance of sufficient numeracy for personal life and employability

Research evidence is growing on the links between numeracy performance and life and work opportunities. The research to be considered includes quantitative literacy data from the *Survey of Aspects of Literacy* (ABS 1997) and studies of school achievement and outcomes in Australia and overseas (Lamb 1997; Marks & Ainley 1997). In general, the types of assessments of numeracy undertaken in these studies focus on computational and arithmetic skills with some text and indicate the importance of these aspects of mathematics achievement for individuals.

The importance of number or computational fluency as an aspect of numeracy both culturally and in mathematics curriculum

This section will explore commonalities in policy guidelines for standard aspects of mathematics curriculum such as:

- the *National Statement on Mathematics for Australian Schools* (AAMT 1996) with a focus on content in areas of mathematics (Number, Space and so on) and separation of representation of mathematical ideas and applying mathematics and solving problems;
- the draft numeracy standards in Australia
- Year 3: 'remember, or work out, basic addition facts to 10 + 10, the matching subtraction facts'. Year 5: 'work out the answers to addition and subtraction problems that involve three-digit whole numbers' (Curriculum Corporation 1999); and
- ethnomathematical research such as that by Alan Bishop on essential elements of mathematics in action across societies.

The discussion will show that social and mathematical grounds indicate that computational fluency should be a fundamental mathematics goal. Mathematics education changed dramatically during the 20th century from a focus on rote acquisition of arithmetic and geometric facts and algorithms, to an emphasis on meaning-making, conceptual understanding, and problem-solving, with the expectation many menial tasks can be undertaken using calculators and computers. The question to be addressed in the remainder of the session is the effect of this change on focus on student learning in important areas.

The importance of computational fluency as shown by workplace research

Research has shown that performance on decontextualised tasks can be a poor relative to performance on contextualised activities. For example, most mathematics educators would be familiar today with the various research studies on the street children of South America. This section will explore the research (Harris 1991; Lave, Murtagh & de la Rocha 1984; Scribner 1968, 1975, 1985a, 1985b; Watson, Hall, Breen & Jeganathan 1990; Zevenbergen 1997), usually using a sociocultural framework for exploring mathematics and numeracy, and look at its impact on school mathematics education.

Issues of assessment format and transfer (Jenkins & Kirsch 1994; Nunes, Schliemann & Carraher 1993) and the nature of mathematics that emerge from studies of occupations (Jenkins & Kirsch 1994; Phelps & Hanley-Maxwell 1997; Strasser, Barr, Evans & Wolf 1991), including the new technological jobs (Chong 1995; Wong 1992), will be discussed. Again, the discussion will show that computational fluency is and will continue to be an important goal for student learning.

Computational fluency in one specific work area: health care

Many educators react to discussions of computational fluency with responses that strategic knowledge is most important and, with the assistance of calculators, computational fluency can be achieved by a variety of means. However, in many aspects of our lives individuals are disadvantaged if they do not have computational fluency. This is most easily established as significant by looking at one vocational area and the critical importance of basic numeracy skills to members of the health care professions. This section of the session will consider some of the research on mathematical skill levels of health care workers including nurses, physicians, faculty and medical students, an area acknowledged as a problem for many years (ABS 1997; Blais & Bath 1992; Jeffries 1983; Miller 1992, 1993; Perlstein et al. 1979; Santamaria, Norris, Clayton & Scott 1997; Stillman, Alison, Croker, Tonkin & White 1998; Wolf 1994).

The importance of computational fluency in further mathematics achievement, possible gender differences in mathematics achievement and the new technological society

Many theories of learning and theories of expertise emphasise the need for strong and efficiently-accessed domains of chunked knowledge that can be recalled and applied with facility (Sternberg 1999; Sweller, van Merrienboer & Paas 1998): what Bereiter and Scardamalia (1989) refer to as 'already-learned scripts'. Computational fluency can be shown to be an important part of expertise not just for social and work skills, but for further advancement in the study of mathematics and general school achievement.

Research has shown that children with learning disabilities, educational disadvantage or poor learning performance, although developing the conceptual knowledge equivalent to that of ‘normal’ students, do not develop computational fluency and rely on strategies such as counting even for basic addition with poor outcomes (Baroody et al. 1982; Finnane 1997; Geary & Brown 1991). Cumming and Elkins (1994, 1996, 1999) found that many ‘normal’ students in middle primary school had poor addition fact fluency. Lack of fluency in the basic facts is related to failure on more demanding mathematics tasks (Cumming & Elkins 1994, 1996, 1999; Geary & Widamin 1992). Geary (1999) stated that the research evidence indicates that children should learn basic computational and procedural skills in arithmetic and other areas of mathematics to the point of automaticity

This section will discuss research from these perspectives and, most significantly, recent analyses (Royer et al. 1999) showing links between computational fluency and school mathematics achievement in a range of domains. It will also discuss research analyses, because of gender differences in solution speed, of large gender differences in favour of males on standardised achievement tests such as the American SAT, despite female students having equivalent or higher mathematical grades, Computational fluency in the contexts of timed tests may play a greater role in university selection in the USA than some areas of more global academic achievement.

The future world appears to make the same demands, even with technological tools to assist in our work and mathematics. Research on demand and possible implications for computational fluency in the techno society (Beishuizen, Stoutjesdijk & Zanting 1996; Sweller & Chandler 1994; Tuovinen & Sweller 1999) will also be discussed in this section.

Current performance data on computational fluency for Australian school children and adults and some overseas data

The discussion to date will have demonstrated that computational fluency is an important goal for mathematics education, when looked at from a range of perspectives and in a range of contexts. Mathematics educators would endorse this in general. The question remains as to how well the goal is being achieved in school education today. As Stacey (1997) noted, the results from the TIMSS indicate that Australian education has ‘certainly succeeded in not emphasising arithmetic computation...in computation, the percentages of students correct are near or below the international average’.

This section will explore some of the available data on computational fluency for school children and adults in Australia (ABS 1997; Chew-Ng 1999; Cumming 1997; Lokan 1997; Lokan, Ford & Greenwood 1997; Menne 2000).

Generally, the data indicates that computational fluency has not been achieved by a significant number of Australians of various ages. National data from the USA shows similar patterns for performance. ‘Computation’ subscores in Iowa have declined to the levels of those for ‘Concepts & Estimation’ and ‘Problems and Data Interpretation’ of twenty years ago, which have improved over the same period due to the changes in curriculum. However, the computation performance is now at the level that created the perceived need to change the curriculum to improve the other areas. Menne’s data (2000) indicates similar concerns in Europe.

How to teach to improve computational fluency

The previous discussions have examined the significance of computational fluency for numeracy, as mathematics applied in life contexts, and school mathematics as a foundation also for further studies. If computational fluency is important, how best is it taught? This section will conclude the session by discussing empirical research on ways to enhance computational fluency. As Ashcraft (1995) and Biggs and Watkins (1996) have noted, the same approach in teaching may not develop all desirable outcomes. As educators we must be prepared to vary our approaches to meet different goals for student learning.

This section will discuss empirical research studies that explore effective instruction and interventions, including children and adolescents with learning difficulties in mathematics (Cumming & Elkins 1999; Felgate, Minnis & Schagen 2000; Fennema & Carpenter 1998; Johnson & Layng 1992; Menne 2000; Royer & Tronsky 1998).

Conclusion

Mathematics education has a considerable body of empirical research on which it can draw. Agendas in mathematics education can be affected by policy, resources and other concerns. It is important, however that we keep the goals for students firmly at the forefront. Often, when we implement new curriculum and strategies we do so in the belief that particular outcomes will eventuate. However, Fennema and Carpenter's study (1998) seeking to remove gender differences in problem solving was based on

> ...an underlying assumption that our program based on understanding will enable all students to learn in an equitable fashion. This assumption may not be valid (Fennema & Carpenter 1998, p. 20).

Educators should not be afraid to look to research from various perspectives to ensure the most informed, encompassing and equitable numeracy outcomes for students do eventuate.

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2. Australian numeracy research projects, 2000

This section provides information about the range of numeracy research projects currently being undertaken under the auspices of the States and Territories, and the Commonwealth.

Australian Numeracy Research Projects 2000
States and territories

Some projects identified in the sections below have been funded by the following Commonwealth initiatives: *Primary School Teacher Professional Development in Support of the National Literacy and Numeracy Plan,* and *Secondary School Literacy and Numeracy Initiatives.*

Australian Capital Territory

Middle Years Numeracy (MYN) project

This pilot project will run through semester two/2000 and focus on the mathematical demands of all learning areas for students in the middle years. The National Schools Network (NSN) and ACT Department of Education and Community Services are working with teachers from two high schools and their feeder primary schools during the pilot stage, using a Research Circle methodology. The NSN is using the ideas first developed in an ARC Collaborative Research Project between the Education Department of WA and Murdoch University, called the *Numeracy Across the Curriculum* project. It is currently conducting a similar Research Circle with a number of NSW primary and high schools. Networking across jurisdictions is expected to enhance the outcomes for all participants.

The MYN Research Circle will explore how teachers in their own school contexts and individual key learning areas can best support students in successfully negotiating the mathematical demands of their work at school. A major outcome of the project will be a framework for addressing and supporting student numeracy development within the context of a school's existing activity.

Chief researcher: John Hogan (john.hogan@bigpond.com).

Enhancing Numeracy Outcomes (ENOS) project

In 2000, two ACT primary schools are participating in the ENOS project. This is a collaborative numeracy research and professional development project with several Tasmanian schools and the University of Tasmania. The focus of the project is the development of mental computation strategies, and the importance and impact of communication in the teaching and learning of mathematics. It is planned that this project will act as a platform for a further project across K–10 that will produce a developmental continuum for mental computation. Application for funding for this further project has been made through the Strategic Partnerships with Industry – Research and Training (SPIRT) program.

Chief researcher: Alistair McIntosh (alistair.mcIntosh@utas.edu.au).

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New South Wales

Counting On: Can students be assisted in moving from unitary-based arithmetical strategies to collection-based strategies?

The transition to secondary school sometimes results in students' numeracy needs falling outside of the scope of secondary syllabus documents and the knowledge of secondary teachers. This can lead to increasing learning deficits for these students as additional teaching does not build on students' knowledge.

Counting On is investigating the efficiency of solution methods used by students who have not achieved stage 3 mathematics outcomes on entry to secondary school and the consequences of strategy preference. The current focus of the research is low-achieving Year 7 students on entry to high school. Over 2001–2002 the focus of the research will broaden to pick up students in the transition between primary school and secondary school.

Chief researchers: Bob Perry (b.perry@uws.edu.au) and Peter Howard (p.howard@mary.acu.edu.au).

Count Me Into Measurement

Count Me Into Measurement examines the development of early measurement concepts from Kindergarten to Year 3. The project is a component of the New South Wales Department of Education and Training *Count Me In Too* program.

Teachers are trialling a research-based Learning Framework in Measurement through implementing suggested lesson activities in length, area, volume and mass. The framework emphasises the identification and use of the structure of repeated units of measurement, and links to multiplication arrays. The level descriptors in the framework detail the strategies and knowledge which students may be expected to demonstrate at that level. In the current trial, teachers are using the listed strategies to monitor and report student learning.

The trial is also focusing on teacher professional development. Teacher-facilitators in 39 schools coordinate lessons and materials, team teach and organise planning meetings. The evaluation of the project will examine the success of the facilitator model, and the effectiveness of the Learning Framework in Measurement in assisting teachers to plan and teach measurement lessons and to assess student knowledge. Teachers and facilitators will provide feedback on the framework, the teaching sequence, student knowledge, and their own learning about teaching measurement.

The collated student learning data will assist in reviewing both the framework levels and investigating the knowledge across the four strands (Length, Area, Volume and Mass). Evaluation of the trial will be completed in March 2001, and will be followed by a more extensive implementation in 2001.

Chief researchers: Lynne Outhred (lynne.outhred@mq.edu.au) and Diane McPhail (diane.mcphail@det.nsw.edu.au).

Count Me Into Space

The NSW Department of Education and Training has taken up the challenge of developing education in Space mathematics. In conjunction with researchers, it has developed a research-based framework for Space mathematics. The framework consists of a theoretical statement, individually-administered assessment tasks and suggested lessons. The focus areas are Part-Whole Relationships and Orientation and Motion. The work has incorporated the extensive work on visual imagery and spatial thinking into the framework and appropriate learning experiences in classrooms. The framework has resulted from the close interaction of researchers with mathematics consultants and teachers.

The current project involves 29 Kindergarten, Year 1 and Year 2 teachers in five schools, with eight students being assessed in each class over two years, 2000–2001. The project is being evaluated by a formal comparison of students participating in the project with those from comparative non-participating schools. There are five control schools with eight students in each of Kindergarten, Year 1 and Year 2 being assessed and reassessed after 10 weeks. The assessed students in each class are selected by the teacher to represent four in the middle of the class, two in the top group and two in the bottom group without the best or worst student being included.

The impact of the assessment and teaching on students' learning and teachers' knowledge and confidence is being qualitatively evaluated. Data has been collected from pre-involvement focus groups with teachers, lesson observations, records of comments in teachers' meetings, consultants' feedback meetings, and a post-involvement focus group with teachers. This data has also been used to improve the tasks and lessons and to guide materials to be used in future learning team development.

Chief researcher: Kay Owens (k.owens@uws.edu.au).

The Secondary Numeracy Assessment Program (SNAP)

SNAP commenced in April 1999 and is scheduled to be completed in July 2001. It is relevant to the middle years of schooling. There are a number of research projects being conducted within this program:

Scoring extended response tasks

Purpose: To investigate the development and scoring of extended response tasks.

In Phase 1 the research used a single embedded case study examining how extended response tasks could be scored. The Rasch model was used to inform decisions about the appropriateness of tasks and criteria during the first phase. The data from this case study indicated that the process up to the first trialling phase was useful in selecting and refining the tasks. The research also revealed a difference between the teacher perceived difficulty of these tasks and the actual difficulty of the tasks. There were indications that teachers may actively assist students when doing numeracy in the classroom. In assessment situations students are expected to work without this assistance. This has possible implications for classroom based assessments of what students are able to do.

Phase 2 is the marking of the tasks using these scoring rubrics. Research is being conducted on the reliability of the marking procedures and the appropriateness of the procedures.

Phase 3 is the reporting of the students' results to schools and parents. The reports to schools include a table indicating the scores for each student on each criterion. Both qualitative and quantitative research methodologies will be used to investigate the use and implications of the report data for the extended response tasks.

Differences in student achievement

Purpose: To investigate the item design characteristics of items with differential performance.

For the SNAP, items are trialled and analysed for appropriateness. The items used within trialling in 2000 are being examined for student achievement differences. Correlation analysis is being undertaken for non-English background students, Aboriginal and Torres Strait Islander students, and students from Disadvantaged Schools Program schools. The item design characteristics are being identified for the items where differences in achievement occur. The intention is to identify those characteristics that are common for different demographic groups. This information has the potential to be used to redesign tasks and to inform teaching strategies that could enhance student achievement.

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Queensland

Supporting Literacy and Numeracy in Queensland Schools

Supporting Literacy and Numeracy in Queensland Schools was a Commonwealth-funded, intersystemic project conducted during 1998 and 1999. The project was a joint initiative of Education Queensland, the Queensland Catholic Education Commission and the Association of Independent Schools of Queensland Inc. While the initiative was coordinated by Education Queensland, developmental processes involved State, Catholic and Independent schools. The project aimed to support implementation of the National Literacy and Numeracy Plan in Queensland schools.

The National Literacy and Numeracy Plan represents a focused national effort intended to build on existing State and Territory initiatives. In response, the *Supporting Literacy and Numeracy in Queensland Schools* initiative saw the development of materials for Queensland schools which augment Queensland's existing Year 2 Diagnostic Net materials developed for Reading, Writing and Number and complementary early intervention materials, including *Support a Reader and Support a Writer.*

In addition to the multimedia CD-ROM *Spelling: Improving Learning Outcomes, numeracy resources produced through this project include Space, Measurement, Chance and Data: Improving Learning Outcomes.* This professional-development resource summarises current research and literature and models effective teaching practice in these strands of the mathematics curriculum. In particular, it outlines current information on common learning and teaching sequences in these strands. It provides practical advice, structures and proformas to support planning, implementing, monitoring and reporting on effective learning programs. Despite the particular relevance for the early and middle years of primary schooling, teachers in other sectors of schooling may find this resource useful in devising appropriate learning programs for individuals and groups of students. The resource package comprises an interactive multimedia CD-ROM and a companion Web site that will continue to provide relevant and updated information. The CD-ROM supports teacher and administrator users and includes parent and facilitator workshops. It is anticipated that this resource will be finalised in term four, 2000.

Support a Maths Learner: Number

This early intervention resource comprises training workshops for use by program coordinators and learning-teaching materials for use by trained teacher aides, parents and volunteers when working with children experiencing difficulties in aspects of early Number – counting, patterning and number representations. The resource complements the Year 2 Diagnostic Net texts, *Number Developmental Continuum and Intervention Guidelines: Number.*

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South Australia

Junior Secondary Numeracy Project (JSNP)

The JSNP is the South Australian Department of Education Training and Employment's component of the Commonwealth's Secondary Literacy and Numeracy Initiatives. The JSNP is investigating and developing strategies to enhance the development of numeracy for low achieving students in Years 8 and 9.

The project began in 1999 with 11 schools from diverse locations around SA. The schools included large metropolitan high schools, a large regional country high school, area schools, a school of distance education and schools for Anangu students in the remote north-western corner of SA. During 1999 two project teachers from each school used classroom based action research to investigate student numeracy and strategies to enhance the numeracy of low achieving students.

In 2000, project teachers have established numeracy teams to focus on the broader issue of a whole school approach to numeracy across the curriculum. Project teachers recognise that for some students low numeracy levels are an impediment to their achievement across several learning areas. Each school is raising teacher awareness and understanding of numeracy, investigating the mathematical understandings inherent in each learning area and trialling strategies to develop student numeracy across the curriculum. Some schools are investigating the use of appropriate tools to measure student numeracy in order to identify low achieving students and to measure growth over time.

The project manager position finishes at the end of July 2000 however numeracy remains a priority in all project schools and the plans and processes in place will ensure a continuing focus on numeracy education.

Further information is available on the project Web site: http://www.nexus.edu.au/TeachStud/jsnumeracy/

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Tasmania

Thinking and Working Mathematically

Thinking and Working Mathematically is a collaborative project between Prospect High School and its five associated primary schools – Summerdale, Hagley, Bracknell, West Launceston and Westbury. This project is designed to explore ways of developing a culture where thinking and working mathematically is valued by teachers, students and parents. The project is facilitated by Associate Professor Alistair McIntosh of the Faculty of Education at the University of Tasmania in Launceston. Implementation is supported by two part-time resource teachers funded by the project and a series of key teachers appointed from each school. This team of people met regularly to share ideas and strategies. The project directly impacts on 120 teachers from K–10 and opportunities for them to meet as a large group is integral to its success.

The foundation for a common understanding of what constitutes working and thinking mathematically is a set of key principles. These principles include encouraging students 'talking maths', relating mathematical ideas to real life, and approaching maths in an investigative and problem solving manner. Teachers are encouraged to employ mathematical learning practices which are developmentally appropriate and include balancing pen and paper with other strategies giving children time to think and value talk as well as writing.

The collections of work samples illustrating how children think and work mathematically is an important feature of the project. These work samples are also supported by evidence of student 'talk', including discussing, reasoning, explaining, justifying, hypothesising and explanations of solution strategies for both correct and incorrect answers. An important research aspect of the project is to find evidence of this talk changing over time. As teachers aim to approach the content of the curriculum in a more investigative and problem solving manner, the project is also investigating whether there is any significant change in the students' attitudes and feelings towards mathematics. Evidence is being collated through student reflection sheets at different stages of the project.

While the project is in its infancy our aim is to support each other in order to make a real difference to our students' ability to be mathematical thinkers.

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Victoria

The Early Numeracy Research Project (ENRP)

The ENRP is a three year project (commencing in January 1999 and to be completed in December 2001) focusing on the mathematical development of students in Prep to Year 2 in Victoria. Thirty-five trial schools are involved in the project – 27 government primary schools, one specialist school, four Catholic schools, three independent schools and 35 matched reference schools. The ENRP, with Director Associate Professor Dr Doug Clarke, is a collaboration between the Australian Catholic University (ACU), Monash University, the Victorian Department of Employment, Education and Training (DEET), the Catholic Education Office, Melbourne Diocese and the Association of Independent Schools Victoria.

This project is researching aspects of school organisation and mathematics teaching and learning in the first three years of schooling, to provide data on strategies that lead to substantial and quantifiable improvements in students' numeracy skills. The research model for the ENRP is based on the design elements from the Hill and Crevola General Model for School Improvement. These comprise:

- leadership and coordination;
- professional learning teams;
- school and class organisation;
- structured classroom program;
- monitoring and assessment;
- intervention and special assistance;
- home, school and community partnerships; and
- standards and targets.

The research team has created a framework for early years numeracy learning with an emphasis on key 'growth points' in students' understanding of mathematics. In 1999, this framework focused on Number (counting, place value, addition and subtraction strategies, multiplication and division strategies) and Measurement (time, length, mass). In 2000, the framework was expanded to include Space, and Chance and Data.

Twice each year (1999–2001) in March and November, every Prep to Year 2 student in the 35 trial schools is interviewed by their teacher for about 30 minutes using a task based interview developed from this framework. This involves over 4,500 students. A random sample of approximately 1,300 Prep to Year 2 students in the 35 reference schools is interviewed twice each year by members of the research team using the same interview. Data from the cohorts of trial and reference schools are analysed with comparative data generated annually. The 1999 ENRP comparative data shows improvement in student learning in both trial and reference schools. However, significantly greater improvement in student achievement has occurred in trial schools in each year level and across all areas of mathematics assessed.

The Professional Learning teams in the trial schools, which include the Early Years Numeracy Coordinator, Principal and Prep to Year 2 teachers, are participating in intensive professional development at statewide, regional cluster and school levels, focusing on the design elements.

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The Middle Years Numeracy Research Project

The Middle Years Numeracy Research Project (Stage 2) has been commissioned by the Victorian Department of Education, Employment and Training (DEET), the Catholic Education Commission of Victoria (CECV) and the Association of Independent Schools of Victoria (AISV) to:

- inform the development of a strategic and coordinated approach and advice for schools about the teaching and learning of numeracy for students in Years 5–9;
- trial and evaluate the proposed approaches in selected Victorian schools; and
- identify and document what works and does not work in numeracy teaching including those students who fall behind.

The project commenced in 1999 and is to be completed at the end of 2000.

Phase 1 of the project involved the collection of baseline data on the numeracy performance of a structured sample of Year 5 to Year 9 students from 20 primary and 20 secondary schools across Victoria. This data was collected by way of a Student Numeracy Profile (a five to six-item written assessment task of approximately 45 minutes) and an Extended Numeracy Task (a 45 to 50-minute classroom activity), both of which were administered and assessed by the teachers concerned using previously trialled scoring frameworks (rubrics). Data concerning current school-wide policies and practices was obtained from each school by means of a written survey, a follow-up interview and the collection of relevant artefacts (e.g., school policies, programs etc.).

Phase 2 of the project involves the development of a framework for advice prepared by the Project Team on the basis of the data collected in Phase 1 and recent research in the area of numeracy education and the Middle Years of schooling.

In accordance with the project brief, the framework has been organised in terms of the key design elements described in the General Design for a Whole-School Approach to School Improvement developed by Hill and Crevola (1997).

The effectiveness of the framework will be evaluated using a range of research tools. These include:

- the use of standardised, student numeracy performance data;
- school-based assessments of numeracy and numeracy-related performance;
- teacher journals;
- student reflections on the teaching and learning case-study interviews of selected staff and students; and

- school visits by project personnel.

The aim of the research is to provide initial advice to the 20 trial schools on how they might begin to improve the numeracy performance of students in Years 5 to 9. This advice will be presented in terms of the general principles outlined by Hill and Crevola followed by some key beginning strategies on how these general principles might be implemented in relation to numeracy education in the middle years of schooling. It will be refined and elaborated on the basis of the trialling experience, the research data collected and the continued monitoring of the relevant research.

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Western Australia

The First Steps in Mathematics (FSiM) project (K–7)

The FSiM project seeks to improve the mathematics outcomes of primary school students, particularly those at risk of not achieving their potential, by improving primary teachers understandings of teaching and learning within a developmental framework.

A review of the existing research literature was used to develop a series of tasks that replicated previous research or targeted aspects of student learning not previously investigated. Interviews with students in a range of schools across Western Australia throughout 1995–1997 built on the research identified in the literature review.

The findings from the interviews with students informed the development of diagnostic maps for Number and Measurement. These diagnostic maps describe the characteristic phases through which children's thinking about number and measurement concepts commonly develops.

Academic consultant to the project, Professor Sue Willis has worked with a team of Education Department of Western Australia project officers throughout the research phase. Resources and professional development stemming from this research will provide the major support for Western Australian schools as they implement an outcomes-focused approach to mathematics teaching and learning. The research phase of the FSiM project concludes in September 2000.

Numeracy Across the Curriculum

Commonwealth funding through the Australian Research Council and from the EDWA enabled research into the numeracy demands and opportunities that exist in learning areas across the curriculum. The work focused on developing a model to assist teachers to recognise and plan for numeracy using a cross-curricular approach.

During 1998–1999 two researchers, John Hogan and Mark Jeffrey, provided participating teachers with professional development about numeracy and observed teachers and students over time. The researchers documented the numeracy demands and opportunities that arose and teachers' responses to them.

As a result of this research a framework for describing numeracy, developed by Chief Investigator Professor Sue Willis, was refined. Professional development and resources that assist teachers to recognise and plan for the development of numeracy skills across the curriculum will be produced by EDWA in 2000. This support for teachers builds on the findings of the *Numeracy Across the Curriculum* research.

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Australian Numeracy Research Projects 2000 Commonwealth of Australia

This section provides details of numeracy and numeracy-related research projects funded through Commonwealth programmes for schools. In addition, the Commonwealth funds significant projects in school-level numeracy and mathematics through Australian Research Council (ARC) grants.

Commonwealth Numeracy Research and Development Initiative

In April 2000 the Commonwealth announced the Commonwealth Numeracy Research and Development Initiative, to provide specific support for research and development projects in school numeracy education, focusing on the primary school level. The Initiative aims to support improved numeracy outcomes for all students. Total funding for the Initiative is $7 million.

The expected outcome of projects under the Initiative is the identification of effective practices in teaching and learning, with a focus on the primary school years, that lead to measurably improved student numeracy outcomes. The dissemination of information about findings is expected to benefit students, educators, education authorities, administrators, professional associations, parents and parent organisations.

The Numeracy Priority Areas identified for research and development to support improved numeracy outcomes are:

- early numeracy;
- effective teaching practice;
- equity;
- home, school and community partnerships;
- technology;
- professional development; and
- national coordination and dissemination activities.

The Commonwealth Numeracy Research and Development Initiative will support a suite of projects in the identified Numeracy Priority Areas. The initiative has two strands, to enable the priority areas to be addressed in important complementary ways:

1. *Strategic numeracy research and development projects* in the identified priority areas, which are linked closely to improved practice in schools. Funding of up to $5 million will be provided to education authorities for approved proposals. Partnerships with and involvement of research organisations such as universities and other organisations such as professional associations and parent groups is encouraged.
2. *National numeracy research and development projects,* to be undertaken where projects are most effectively organised on a national basis.

Projects under the first strand are currently under development and further information is expected to be available in December 2000.

Two projects to take place under the *National numeracy research and development projects* strand of the initiative have been advertised for open tender in the national press, and are outlined below. Further projects are under development.

A mapping, review and analysis of Australian research in numeracy learning at the primary school level.

This one-year project, which is identified as a national initiative under the recently announced Commonwealth Numeracy Research and Development Initiative, will provide a systematic, analytical mapping of key research in Australia in numeracy teaching and learning at the primary school level and it will review this, taking into account the international research context. The project will synthesise key themes, issues and findings from the research. This will provide an information base to assist in the development of policy and programmes to enhance students' numeracy and to assist in the conduct of future research and development. The project will identify areas where further research would be most beneficial in the context of ensuring that all students have sound numeracy skills by the time they leave primary school.

The project will produce a major report which outlines the project's findings and additional materials which will be of value to a range of practitioners.

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Numeracy in the Early Years Project

This project will be funded from the *National numeracy research and development projects* strand of the Commonwealth Numeracy Research and Development Initiative. The two-year project will provide information on the practices and learning experiences that support the early numeracy development of a diverse and nationally representative sample of children in the year before they begin school, and during their first year of school.

The project will encompass at least three States and Territories, and will include both quantitative and qualitative research in an analysis of children's home, preschool, childcare and school numeracy experiences, as well as examining the beliefs and practices of parents, childcare workers and early childhood educators with regard to numeracy.

Part of the project will involve the publication of a report detailing the project findings, and also a booklet suitable for use by early childhood professionals, parents and others involved in the education and care of young children. The booklet will set out principles to guide the development of effective practices, and outline strategies for engaging children who are likely to experience difficulty with their numeracy development.

The project was advertised in the *Weekend Australian* on 16 September 2000, and tenders will close on 31 October 2000.

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Further Numeracy Research

Project to Investigate the Preparation of Teachers to Teach English Literacy and Numeracy in Primary and Secondary Schools

The Commonwealth is developing a research project to investigate the pre-service education and training of teachers to teach English literacy and numeracy in the early and middle years of schooling. The project will have two phases:

- a review of current research on effective practice in teacher pre-service education and the mapping of pre-service teacher education courses; and
- a survey of new teachers, principals and experienced teachers to establish what strategies student teachers have learnt, and how well prepared they believe they are to teach English literacy and numeracy in the classroom.

Tenders for the project were advertised on 26 August 2000 and closed on 18 September 2000.

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Research on Innovation and Best Practice in Improving Student Learning Outcomes

The Commonwealth through the Quality Outcomes Programme has funded a research project titled, *Research on Innovation and Best Practice in Improving Student Learning Outcomes* (IBPP). The study was carried out over two years by a consortium led by Professor Peter Cuttance of Sydney University and it provided a model through which schools developed the capacity to evaluate the success of innovations in terms of their impact on student learning outcomes. The research documents new and innovative approaches to the improvement of schools' performance in a number of curriculum areas, of which Mathematics is one. The final report included a *Themed Report on Mathematics in Australian Schools*, which will be part of a collated volume being developed on the whole project. This publication is expected to be available in December 2000.

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Issues Paper on Assessment and Reporting of Student Achievement for Students with Specific Educational Needs Against Literacy and Numeracy Benchmarks

This study, conducted for the Commonwealth by the Australian Council for Educational Research, indicates the critical issues in relation to the assessment and reporting of performance outcomes of students with specific educational needs against literacy and numeracy benchmarks. It is important for all students with specific educational needs including: Indigenous students, learners of English as a second language and students with disabilities and learning difficulties.

The report provides background material to inform policy decisions and would be useful in informing the collaborative development of approaches for handling assessment and reporting of the performance outcomes of students with specific educational needs against benchmark standards.

The Report Summary and Full Report are available at http://www.detya.gov.au/schools/LiteracyNumeracy/summary.pdf and

http://www.detya.gov.au/schools/LiteracyNumeracy/issues.pdf , respectively.

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Literacy, Numeracy and Students with Disabilities

The Literacy, Numeracy and Students with Disabilities project was undertaken by researchers at the Schonell Special Education Research Centre at the University of Queensland, the Department of Special Education and Disability at Flinders University of South Australia and the Deafness Student Unit at the University of Melbourne. The primary purpose of the study was to investigate the provision of literacy and numeracy to students with disabilities in Australian primary schools. The project studied students enrolled in regular classes or in special classes in regular schools. The project did not study students enrolled in special schools.

Generally, the research found that at the time a much greater emphasis had been placed on the development of literacy in comparison to numeracy in students with disabilities. There is a lack of published literature which is up-to-date in the area of numeracy development for students with all types of disabilities.

Factors such as attendance in regular schools and early application of assistive, adaptive or augmentative devices, communication skills, and health and medical problems appear to make a difference to achievement.

Where teachers and parents had high expectations for developing independence at school and at home these students did well. Motivational variables also appeared to play a significant role in the literacy and numeracy achievement of these students.

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The executive summary is available at:

http://www.detya.gov.au/schools/LiteracyNumeracy/swd.pdf

Mapping the Territory, Primary Students with Learning Difficulties: Literacy and Numeracy

The *Mapping the Territory, Primary Students with Learning Difficulties: Literacy and Numeracy* project was undertaken by researchers at Edith Cowan University, the University of Newcastle, the University of Melbourne, and the University of Queensland. The primary purpose of the study was to provide a national picture of how students with learning difficulties or disabilities are supported in their literacy and numeracy learning in regular primary school settings and to identify successful strategies for addressing the literacy and numeracy needs of these students.

Good initial early years teaching that engages children's desire to learn may help in the prevention of difficulties in numeracy. Characteristics of effective early years numeracy classrooms include the following:

- Development and use of mathematical language
- Hands on activities
- Real life problem solving approach
- Regular practice in mental computation
- Correction at the point of error
- Regular assessment using contextualised problems
- Sequential introduction of concepts and facts in small steps
- Scaffolding learning by working from the known to the unknown
- Consolidation of learning

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The report is available at: http://www.detya.gov.au/schools/LiteracyNumeracy/index.htm

Indigenous Students Achieving in Numeracy

The Australian Association of Mathematics Teachers' *Indigenous Students Achieving in Numeracy* (ISAN) project was funded under the Strategic Results Projects element of the Commonwealth's Indigenous Education Strategic Initiatives Programme (IESIP) in 1998. The project aimed to explore varying teaching practices to improve levels of numeracy acquisition among Indigenous students. It operated at five sites (rural and remote school communities in northern and central Australia), involving 77 primary and junior secondary students.

The procedures used in each site to establish baselines and improvement varied. Commonly used instruments were formal and informal written tests, oral tests, observation and work samples. These processes were replicated in the final summative assessment. A common model for summarising each student's progress was agreed and used in all participating schools.

Results indicate that the following factors can be very effective in achieving numeracy gains:

- collaboration between all elements of the school community;
- attention to the development of students' understanding and use of the language of mathematics in English;
- work with small groups in a withdrawal program (with one exception);
- person(s) established and resourced to attend to students' numeracy development as a special responsibility; and
- revised teaching strategies.

Each of the participating schools has general intentions and strategies for continuing the work of the project; three have specific actions under way to consolidate and extend the work.

Information can be found in the following Commonwealth report:

What Works? Explorations in Improving Outcomes for Indigenous Students, IESIP SRP National Coordination and Evaluation Team, March 2000

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TIMSS repeat Video study

With funding from Commonwealth, State and Territory and United States governments, Australia is participating in the TIMSS-Repeat Video Study. The study involves the collection of videotaped observations of classroom instruction from nationally representative samples of schools and classes.

The interactions of students and teachers in Year 8 mathematics and science classrooms in up to 100 schools are being recorded, examined and compared in the following countries: Australia, Czech Republic, Hong Kong, Japan, Netherlands, Switzerland and the United States.

The purpose of the study is to assess the relationship between teaching practice and student performance and to better understand the processes of classroom instruction in different cultures in order to improve student learning.

ACER is conducting the Australian part of the study. Filming of the videos has been completed in Australia and the various data forms are undergoing complex processing and integration in the United States. Reports of the study are expected to be released in late 2002.

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Numeracy Contextual Papers

The Australian Association of Mathematics Teachers (AAMT) was contracted by the Commonwealth to contribute to aspects of the work of developing its numeracy paper *Numeracy, A Priority for All: Challenges for Australian Schools.* As part of this, the AAMT commissioned the writing of a set of papers to provide some background and contextual information. The papers include a range of research information. The papers are as follows:

- *Planning for an Emphasis on Numeracy in the Curriculum* (Mr John Hogan and Ms Marian Kemp, Murdoch University)
- *Early Childhood Numeracy* (Associate Professor Bob Perry, University of Western Sydney, for the Australian Early Childhood Association)
- *Identification and Evaluation of Teaching Practices that Enhance Numeracy Achievement* (Dr Max Stephens, Education Consultant, Victoria)
- *Numeracy Assessment and Associated Issues* (Dr Jan Lokan, Mr Brian Doig and Ms Catherine Underwood, Australian Council for Educational Research)
- *Our Changing Technological Society: Demands and Links between Numeracy Performance and Life Outcomes (Employment, Education and Training)* (Associate Professor Joy Cumming, Griffith University)
- *Supporting Teachers to Implement a Numeracy Education Agenda* (Dr Janette Bobis, University of Sydney)
- *Numeracy Education: What do We Know and What can We Learn from the Literacy Experience* (Professor Peter Hill, University of Melbourne)

These papers are available from the Australian Association of Mathematics Teachers website at: http://www.aamt.edu.au/AAMT/ctxintro.html

The Middle Years Initiative

The Commonwealth has allocated $5 million over four years for strategic national projects related to the middle years of schooling. A number of research projects are currently being developed to address the literacy and numeracy needs of students in the middle years of schooling who have not developed foundational literacy and numeracy skills and therefore have difficulty coping with the demands of the school curriculum. Projects will focus on priority areas to extend assistance to educationally disadvantaged students, including Indigenous students and to assist students who may have literacy and numeracy difficulties in the transition from primary to secondary school.

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Primary School Teacher Professional Development in Support of the National Literacy and Numeracy Plan

In the 1997 Budget, the Commonwealth Government announced grants totalling $7 million over the three years from 1997 to 1999 to assist State and Territory education authorities to implement strategic professional development initiatives to support the implementation of the National Literacy and Numeracy Plan. These funds were sourced from the Commonwealth's Literacy and Numeracy Programme.

All States and Territories received funding under this initiative to conduct projects to foster improvement in literacy and numeracy outcomes for students in the early years through the provision of teacher professional development initiatives which facilitated:

- the use of comprehensive screening strategies to identify those students at risk of not making adequate progress towards the National Literacy and Numeracy Goal,
- intervention as early as possible to address the needs of students at risk, and
- the assessment of student progress against the national benchmarks.

Examples of numeracy work under this initiative are included here as a number of projects include significant components of research and / or development. The following cross sectoral projects were part of the initiative:

Supporting Literacy and Numeracy in Queensland Schools

This joint Education Queensland, Catholic Education Commission of Queensland and Association of Independent Schools of Queensland project is outlined under QUEENSLAND above.

NSW Teacher professional development in support of the National Plan

Project description:

During 1998 and 1999, the New South Wales project in support of the National Literacy and Numeracy Plan operated on behalf of the NSW Department of Education and Training, the Catholic Education Commission of NSW and the Association of Independent Schools of NSW.

During 1998 and 1999, the project operated through a network of approximately 350 pilot schools (1600 teachers) which were funded to evaluate draft materials and participate in professional development opportunities with the assistance of a project grant.

During 1998, the project focused on the development, trialing, consultation and evaluation of the *Starting Kindergarten* document with assessment of students in relation to Foundation level outcomes. The focus of the project for 1999 extended to the trialing and evaluation of consultation draft assessment materials for *Starting Year 1* and *Starting Year 3* in literacy and numeracy through a network of pilot schools. The purpose of the trial was to gauge how well the documents assisted teachers in identifying the literacy and numeracy achievements of their students during Term 1 of Year 1 and Year 3 and in identifying those students who may be experiencing difficulty. The trial was also designed to provide direction for planning teaching and learning experiences based on these judgments.

Pilot schools were involved in school-based professional development opportunities which focused on monitoring student progress and gathering work samples and teaching strategies. To assist with this task, trialing teachers received a Recording Booklet which outlined a process to use when monitoring student progress, planning for teaching and assessing student achievement.

Two extensive independent evaluation reports were commissioned during the project. The evaluations sought the views of teachers, consultants / advisors, tertiary educators, parents and professional teachers' organisations. The final materials were informed by the findings of the two evaluation reports. The findings also informed the development of the support materials for teachers, the video and support materials for parents. These materials reflect the issues and concerns raised by teachers during trialing.

Resources produced:

Materials from the project have been finalised in the form of the *Starting with Assessment* kit and made available to schools in 2000.

The resource provides:

- a framework for assessing students with the key points identified as Starting Kindergarten, Starting Year 1, Starting Year 3;
- support materials outlining classroom based assessment strategies, exemplar work samples and implications for teaching; and
- support materials for teachers including a video and workshop session notes; and
- support materials for parents.

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Northern Territory Literacy and Numeracy Support Program

The *Teacher Professional Development in Support of the Literacy and Numeracy Plan (Literacy and Numeracy Support)* project, undertaken by the Northern Territory Department of Education, the Catholic Education Office of the Northern Territory and the Association of Independent Schools of the Northern Territory, complemented the materials and personnel provided by the Northern Territory Department of Education for teacher professional development programs in support of the Northern Territory Literacy and Numeracy Plan, and the National Literacy and Numeracy Plan.

It was implemented in four strands as follows.

Strand 1:

Map existing professional development programs currently used in the Northern Territory to:

- enhance all teachers' literacy and numeracy teaching and assessment skills;
- provide extra support (intervention) for students who are deemed to be 'at risk'; and
- evaluate how comprehensive is their coverage and how effective they are, and to identify any supplementation needed.

This task was carried out and comprehensively documented in the 1998 Northern Territory Literacy Plan, the 1998 Northern Territory Numeracy Plan. The situation was reviewed during 1998 and 1999 and again comprehensively documented in the 1999 Literacy and Numeracy Plan Update. These documents are available on request and should be consulted for details of particular projects and programs.

Strand 2:

Provide systematic and strategically managed information about the Northern Territory Literacy and Numeracy Plan and the progress of its implementation, in a visual, user-friendly format.

This strand was also implemented most comprehensively through the development of the 1998 Northern Territory Literacy Plan Documents and an accompanying poster which were widely distributed throughout the Northern Territory educational community.

Information sessions were held at a range of professional forums and schools were provided with information that could be distributed through their parent newsletters on an ongoing basis to maintain currency of information with regard to future developments.

Strand 3:

Further develop the Multilevel Assessment Program (MAP)

The vehicle for the collection of data on students' literacy and numeracy in the primary years is the MAP, a Territory-wide assessment program for monitoring standards at Years 3 and 5.

In 1997 the Northern Territory Board of Studies made two significant changes to the MAP to take effect from 1998. This was in order to implement the National Plan for reporting student performance in writing and spelling against the nationally agreed benchmarks. These changes were:

- to introduce a Common Writing Task (CWT) for all Years 3 and 5 students in urban schools, and for all 8 and 10 year old students in non-urban schools; and
- to extend to all urban schools the external moderation of the school-based assessment of Year 3 and Year 5 students' writing.

The project officer was based in Curriculum Services Branch during 1998 and 1999.

Strand 4:

Further develop the document *Assessment in the Early Years of School* and help teachers understand how to use it.

During 1997 and 1998, the Northern Territory Board of Studies Early Childhood Advisory Committee coordinated the writing and publishing of the resource *Assessment in the Early Years of School,* later renamed *Assessment, Intervention and Reporting in the Early Years,* to assist schools to address the first point in the National Literacy and Numeracy Plan. A copy of this document is available on request.

During 1998 and 1999, this strand of the project was implemented through the appointment of project officers in the Alice Springs and Darwin Regions and by an alternative, collaborative workshop approach in Katherine and East Arnhem Regions. The draft document was distributed and introduced by the Project Officers to schools in the Alice Springs, Barkly and Darwin areas during 1998. In 1999, the published booklet was distributed to all schools and promoted through the Katherine and East Arnhem workshops.

Outcomes:

There was considerable success in achieving outcomes for the first three strands and although the fourth was not completely achieved because of some difficulties encountered in the Katherine and East Arnhem regions, significant progress was made.

The project officers for both the Multilevel Assessment project and the Assessment in the Early Years project worked closely with each other and with the officers responsible for the implementation of Outcomes Based Education and Profiles, the Early Childhood Subject Area Committee and the various subject area officers.

Over the two year period, all regional advisory personnel were provided with relevant professional development which formed an integral component of their advisory brief, especially when visiting small remote and Aboriginal schools.

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National Literacy Program: Literacy and Numeracy Professional Development: SA

The project has been known as the *National Literacy and Numeracy Program: Literacy and Numeracy Professional Development: SA*. The project has provided professional development in literacy and numeracy to R-5 teachers from the three education sectors in South Australia. It has provided support for teachers and schools to extend their knowledge of literacy and numeracy, repertoires of teaching and learning strategies, and effective assessment techniques. Teachers have developed their capacity to adapt their teaching so they can respond more effectively to students' needs and abilities. The project emphasised the need for teachers to plan for assessment when they plan for teaching so that they can provide the explicit teaching required by individual or groups of students.

At the onset of the project in 1998, project officers established four networks – an R–2 literacy, R-2 numeracy, 3-5 literacy and 3-5 numeracy. A total of 48 schools and 82 teachers were involved. The networks met on a number of occasions and all participants were involved in professional development that has supported them to explore identification of students at risk of not meeting the benchmarks. Professional development was also provided on a number of related topics. Participants in the networks participated in research projects that focused on assessment and on responsive teaching for students. The teachers then wrote case studies of their research. In 1999, project officers established two R-5 networks, one in literacy and one in numeracy. A total of 28 schools and 44 teachers continued to be involved in the project. The project team and all 1999 network teachers provided professional development to other teachers and parents across the state.

Teachers were provided with opportunities to have their work accredited, by the University of South Australia, towards a Graduate Certificate of Education (Professional Practice), Bachelor of Education or Master of Education. The standard of the programme was such that 20 teachers were awarded 2 x 4.5 units. The University of SA also believed that the high quality and standard of the professional development offered by the project, warranted granting project team members a 9.0 unit status towards a Masters of Education.

In 1999, all network schools were encouraged to nominate members of their local communities to become a *Friend of Literacy and Numeracy* at their school. Fourteen of the twenty eight programme schools participated, and of these, twelve were rural schools. The *Friends* programme worked extremely well in small rural schools, but was less successful in larger schools.

The programme developed a web site to promote the project and publish teachers' work. Teachers' work was also promoted through a Showcase and Spotlight seminars, open days and shopping centre displays. The whole day Showcase was held on Saturday 4 September 1999, and was opened by Ms Trish Worth. The work of 66 schools was showcased either through workshops or large poster displays. Three Spotlight seminars were held in rural South Australia, all of which were well attended. A total of 30 schools showcased their work and two teachers brought members of their class along to demonstrate their learning.

The products of the project included a booklet of annotations of literacy and numeracy resources, sets of four books of teachers' case studies, a journal of articles, and a series of units of work.

Teacher Learning Outcomes

Evaluations were conducted for the 1998 and 1999 components of the project. The emphasis of the evaluations were its effectiveness in relation to teachers' learning, and implicit in the data collected as part of the evaluations, are a range of indicators of improvement in student learning as a result of increased teacher learning.

The evaluation of the 1999 programme demonstrated that the learning of teachers in relation to literacy and numeracy, has increased significantly over the two years of the programme. In particular there were increases in teachers' knowledge, teaching skills and increased confidence in identifying and analysing students' learning needs.

There were also clear indications that a majority of teachers in the programme are collecting base line data on students. Teachers have developed a range of strategies for determining students' learning needs and designing teacher strategies to meet these needs. However, there are also indications that teachers are less confident in interpreting data on student learning and in using these interpretations to plan for further learning.

Teachers indicated increased understandings of numeracy and mathematics and of the learning needs of 'at risk' students as examples of their increased knowledge. In addition, principals indicated that teachers were becoming more explicit and specific in teaching methods and had developed increased understandings around literacy.

An interesting conclusion reached in relation to the use of benchmarks was that teachers expressed increased awareness of benchmarks but less use of benchmarks in teaching, assessment of student learning and in reporting to parents. Elsewhere in the report it was stated that in the project teams' opinion, there was a high degree of confusion among school leaders about the purpose and use of the National Benchmarks. These statements highlight the need for education systems to support the implementation of benchmarks and reporting requirements with appropriate professional development.

Further information about these projects, including contact details for project officers, is available at: http://www.detya.gov.au/schools/LiteracyNumeracy/projects.htm .

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Secondary School Literacy and Numeracy Initiatives

In February 1998, Dr Kemp, Commonwealth Minister for Education, Training and Youth Affairs approved $5 million from the Quality Outcomes Programme to support pilot projects which address the literacy and numeracy needs of those students who have progressed to secondary school without achieving a minimum acceptable standard of literacy and numeracy at the end of primary school.

This initiative is targeted at those students in the compulsory years of secondary school who may not have developed basic literacy and numeracy skills which enable them to cope with the demands of the secondary school curriculum. Government and non-government education authorities were invited to apply for funding under this initiative.

A total of seventeen projects were approved for funding under this initiative. The projects have included implementation of pilot programmes ranging from curriculum materials development, professional development projects and researching new intervention strategies with the aim of improving the literacy and numeracy skills of the lowest achieving secondary school students.

Examples of numeracy work under this initiative are included here as a number of projects include significant components of research and/or development. The following cross sectoral projects were part of the initiative:

Junior Secondary Numeracy Project

This Commonwealth funded project, undertaken by the South Australian Department of Education, Training and Employment, the South Australian Catholic Education Office and the Independent Schools Board of South Australia, is outlined under SOUTH AUSTRALIA above.

teachers@work - Supporting Year 8-10 Literacy and Numeracy

teachers@work is the product of a collaborative project between The Association of Independent Schools of Queensland, Education Queensland, and the Queensland Catholic Education Commission.

The project is targeted at the needs of Junior Secondary teachers and students, and provides a professional development program as well as teaching resources, which target literacy and numeracy demands across the curriculum.

The aim of teachers@work is to address the requirements of teachers as they provide support for Junior Secondary students experiencing significant difficulties in literacy and numeracy learning. This support occurs across all subject areas within the contexts of mainstream classroom programs.

The package features:

- a rich professional development component comprising 4 sections (Challenges of Junior Secondary Schools, Successful Teaching and Learning, Literacy Case Study, Numeracy Case Study)

These sections are interactive, providing theoretical background, real classroom examples, assistance with identifying areas of difficulty, and sound teaching and learning strategies, supported by fact sheets, video and audio illustrations, and a reflective journal component. The end user can work through these sections, following the lead of the case study teacher, and develop a tight unit of work, complete with appropriate support strategies to assist the target group of students.

- a Teaching Resources section, presenting many literacy, numeracy and technology support strategies, described in detail and supported by graphic and video examples. These strategies are linked closely to the theoretical and case study components in the first part of the program. They are presented to link with the profiles of students who are struggling with literacy and numeracy. Each strategy forms part of a "problem-solution" structure, complete with sample activities from real classrooms.

The program is being distributed to all Queensland schools in CD ROM format supported by a web site. A print/video version will be also developed.

The teachers@work website can be accessed through the following address:

http://education.qld.gov.au/learning_ent/ldf/schools/cdroms/twork/

Contact:
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Planning and Teaching for Numeracy in Years 7 to 9

This project was conducted by the Department of Education, Tasmania, Catholic Education Office, Tasmania and Association of Independent Schools, Tasmania.

The primary goal of the project was to improve the numeracy outcomes of students identified as low achieving in Years 7 to 9 in the focus schools.

This goal was central to all actions undertaken within the project. The actions of the project included identifying and supporting numeracy leadership in participating schools, identifying and supporting low achieving students in existing Mathematics classrooms and identifying and developing classroom materials for use with such students in their regular Mathematics programs.

Initially, project sessions concentrated on raising teacher awareness of the need to provide a meaningful and adequately resourced numeracy program for low achieving students in Years 7 to 9. Teachers identified resource needs and formed working groups to collect/develop materials, which were then published and shared among the participating schools.

Evaluation of the project was based on case studies: interviews with participating teachers.

Specific objectives and related outcomes of the project included the following:

1. To develop a numeracy program for low achieving students in Years 7 to 9 which may be used to support the existing Mathematics programs in Tasmanian schools and which may be individually tailored to meet the needs of such students and delivered in a variety of ways.

   Attention was focused on the need to provide a coherent numeracy/Mathematics program for all students, and particularly the often-neglected lower achieving group of students. No formally-documented program was developed within the Project. Teachers did not want a documented program for low achievers that was separate from existing Mathematics programs used in their schools. Rather, they were seeking ways to make existing programs more accessible to the low achieving students through more appropriate materials, resources and hands-on experience for these students.

   A collection of the resources was developed during the course of the project.

2. To develop a range of plans, strategies and support materials (print and electronic delivery) for use with low achieving students.

   The project developed, published and shared a range of print and hands-on resources for use in classrooms. There developed a sense of awareness and understanding of the nature of the materials that benefit low achieving students.

3. To identify numeracy program leaders in the Focus Schools and support them with appropriate professional development.

   Schools identified their numeracy leaders for the purposes of the project. All aspects of the Project (the discussions, the development and sharing of materials) provided a professional development opportunity for school-based numeracy leaders. Some leaders were in their first years of teaching - some in country schools in their first full year of teaching and the designated teacher in charge of

Mathematics/numeracy. The project sessions gave them regular contact with experienced teachers and leaders resulting in formal and informal support networks and mentoring to be established and fostered.

In Government schools numeracy is viewed as a cross-curriculum issue, with all teachers having responsibility for the development and enhancement of students' numeracy achievement. A collection of cross-learning-area numeracy tasks was developed and published.

4. To identify how successful teachers identify and assess students at risk of failing to achieve desired numeracy outcomes.

   The project provided a forum for the exchange of ideas – successful and otherwise – that schools had previously employed and were employing to cater for low achieving students. Discussions and exchanges about classroom management strategies identified a variety of approaches schools were employing to address the needs of low achieving students. These included:

   - parent tutoring;
   - peer tutoring; and
   - use of 'under teaching load' teachers in in-class tutoring roles.

   The strategies, in the main, were attempts to avoid withdrawal of students from their regular classroom settings and programs. Staffing and timetabling constraints (and school philosophy in some cases) precluded separate teaching groups to be established, and ad hoc withdrawal was not seen to be a useful nor worthwhile alternative. Some schools however described timetabling arrangements where groups of low achieving students formed special classes with low teacher-student ratios. The trade-off was larger classes elsewhere in the school.

5. To explore the use of technology in effective numeracy teaching.

   Project funding enabled software titles to be purchased for trialing in schools and demonstration at Project sessions. The lack of use of technology in Mathematics and numeracy classrooms remains a concern. Mathematics teachers still do not have easy access to computers. Many schools concentrate computers in specific-purpose computer rooms, rather than provide ready availability for small group work in classroom settings.

6. To commence the process to identify the teacher competencies which lead students to achievement of desired numeracy outcomes.

   This objective was approached by way of challenging teachers to:

   - reflect on and describe their initial experiences and views of numeracy;
   - undertake a numeracy audit of programs which exist in their schools;
   - identify and describe the needs of low achieving students and the extent to which teachers are attempting to meet these needs; and
   - describe the type of support teachers require to address more adequately the needs of this group of students.

   From this position some project teachers were co-opted to participate in the numeracy teacher competency identification process (see Objective 8).

7. To provide professional development for teachers in teaching for numeracy in the focus schools for this project.

   All aspects of the project had an element of professional learning, both formal and informal, for teachers.

8. To begin the process of identifying and documenting numeracy teacher competencies.

   Project funding was used to commence the identification and documentation of numeracy teacher competencies. This work is continuing beyond the life of the Project with funding from the Department of Education. The project provided a pool of informed and committed numeracy leaders from which a number were selected to assist in a functional analysis process leading to identifying numeracy teacher competencies. The documentation arising from this process will be presented for national accreditation.

Enquiries about the availability of the materials developed and published in the project can be directed to the following personnel.

Contacts:
Alison Jacob
Deputy Secretary
Strategic Development and Evaluation
Department of Education
GPO Box 169
HOBART TAS 7001

Professional enquiries about the Project
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The NT Secondary Schools Literacy and Numeracy Intervention Pilot Project 1999

The Secondary Schools Literacy and Numeracy Intervention Pilot Project was implemented at Taminmin and Palmerston High Schools during 1999 to trial, document and evaluate literacy and numeracy intervention programs for 'at risk' secondary students in two Northern Territory government schools, and to provide associated professional development for teachers of these students.

Palmerston High School is a comprehensive government high school located in Driver, a suburb of Palmerston, which is a satellite town some 20 km from Darwin. The school has a population of 510 with the steady increase of enrolments due largely to the build up of Defence Force at Robertson Barracks and the general expansion of a new town. The school comprises a Principal, two Assistant Principals, 5 Senior teachers and 38 teaching staff. The student population is drawn from a disproportionately socio-economically disadvantaged sector.

Taminmin High School is situated at Humpty Doo in the rural area 45 km south of Darwin. The school services approximately 500 students from a large geographical area where the steadily increasing population reflects the opening up of the rural area for lifestyle and horticultural development. The school comprises a Principal, four Assistant Principals (2 establishment, 1 supernumerary, 1 farm manager) and 36 teaching staff. Family circumstances of students range from unemployed to professionals who commute to Darwin for work. In this area there is no public transport and students are often isolated from their peers during weekends and holidays. School is often seen as a social venue as well as an educational institution. Some sections of the school population are highly mobile.

At both schools, a class of approximately fifteen Year 9 students was created and staffed by an above-establishment teacher. The teachers were selected on the basis of their:

- recognised teaching qualifications;
- successful teaching experience in the middle years of schooling;
- successful experience in providing educational leadership;
- demonstrated initiative and self management skills;
- high quality written and oral communication;
- expertise in organisational tasks;
- flexibility in a changing environment;
- ability to operate as a member of a team, liaise effectively with parents and other teachers, and take a holistic view of educational programs across the school;
- proven empathetic attitude towards students;
- knowledge of the NTDE's Literacy and Numeracy Plan, policies, curriculum and BACOS requirements in literacy and numeracy rich subjects; and
- knowledge of contemporary educational theory and practice in the areas of literacy and numeracy and behaviour management.

Both teachers had primary teaching backgrounds with specialist skills in teaching literacy.

In each school, the class operated across four core learning areas and provided students with stability, continuity and a needs-based approach to literacy and numeracy across those learning areas. The project targeted students who were educationally disadvantaged, required assistance to improve their literacy and numeracy skills, but were most likely to benefit from intervention. These students were identified in consultation with teachers, the students themselves and their parents. Essentially they were students who had ability but were at risk of not reaching their full potential. It was also felt that the students would benefit in other areas such as self-esteem, an improvement in their attitude to school and a positive move towards retention at senior school level.

At the student level, outcomes of the project were very positive with a majority of students demonstrating considerable improvements in both literacy and numeracy and across other learning areas.

- At Palmerston High, at the end of the first semester, average reading age improved from 9.8 years to 11.0 years and average spelling age from 10.3 years to 11.8 years. In the various strands of numeracy, the improvement was at least one profile level.
- At Taminmin High, over a 15 week period, the average spelling age improved from 11.10 years to 12.2 years and the average reading age from 10.00 years to 10.10 years.
- At both schools it was evident that improved student confidence reflected in their participation and achievement in other learning areas. For those who returned successfully to the mainstream, this was highlighted in their results across the learning areas.

At the school and system levels, the project highlighted issues relating to:

- planning and preparation;
- orientation and management;
- resourcing;
- reintegration of students into the mainstream; and
- school climate and organisation.

These form the basis for the major recommendations.

Additionally, as part of the Territory wide significance aspect of the project, a professional development seminar was held in fourth term to bring together representatives from secondary schools across the Northern Territory. An interesting facet of the seminar was that it was held in conjunction with an essentially primary-based numeracy project and provided a range of joint sessions. The seminar enabled teachers to visit the two project schools, exchange ideas with both primary and secondary teachers, identify critical issues, and make recommendations.

The most significant recommendations related to the need for collaboration, whole school approaches, reassessment of school organisations and structures, interaction between primary and secondary schools, networking, and dissemination of best practice.

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Transition Numeracy Project

This project is due to be completed in December 2000.

The project focuses on developing learning partnerships with and between Year 7 and Year 8 classroom teachers within school communities for the purposes of identifying, developing strategies to help, and monitoring the progress of students who are likely to have difficulty making adequate progress in their learning of mathematics in secondary school.

The project supports the current EDWA curriculum improvement initiatives through two types of activities. The project seeks to:

- Collaboratively develop expertise with groups of classroom teachers from selected primary/secondary clusters of schools, using an action research approach, and making use of the Outcomes and Standards Framework, the Student Outcomes Statements and First Steps in mathematics support materials.

Successful Interventions: A Secondary Literacy and Numeracy Initiative

This Commonwealth funded project is being undertaken by the Victorian Department of Education, Employment and Training, Catholic Education Commission of Victoria and the Association of Independent Schools of Victoria. Part of the funding provided by the Commonwealth is being used to support the *Middle Years Numeracy Research Project* (Stage 2), commissioned by all three education authorities in Victoria, outlined under VICTORIA above.

Further information about these projects, including contact details for project officers, is available at: http://www.detya.gov.au/schools/LiteracyNumeracy/projects.htm .

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3. Poster presentations

Poster presentations

Jennie Bickmore-Brand
Western Australia
Assessing resources in mixed modal delivery for teaching in numeracy and/or mathematics?

Brian Doig and Cath Pearn
Australian Council for Educational Research
How does 'Maths Intervention' work?

Rhonda Faraghar,
Flinders University of South Australia
What numeracy means in the context of intellectual disability

Peter Finch (with Josie Calabrese, Richard Churchill, Andrew Smith, Jenny Switala, Chris Tatyrzo, Glenys Taylor, Paula Thomas, Doug Weaver)
Taperoo High School, Adelaide
Approaches to numeracy at Taperoo High School: a cross-curricular theme

Maureen Finnane
Schonell Special Education Research Centre, Queensland University
The "actively inefficient learner": improving the numeracy learning of students with mathematical learning difficulties

Peter Gould
Department of Education and Training, NSW
Count me into Space

Marion Meiers and Prue Anderson
Australian Council for Educational Research
Developing common assessment tasks in literacy and numeracy for Years P – 2 in a longitudinal study

Joanne T. Mulligan
Division of Early Childhood and Education
Macquarie University, Sydney
The Role of Imagery in Young Children's Representations of Number: A Longitudinal Study

Gerry Mulhearn and Sue Emmett
South Australian Department of Education, Training and Employment
The Development of a School Entry Assessment Process for Numeracy

Bob Perry, University of Western Sydney
and Peter Howard, Australian Catholic University
"Counting On": the evaluation so far

Dr Jenny Young-Loveridge, University of Waikato, NZ
Children's understanding of the number system between Years 3 and 4.

Betty Johnston and Keiko Yasukawa
University of Technology, Sydney
Adult numeracy research projects: implications for research into school numeracy

4. Conference program

SUNDAY 15 OCTOBER

6.30 pm – 8.00 pm
Opening reception, Carlton Crest Hotel

DAY 1: MONDAY 16 OCTOBER

8.15 am
Registration and coffee

9.00 am
Welcome
Dr Geoff Masters, Executive Director, ACER

Opening comments
Chair: Professor Jillian Maling, AM, Chair, ACER Council

9.30 am
Plenary address
Professor Margaret Brown, Professor of Mathematics Education, School of Education, Kings College London
What kinds of teaching and what other factors accelerate primary pupils' progress in learning numeracy?
The Leverhulme Numeracy Research Project based at King's College London has completed 3 years of a 5-year longitudinal study of two cohorts, each with more than 1500 primary school children. Alongside this large-scale monitoring are five small–scale projects focusing on specific aspects of numeracy teaching and learning.

10.30 am
Panel response: Implications for policy and practice in Australia.

- *Peter Luxton, Principal, Forest Lake State School, Queensland*
- *Graham Meiklejohn, Principal Project Officer (1–10 Mathematics), Queensland School Curriculum Council*
- *Di Weddell, Director, Benchmarking, Assessment and Numeracy Policy Section, Department of Education, Training and Youth Affairs, Canberra*

11.00 am
Morning tea

11.30 am
Concurrent sessions 1

Session A
Associate Professor Doug Clarke, Director, Early Numeracy Research Project, Australian Catholic University
Jill Cheeseman, Project Manager, Early Numeracy Research Project, Australian Catholic University
Improving students' numeracy learning: Some insights from the first year of the Early Numeracy Research Project.
A major feature of the Early Numeracy Research Project is a one-to-one interview with all children at the beginning and end of the school year. Data from the first year will be shared, as will some of the things which have been learned about understanding, assessing and developing children's understanding in the early years.
Chair: Penny Bedson, Senior Education Officer, Numeracy, Teaching and Learning Branch, Education Queensland

Session B
Dr Robyn Zevenbergen, Senior Lecturer, Griffith University.
Language Implications for Numeracy: A study of language use of disadvantaged students.
An investigation which suggests that language is a key factor to consider when students come to learn school mathematics and numeracy.
Chair: Associate Professor Joy Cumming, Griffith University

Session C
Dr Jan Lokan, Deputy Head of Measurement Division, ACER
International perspectives on numeracy learning: TIMSS and PISA.
Two major international studies highlight crucial aspects of numeracy learning.
Chair: Will Morony, Professional Officer, Australian Association of Mathematics Teachers

12.30 pm
Panel Discussion: Implications for Improving Numeracy Learning.
Chair: Associate Professor Joy Cumming, Griffith University
Margaret Brown, Mike Askew, Doug Clarke, Jill Cheeseman, Robyn Zevenbergen, Jan Lokan

1.00 pm
Lunch and Poster Session

2.00 pm
Focus group workshops
Identifying directions, priorities, and issues for improving numeracy learning.

2.45 pm
Focus group reporting session

3.15 pm
Afternoon tea

3.45 pm
Concurrent sessions 2

Session D
Associate Professor Dianne Siemon, Department of School and Early Childhood Education, RMIT University
Researching Numeracy in the Middle Years - the Experience of the Middle Years Numeracy Research Project.
The Middle Years Numeracy Research Project is being conducted in Victorian schools. Some images of what appears to be working towards improved numeracy learning will be shared, together with an emergent framework for understanding numeracy development in Years 5 to 9.
Chair: Marion Meiers, Research Fellow, ACER

Session E
Peter Gould, Chief Education Officer, Mathematics, Department of Education and Training, NSW
Count Me In Too: Creating a choir in the swamp. This session will report on work related to turning the results of research into students' solution strategies in number into a pathway of practice for real classrooms.
Chair: Dr Jan Lokan, Deputy Head of Measurement Division, ACER

Session F
Debbie Efthymiades and Josie Roberts, Northern Territory Department of Education, Will Morony, AAMT
Improving numeracy learning for Indigenous students. A report of teachers' 'work in progress' aimed at addressing issues in numeracy education for groups of Indigenous students. The inter-relationships between research, practice and development will be discussed.
Chair: Dr Geoff Masters, Executive Director, ACER

4.45 pm – 5.15pm
Plenary session
Dr John Ainley, Deputy Director and Head of Policy Research Division, ACER
Strategic directions

7.00 pm
Conference dinner
Speaker: Dr Mike Askew, Kings College, London

DAY 2: TUESDAY 17 OCTOBER

9.00 am
Plenary address
Chair: Dr Geoff Masters, Executive Director, ACER

Professor Sue Willis, Dean of Education, Monash University
Strengthening Numeracy – Reducing Risk.

10.00 am
Panel response
- *Vince Geiger, President, AAMT*
- *Peter Gould, Chief Education Officer, Mathematics, Department of Education and Training, NSW*
- *Peter Galbraith, President, Mathematics Education Research Group of Australasia*

10.45 am
Morning tea

11.15 am
Concurrent sessions 3

Session G
Associate Professor Alistair McIntosh, and Dr. Shelley Dole, School of Early Childhood and Primary Education, Faculty of Education, University of Tasmania
Research on Mental Computation and Number Sense and its Implications for Numeracy.
Mental computation and number sense, and its significance for the development of numeracy in primary and middle school classrooms.
Chair: Dr John Ainley, Deputy Director and Head of Policy Research Division, ACER

Session H
Margaret Forster, Senior Research Fellow, Marion Meiers, Research Fellow, Andrew Stephanou, Research Fellow, ACER
Constructing scales for reporting growth in numeracy: the ACER Longitudinal Literacy and Numeracy Study.
Data from this seven-year longitudinal study is being used to construct a set of numeracy scales which can be used to describe and illustrate student achievement, and to show growth over time.
Chair: Vince Geiger, President, Australian Association of Mathematics Teachers

Session I
Associate Professor Joy Cumming, Griffith University
Computational numeracy.
The significance of, and current performance data, on computational fluency for personal, social, work and mathematical contexts.
Chair: Professor Jillian Maling, Chair ACER Council

12.15 pm
Panel session: Implications for improving numeracy learning.
Moderator: Will Morony, AAMT
Sue Willis, Alistair McIntosh, Shelley Dole, Marion Meiers, Andrew Stephanou, Joy Cumming

12.45 pm
Lunch and Poster Session

1.45 pm
Focus group workshops
Responding to collated directions, priorities and issues from Day 1

2.30 pm
Focus group reporting session

2.45 pm
Closing comments
Professor Margaret Brown and Dr Mike Askew, Kings College, London
Improving numeracy learning: What does the research tell us?

3.15
Close of conference