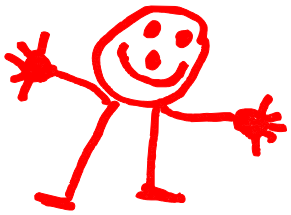

A GOOD START TO NUMERACY

Effective numeracy strategies from research and practice in early childhood

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FOREWORD

A Good Start to Numeracy is a review of the international and Australian research literature on numeracy in early childhood that complements the Department of Education, Science and Training's major review of the numeracy literature being undertaken by Deakin University. While this major review is designed to 'map the territory' in numeracy, *A Good Start to Numeracy* is designed to provide early childhood professionals and parents with a basis for identifying effective numeracy strategies.

In other words, *A Good Start to Numeracy* is not an exhaustive listing of all available materials on research and practice, but is an overview of the research and practice in early childhood numeracy. The emphasis is on examining the research literature for effective strategies and practices, and summaries of these are presented at the end of each section as *Sandpit Suggestions*.

Following accepted definitions of early childhood, the literature search was limited, as much as possible, to research on children between birth and eight years of age.

The research on effective numeracy practices in early childhood was explored by accessing major Australian and international databases for research conducted within the last ten years. The five databases accessed were:

- Australian Education Index
- British Education Index
- EBSCOHost
- MATHDI
- PsycINFO.

Additional resources used were the Australian Council for Educational Research (ACER) Cunningham Library holdings and the annual conference paper archive of the Australian Association for Research in Education (AARE).

The main contexts of numeracy for young children have been used as organizing themes for the results of the synthesis of the research literature. These contexts are:

- the home;
- the pre-school; and
- the early years of school.

Following these sections some over-arching issues, such as appropriate pedagogy for Indigenous children, are examined.

The final section provides a brief summary of the review as a whole.

In addition to examining the printed research, electronic sites containing effective strategies and practices have also been explored. Such sites form a valuable resource for practitioners, and the web-page addresses for these have been included in *A Good Start to Numeracy*. Also included, for access by interested readers, is a list of relevant educational organizations.

INTRODUCTION

What is numeracy?

When discussing effective numeracy strategies, it must be remembered that 'numeracy' is a term that is defined in a number of different ways and that everyone believes that their definition is shared by everyone else!

Numeracy, originally a British term, is not used outside Britain and some of its former colonies, particularly Australia and New Zealand. Educators in other parts of the world speak of *school mathematics*, *quantitative literacy* or *mathematical literacy.* Further, a difficulty in capturing the meaning of numeracy stems from the fact that since its coining in the *Crowther Report* (Crowther, 1959) as a set of high-level skills and dispositions needed by a managerial elite, the definition of 'numeracy' has undergone dramatic changes.

After Crowther's original definition, numeracy made a later official appearance in the influential *Cockcroft Report* (Cockcroft, 1982) where it appeared defined as the skills and dispositions needed by ordinary people in work and daily life. Since then, definitions have abounded!

Numeracy is also called school mathematics, quantitative literacy or *mathematical literacy*

The report of a national numeracy conference in Australia in 1997, funded by the Commonwealth, suggests that numeracy

> is 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.
>
> *(Australian Association of Mathematics Teachers, 1997)*

The statement continues:

> *Thus numeracy is:*
>
> - *distinct from literacy;*
> - *more than number sense;*
> - *not only school mathematics; and*
> - *cross-curricular.*
>
> (Australian Association of Mathematics Teachers, 1997, 39)

Numeracy includes the effective use of mathematics to meet the general demands of life.

More recently, the report *Numeracy, a Priority for All: Challenges for Australian Schools* (Department of Education, Training and Youth Affairs, 2000) re-emphasises that

> Current Australian approaches in the early and middle years of schooling broadly include the development of students' mathematical knowledge, skills and understandings, and the fostering of students' capacities and disposition to make effective use of this learning. Approaches tend to emphasise providing support for learning and enabling students to effectively deal with the general demands of their lives. (p 4)

The term numeracy is used in a broad way here.

To make a review of numeracy research and strategies of more use, our use of the term numeracy must be broadened to include research and practice from those many countries where the term numeracy is not used. Terms such as quantitative literacy, mathematical literacy and school mathematics all focus on facets of the Australian approach to numeracy. In light of this, it is necessary for the reader to bear in mind that from here on 'numeracy' will be treated in this broader way.

Why a focus on numeracy?

The importance of a numerate citizenry in a technological age is recognized universally (Department of Education Training and Youth Affairs, 1999; Her Majesty's Inspectorate, 1998; National Council of Teachers of Mathematics, 2000). Steen, in his article on quantitative literacy, argues that 'Considering the deluge of numbers and their importance in so many aspects of life, one would think that schools would focus as much on numeracy as on literacy, on equipping students to deal intelligently with quantitative as well as verbal information … Quantitative thought must be regarded as much more than an affair of the mathematics classroom alone' (Steen, 2001, 58).

In Australia, all State, Territory and Commonwealth Education Ministers have agreed on a national goal that states 'that every child leaving primary school should be numerate, and be able to read, write and spell at an appropriate level' (Department of Education, Training and Youth Affairs, 2001). Similarly, according to Steen, to 'develop an informed citizenry and to support a democratic government, schools must graduate students who are numerate as well as literate' (Steen, 1999, 8). A similar goal is espoused by the Organisation for Economic Co-operation and Development (OECD) countries involved in the *Programme for International Student Assessment* (PISA) (Organisation for Economic Co-operation and Development, 2000), of which Australia is one.

Every child leaving primary school should be numerate …

The OECD review of early childhood education, *Starting Strong*, states that the reasons for investing in early childhood are 'embedded in cultural and social beliefs about young children, the roles of families and government' with the added view that 'childhood [is] an investment with the future adult in mind'. Further, the report also suggests that early childhood policy is shaped by objectives that include 'enhancing school readiness and children's later educational outcomes' (Organisation for Economic Co-operation and Development, 2001, 38). In order to achieve these objectives many countries have developed appropriate pedagogical frameworks for working with young children.

These frameworks tend to focus on children's overall development 'rather than on narrow literacy and numeracy objectives' (Organisation for Economic Co-operation and Development, 2001, 109) although, as expected, approaches vary from country to country. In several countries, including Australia, it is reported that the dominant approach is one in which reading, writing and measuring are integrated into communication and representational skills.

Numeracy creates challenges to the thinking of early childhood professionals and parents …

This approach is consistent with a view that early childhood provision should provide holistic child development and contrasts with countries like the UK and the United States where the emphasis is on more formal instruction in literacy and numeracy as a way of ensuring 'that children will develop mastery of these important skills at the beginning of primary school' (Organisation for Economic Co-operation and Development, 2001, 115).

In the Australian background report prepared for the OECD Review, cited above, the point is made that in Australia the debate over early childhood curriculum focus (child development or subject-matter) is similar to that being held internationally (Press & Hayes, 2000, 40). An issue raised in the background to this report is the effect of reporting school educational outcomes nationally. The effect of a national benchmark for numeracy at Year 3 'may have implications for curriculum and pedagogical practice in the early childhood years, particularly as there is a focus upon the role of early intervention in improving student outcomes' (Press & Hayes, 2000, 41).

An emphasis on numeracy outcomes, no matter which definition of numeracy or which outcomes are aspired to, indicates that early childhood professionals and parents are being faced with challenges to their thinking about, and their

strategies for, student learning in the early childhood years. The following chapters describe what the key issues might be and effective strategies that address them.

Sandpit Suggestions for Everyone

Everyone should remember that:

- Numeracy is more than number
- Many people use mathematics or mathematical literacy as synonyms for numeracy
- Being numerate means using mathematics effectively to meet the general demands of one's current and future life
- Numeracy is everyone's business

NUMERACY IN EARLY CHILDHOOD

The importance of numeracy in the early years cannot be underestimated. As Morrow says in her Preface to *A Snapshot of the Early Years of Schooling*, providing 'the next generation of young Australians with a sound preparation for life requires nothing less than the best that we, as a society, can offer' (Commonwealth of Australia, 1992). The Tasmanian Department of Education's Early Childhood Review also affirms that '[current curriculum] developments in Tasmania firmly position numeracy as a core mathematical concern of the early childhood curriculum' (MacNaughton, 1999).

Numeracy is a core mathematical concern of the early childhood curriculum …

There are at least two incentives for supporting this emphasis. One is that, like literacy, the foundations of numeracy are laid in the experiences of children as they 'undergo unparalleled cognitive, social, and emotional growth' during their early years (Diezman & Yelland, 2000, 48). Research, such as that of Stevenson and Stigler (Stevenson & Stigler, 1992), has claimed that the quality and quantity of early mathematical experiences are the main factors in determining subsequent achievement, a claim more recently supported by Young-Loveridge and her colleagues (Young-Loveridge, Peters, & Carr, 1997).

The second incentive is the large number of children entering pre-schools and schools with some well-developed numeracy skills. Young-Loveridge *et al.* reported that of 154 four-year-olds in New Zealand '80% could rote count to five, 87% could recognise a picture pattern of two, [and] 90% could make a set of two objects (Young-Loveridge et al., 1997). Other researchers report the significant development of numeracy skills by infants (see Sophian, 1998; Wynn, 1998) and pre-schoolers (see, for example, Munn, 1998), and at the present time the Canadian government is conducting a large-scale study of the development of young children before they enter pre-school or formal schooling (Human Resources Development Canada, 2001). This study, the *National Longitudinal Survey of Canadian Youth*, is assessing the development of children under 5-years-of-age using an assessment instrument (*Who am I?*) that is especially designed for assessing, *inter alia*, numeracy at this age (de Lemos & Doig, 1999a).

What is early childhood numeracy?

Australian approaches to numeracy are broader than those in most other places …

It was stated above that Australian approaches to numeracy are broader than those used in most places, and this difference is evident in the research literature into young children's numeracy capabilities. Research that seeks to answer the question *What numeracy skills do young children have?* focuses on early number development, and in these cases one must assume that number *is* numeracy (see, for example, Durkin, 1993); this is a commonly found view in early childhood research. For example, in Munn and Schaffer's investigation of literacy and numeracy in Scottish nurseries, numeracy was defined in terms of Piagetian number development; that is, 'enumeration, classification, comparison, seriation, or one-to-one correspondence' (Munn & Schaffer, 1993, 67).

Numeracy is often equated with number in the early years …

Further support for the view of numeracy as number is provided by assessment research. The recently developed infant numeracy assessment *Utrecht Numeracy Test* (Van De Rijt & Van Luit, 1999) assesses 'milestones in the development of infant numeracy skills' (65) and specifically 'omits measurement, symbolic and non-numerical situations' (66).

However, other researchers, notably in Australia, argue that the foundational processes for numeracy are more general. For example, Hunting offers the view that 'meaningful mathematics learning occurs when each child associates some personal experience — grounded in action, or negotiated through social interactions with others — with symbols' (Hunting, 1999, 80), while Diezman and Yelland argue that the foundational processes of mathematical literacy are

representation, manipulation, reasoning, and problem solving (Diezman & Yelland, 2000), a position that is in agreement with approaches to numeracy adopted in Australia. Similarly, Smith reports on three-year-olds engaged in activities that involve number and spatial sense, and suggests further activities that focus on measuring, time and number (Smith, 2001).

The nature of early childhood numeracy, as it pertains to the home, the pre-school and the early years of school, are further examined in the following sections.

Sandpit Suggestions

Everyone should remember that:

- Numeracy is a core part of the early childhood years
- A good early childhood start in numeracy is critical to later numeracy success
- Many children have well-developed numeracy skills before they start formal education
- Children's early numeracy skills encompass more than number

NUMERACY AT HOME

The place of parents in early childhood education has been recognised as central for many years, and as Ebbeck noted, in her tenets of early childhood education, 'research overseas and in Australia has highlighted the critical role that parents play in fostering children's development' (Ebbeck, 1991, 9). More recently it has been suggested that numeracy programs within the home, 'by involving parents in a non-trivial way, as shareholders and as instructors interacting with the child', not only address sensitivity to the needs of the child, but also automatically incorporate the wider social and cultural context (van Tuill, Leseman, & Rispens, 2001, 149).

The real job in education comes long before children get to school …

This suggestion is in contrast to those who assume that numeracy in early childhood means the early years of school. However, approaches in Australia tend to make no such a restriction. As Brazelton (quoted by Robinson, 1996, 380) puts it, 'the real job in education comes long before children get to school'. The Family and Children's Policy Office in Western Australia quotes the (Western Australian) *Taskforce on Families* as saying that

> there is growing recognition that the experiences and environment provided to children in the first five years of their life plays a significant role in their performance at school … When the home provides opportunities that promote a child's development and when parents have the information and skills to give such opportunities, children are usually better prepared.
>
> (Taskforce on Families in Western Australia, 1995)

The Australian report for the OECD thematic review of early childhood policies (Press & Hayes, 2000) points out that 'parental involvement is regarded [by State and Federal governments] as an important factor in ensuring positive outcomes for children' (Press & Hayes, 2000, 48). In a recent English study of 3- and 4-year-olds, it was found that the 'children showed considerable knowledge and some consistent patterns of responding … [and] the findings are unlikely to result from children noticing the numerals unaided and inventing their own ideas about what they mean' (Ewers-Rogers & Cowan, 1996, 23). In other words, the children needed a mentor or helper, and at this age who better placed than a parent?

Parental involvement is regarded as an important factor in ensuring positive outcomes for children …

The Western Australian Government's Office of Family and Children's Policy, in their family consultation paper *Families and Children in the New Millennium*, argue that 'parents are the most important teachers of the values, attitudes, beliefs and life skills that provide the foundation for children's formal education' (Family and Children's Policy Office, 1999, 8).

Bottle (Bottle, 1998, 2) asserts that 'attitudes, high expectations and encouragement by the parent leads to higher achievement of the child' and further that 'experiences prior to school are important for the attainment of some mathematical skills'. Liedtke, working with young blind children, contends that 'prior to formal schooling parents can, whenever the opportunities arise, present tasks and ask questions that will begin to provide insights into an understanding of number' (Liedtke, 1998).

The view of influential Russian educational psychologist Vygotsky is put by Nixon and Aldwinckle as 'adults and more competent others play a major role in transmission of knowledge and challenging a child to perform cognitively beyond what they can achieve on their own' (Nixon & Aldwinckle, 1997, 111).

Is there numeracy before school?

Basic mathematical understandings are present in children as young as three years of age …

The studies of children's mathematical development undertaken by Jean Piaget were based on interviews with young children before they had had any formal mathematical experiences. Martin Hughes, in his research reported in *Children and Number* (Hughes, 1986), found evidence that many basic mathematical understandings were present in children as young as three years of age, a finding supported by the work of Aubrey and her co-workers (Aubrey, Godfrey, Kavkler, Magajna, & Tancig, 2000). Gelman and Gallistel in *The Child's Understanding of Number* reported that 'children as young as 2 years can accurately judge numerosity provided that the numerosity is not larger than two or three' (Gelman & Gallistel, 1978, 55).

In the United States a study looking at early childhood programs for children at risk found that children of ages three to five had a wide range of literacy and numeracy skills and urged pre-school teachers to maintain children's engagement to further develop these skills and understandings (Zill, Collins, West, & Hausken, 1995). A similar finding was reported by Young-Loveridge (1996). Again in the United States, Kilpatrick and his colleagues reported that 'most pre-schoolers show that they can understand and perform simple addition and subtraction by at least 3 years of age' (Kilpatrick, Swafford, & Findell, 2001).

… including understanding of simple addition and subtraction …

Ewers-Rogers and Cowan suggest that previous studies have examined and observed that pre-school children are capable of, and may well be helped at school by their knowledge of, 'counting, reading and writing of numbers, understanding of simple addition and subtraction, numerical reasoning, classifying of objects and shapes, estimating, measuring, [and the] reproduction of number patterns' (Ewers-Rogers & Cowan, 1996, 15).

Programs for numeracy at home

In Munn and Schaffer's study of 2- and 3-year-olds in Scottish nurseries, it was the frequency of one-to-one numeracy interactions between adult and child that appeared to have the most benefit, and so they recommended that adult carers give more attention to numeracy interactions for maximizing the benefit for children (Munn & Schaffer, 1993, 78). Their recommendation will be difficult to implement as Jones asserts that, at least by primary school teachers, 'parental involvement in the teaching of mathematics has not been encouraged in the same way [as reading]' (Jones, 1998, 65).

This lack of encouragement may explain why there are few programs recorded in the literature that describe parents promoting numeracy development for their children. However, there are some programs that have been devised for other areas of child development that have implications for early numeracy development. One such program is the *Home Instruction Program for Preschool Youngsters* (HIPPY) project.

HIPPY is a home-based parent involvement program …

HIPPY, as its name suggests, is a home-based early-intervention parent involvement program designed to support parents who are seen as their child's first and most influential teacher. HIPPY was developed from a research project in 1969 that studied home-based education for parents of pre-school children and in 1975 HIPPY became a country-wide, home-based childhood program in Israel. The first HIPPY program outside Israel began in Turkey, followed by the United States in 1984.

After reviewing the HIPPY activities with parent educators, parents spend 15 minutes a day teaching their child school readiness skills. Parent educators, themselves parents of young children from the communities they serve, visit each parent at home bringing a storybook and packet of activities. The activities concentrate on language development, sensory perceptual

discrimination skills, and problem solving. Joanne Donne, the Australian National Director of HIPPY says that 'HIPPY sessions focus on basic educational concepts such as shapes, colours, language, logical thinking and motor co-ordination' (Prins, 2001). HIPPY supporters argue that although primarily focused on literacy development, any program developing language and problem-solving skills at this age will have consequential numeracy effects.

The weekly home activity package provides a springboard for educational enrichment and is designed to provide parents with a structure for implementing the program. Each activity takes five to ten minutes and a series of activities focused on a skill or concept is used over a period of time. The activities are the basic elements of HIPPY and the way in which they are used is critical to the successful implementation of the program. HIPPY was introduced recently into Australia by the Brotherhood of St Laurence in Melbourne (Gilley, 1999) and in Hobart by the Brighton Council with State Government, Community Support Levy and Mission Australia funding.

Step-up Anew is similar to HIPPY in that it focused on parents as instructors of their children …

In the Netherlands a version of the HIPPY program was trialled in 1989–1991, but was not as successful as in Israel. However, the Dutch followed up with a version of HIPPY called *Opstap opnieuw* (*Step-up Anew*). The newer program maintained the basic strategies of HIPPY described above.

The goals of the new program, *Step-up Anew*, were 'to improve school achievement in reading, writing and math, and to reduce grade retention and referrals to special education' (van Tuill et al., 2001, 150). The age of onset, (4–5 years), intensity, duration, and frequency of the group meetings, were the same as in the former Dutch HIPPY program and 'the major change concerned the programme's content or "curriculum"' (van Tuill *et al.*, 2001, 149). This curriculum, described as 'emergent numeracy', covered aspects of number and logico-mathematical concepts (van Tuill et al., 2001, 150). Age-appropriate concrete, meaningful and attractive activities were provided to parents to actualize the project within the home.

The reported outcomes of *Step-up Anew* are mixed. The outcomes for children of Turkish background were statistically significant 'modest effects in the cognitive and emergent numeracy domains' (van Tuill et al., 2001, 154), whilst for the children of Moroccan background there were no positive effects at all.

The Family Numeracy Programme*'s over-arching goal was to break the cycle of underachievement and low expectation in numeracy that affects the lives of some families …*

The *Family Numeracy Programme* (*FNP*) (The Basic Skills Agency, 1998) was a one-year pilot program conducted in the UK by the Basic Skills Agency and sought to build on earlier initiatives. The program ran from April 1997 to March 1998, and was designed to help parents improve their own and their children's numeracy skills. The designers of the program claim that the *FNP* presents a model of an effective approach to family numeracy. The program included 'a variety of locally designed approaches. Almost all (the courses) were aimed at parents with children between 3 and 5 years old' (The Basic Skills Agency, 1998, 9).

The *FNP* authors state that their over-arching goal was to 'break the cycle of underachievement and low expectation in numeracy that affects the lives of some families' (The Basic Skills Agency, 1998, 10), and that this could be achieved by improving parents' numeracy skills as 'we know when parents have poor basic skills, including numeracy, their children are more likely to experience the same difficulties' (The Basic Skills Agency, 1998, 10).

The *FNP* sought to find the most effective ways of 'raising the level of home support for numeracy, offering a quick-start and immediate gains in numeracy for 3–5 year old children at risk of underachievement' and 'offering a re-start for their parents' numeracy learning and an impact on their numeracy level' (The Basic Skills Agency, 1998, 2).

Effective factors included activities for parents to develop their child's numeracy at home …

Fourteen experimental family numeracy programs participated in the study and the National Foundation for Educational Research (NFER) evaluated their effectiveness against control (non-participating) children and parents. The key questions to be answered about the *FNP* programs were: *Did the programs work? What kind of program worked best?* and *What are the core features of a successful model?* The analysis by NFER found that the pilot programs did work and at a statistically significant level for both boys and girls, compared with control group children. This was in both number and the use of mathematical language. The programs that the evaluation found to be most effective had three key strands: joint and separate sessions for parents and children, a structured numeracy curriculum, and 'bridging' activities for parents to develop their child's numeracy at home (The Basic Skills Agency, 1998, 30–32).

What can parents do?

Resnick, cited in Boulton-Lewis, (1994, 87) suggests that there are four general differences between learning in, and out of, formal education. The features of 'out of school' learning are summarized as where children work collaboratively with other children or adults, materials are integral aids to most thinking, the learning is closely connected to objects and events, and is situation specific. While Resnick goes on to suggest that school does not prepare children well for the world outside school, for parents, however, the 'learning outside school' list is encouraging, as it is clear that 'outside' learning can fit naturally and easily into home experiences, and the HIPPY, *Step-up Anew* and *Family Numeracy Programme* all attest to the effectiveness of action by parents in the numeracy development of their children.

Parents should ask more open-ended questions …

While most research focuses on planned programs of action for and by parents, it does not suggest that individual parents should not attempt to develop their own children's numeracy. For many years publications providing suggestions for parents who wish to develop their children's numeracy have been available (see, for example, *A Parent's Guide to Early Childhood Education* by Dodge & Phinney, 1992). More general suggestions are to be found in publications such as Ebbeck's (1991) where the advice on 'teaching methods' for parents is to employ a 'learning by doing' approach, and provide positive feedback to the child at all times (187). Further, it is suggested that parents can use a 'variety of questioning techniques' but the more 'useful are the open-ended questions which elicit extended language responses' (Ebbeck, 1991, 188–189). Open questions included in this book are: '*How are these pieces of cheese different? and How are they the same?*' (189).

… and use children's books …

Large research programs, like the Family Numeracy project in the UK, also provide a source of ideas and suggestions for ways in which parents can develop numeracy at home. For example, the folk-tale *The Three Billy-Goats Gruff* can be a stimulus for counting to three, arranging objects in order of size, and developing the ordinal numbers first, second and third (The Basic Skills Agency, 1998, 64). Other sources of ideas for numeracy development based on children's literature can be found in publications like *Links: A guide to maths in children's literature* (Doig, 1989, 2). Here it is suggested that children's books can 'introduce (or reinforce) the vocabulary associated with a particular concept' (e.g. bigness in *Jack and the Beanstalk*) or 'demonstrate the uses of mathematics' via counting books.

Many of the *Sandpit Suggestions* below have been adapted from Liedtke (Liedtke, 1997, 2000) and offer more ideas for parents to continue their children's numeracy development.

Sandpit Suggestions for Parents

- After a task has been completed ask: *Is there another way?*
- Play *Which does not belong?* with familiar objects
- As you compare two objects use and emphasise the terms *bigger/smaller, longer/shorter, heavier/lighter, holds more/holds less* and so on
- Ask: *Sort these (toys, blocks) in some way. Tell me how you did it.*
- Group some playthings and ask: *How have I sorted these?*
- When a model (of a building, car) has been made ask: *Try and build one exactly the same. One a little bit like it. Very different from it*.
- Ask: *Find a spoon for each plate, an egg for each eggcup …*
- When appropriate use the expressions *just as many*, *the same number of* …
- Always count, compare and order aloud using the appropriate language: *I need a **bigger** pot for this soup*
- Talk to your own parents about their numeracy suggestions for young children
- Share your ideas for numeracy activities with other parents
- Borrow measuring and spatial equipment from your local toy library
- Ask your local pre-school professionals for numeracy suggestions
- Join an appropriate parent group or join or start a playgroup

NUMERACY IN THE PRE-SCHOOL

Research, such as that of Stevenson and Stigler (1992), has claimed that the quality and quantity of early mathematical experiences are the main factors in determining subsequent achievement, a claim supported by more recent research. The 'long-lasting impact of an unfavourable start in formal education' is that 'initial disadvantages seldom disappear, and there is evidence that gaps tend to widen' (van Tuill *et al.*, 2001, 148). In the early 1960s *Project Head Start* too had this view when it was created in the United States, and although early research showed that Head Start had only modest effects, more recent research has suggested that there were more lasting effects in areas such as lower rates of repeating grades (see, for example, Lunenburg, 1994).

Initial disadvantages seldom disappear, and there is evidence that gaps tend to widen …

Unquestionably, children's pre-school numeracy experiences should be the best that we can provide, as research shows that 'the benefits for children only occur … if the programs are of high quality' (Huntley, 1998, 1). (For a more detailed examination of the effects of quality pre-school programs see Raban, 2000). However, the questions of what should constitute numeracy in the pre-school and how it should be presented to children remain to be answered.

What is pre-school numeracy?

The research reviewed in earlier sections details the development of numeracy skills and understandings in the early years, up to, and in some cases including, the pre-school years. While much of the research has a focus on number, there is considerable support for the inclusion of other aspects of mathematics such as spatial and measurement skills and understandings.

The authors of the Dutch *Additional Early Mathematics* (*AEM*) program (Van De Rijt & Van Luit, 1998), for example, argue that 'it can be concluded that the [*AEM*] program has a positive influence on the development and use of general sort, match and order strategies and counting strategies which leads to early mathematical competence', a point of view that contrasts with that of Thompson (1997) who recommends 'that counting should constitute the basis of the early years number curriculum' .

The benefits for children only occur … if the programs are of high quality …

The Dutch view is supported by Urbanska, who investigated the numerical competency of Polish pre-school children (Urbanska, 1993) where children's numerical skills, such as division, summing, and equality were assessed. In Australia, Pepper and Hunting (Pepper & Hunting, 1998) found that the level of counting skill did not have a bearing on children's division (sharing) capabilities.

Other researchers have taken an even broader view of pre-school numeracy. For example, de Lemos and Doig (de Lemos & Doig, 1999b) include simple geometric figures in their assessment instrument *Who Am I? Who Am I?* comprises a series of copying and writing tasks in which the child is asked to write their name, copy a series of simple geometrical shapes, write some numbers, letters, words and a sentence, and draw a picture of themself.

Young children can copy simple geometrical shapes such as a circle, a cross, a square, a triangle or a diamond …

Numeracy programs that involve parents working with their own children, such as HIPPY, provide an indication of what pre-school numeracy could involve. The work of *Step-up Anew* in the Netherlands (van Tuill et al., 2001) as reported above, for example, includes logico-mathematical skills in addition to number work. Again, Smith reports of three-year-olds engaged in activities involving number and spatial sense, and suggests numeracy activities that focus on measuring and time (Smith, 2001).

What is an effective numeracy curriculum?

Curriculum is taken to be the numeracy content and the pedagogy adopted …

In discussing 'curriculum' it is taken that, *inter alia,* the critical facets are the numeracy content and the teaching approach adopted. Thus, to ask what are the features of an effective numeracy curriculum in the early years would seem to be a question founded on an assumption of 'one size fits all' unlike Raban's 'third tension' for pre-school provision, which recognizes a dichotomy between a 'view of childhood as a special time in its own right as opposed to an opportunity for the future' (Raban, 2000, 29). This dichotomy needs considered attention as one's view of childhood has a critical impact on the pre-school curriculum.

The United States based Blind Children's Center states that the 'goal of …[its] Infant Program is to maximize an infant's potential and lay the foundation for future development' (Blind Children's Center, 2001) while the opposite viewpoint is taken by the Birmingham Family Times editorial, *Taking Play Out of Preschool*, which states that, as opposed to skills, children 'need experiences with peers, problem solving, books, games, music, art, dramatic play, and fine and gross motor activities' (Editorial, 2001, 1).

The 'one size fits all' assumption is supported neither by the findings of research nor the opinions of stake-holders. Sophian, speaking from a cognitive scientist's perspective, suggests that a 'fundamental insight that has emerged from cognitive development research is that children's cognitive performances are profoundly variable and that performance variability is a reflection of important properties of their knowledge' (Sophian, 1999, 19).

No single curriculum or pedagogical approach can be identified as best …

The National Academy Press in the United States has recently e-published (2000) for the National Research Council Committee on Early Childhood Pedagogy, *Eager to Learn*. This book states that 'while no single curriculum or pedagogical approach can be identified as best, children who attend well-planned, high-quality early childhood programs in which curriculum aims are specified and integrated across domains tend to learn more and are better prepared to master the complex demands of formal schooling' (Bowman, Donovon, & Burns, 2000, 7). Further, developing children's interests during the pre-school years is 'particularly important … when attention and self-regulation are nascent abilities' (Bowman *et al.*, 2000, 9).

The US Department of Education's guide to high-quality early childhood programs contains criteria for evaluating effective early childhood programs (Dwyer, Chait, & McKee, 2000). Numeracy is included as part of mathematics and science for problem solving, and an effective program is one that 'encourages direct, first hand, interactive experiences with natural and manipulative materials … develops children's understanding of key vocabulary … provides instruction and practice in recognizing numerals, counting objects, describing and naming shapes, reproducing and extending simple patterns, using basic measurement tools, and collecting and organizing information' (Dwyer *et al.*, 2000, 18).

Reggio Emilia … projects are in-depth investigations …

Another approach to curriculum claimed to be effective, and one that has become popular recently in Australia (see, for example, Fleer, 1997), is that taken by the community of Reggio Emilia in Italy (New, 2000). This approach to curriculum is one of integration, where groups of children explore topics of interest through project work. Each of these projects is 'an in-depth investigation of a topic worth learning more about' (Katz, 1994).

Further details of the features of effective (Reggio Emilia) projects include project selection considerations that include the 'characteristics of the particular group of children … the school's wider cultural community … the topic's potential contribution to later learning, and … the teacher's own knowledge of the topic' (Katz & Chard, 1998).

As we can see, there are many perspectives on what is an effective numeracy curriculum in terms of teaching approach. However, there remain other curriculum issues that arise no matter which theoretical or philosophical orientation one has.

The first of these issues is that of the appropriateness and emphases of the curriculum content. As described above, many children come to pre-school with the understandings and skills that pre-school programs are designed to instil, while other children do not. A reliance on global theories of child development alone would seem not to provide the basis for programs that are suitable for all.

To provide a program that is appropriate for each child, early childhood professionals need to be aware of the research findings, and how these might be translated into pre-school practice. These findings are readily accessible through the web-sites of organizations such as the National Association for the Education of Young Children (NAEYC) (see, for example, Bredekamp, Knuth, Kunesh, & Shulman, 1992).

Teachers need techniques for assessing the current numeracy understandings of children …

A further aspect of appropriate programming is assessment. As stated by Copley, 'authentic assessment is and should be the basis for educational decisions that effect those children' (Copley, 1999, 183). In this definition of authentic assessment, observing, listening and questioning skills provide data for reflection and interpretation that are the basis for future planning. Clearly Copley considers that there is a need for professionals to have assessment skills and techniques for assessing the current numeracy understandings of the children in their pre-school. Fortunately, suitable formal assessment techniques for assessing children's numeracy capabilities at this age are available (see, for example, de Lemos & Doig, 1999a; Griffin, Case, & Siegler, 1994).

Technology brings with it new challenges …

Another issue is the role of technology in the pre-school. Views on this issue range from those who believe that computers have no place at all in a pre-school through to those who believe the opposite. Yelland has long been an advocate for the use of technology in pre-schools. Her research into teachers' perceptions of computers showed that there is a continuing, although decreasing, negative attitude towards them (Yelland, Richardson, & Russell, 1998). (However, she reports that pre-service teacher trainees were more positive in their attitudes than teachers, indicating that the eventual position would become positive overall.) In terms of the use of computers in pre-school settings, 'though 63% of teachers gave positive response to computers in pre-school there was a high percentage (42%) who did not want a computer in their setting (Yelland *et al.*, 1998, 7).

Yelland lays part of the blame for the low inclusion of computer-based activities in pre-school settings on 'the lack of meaningful application for technology in specific curriculum documents in the area of mathematics' and continues that this is 'despite the fact that research has revealed that young children's use of technology can be beneficial for cognition and learning as well as the social and emotional development of young children' (Yelland, 1998, 52).

The digital divide is the difference in access to technology …

However, the use of technology brings with it new challenges for the pre-school professional. As Clements argues, the 'importance of *guiding children to see and build mathematical ideas embedded* in software cannot be overemphasized' (original emphasis) (Clements, 1999, 124). A further consequence of technology use, Clements claims, is the necessity for careful selection of software, particularly with relation to the software's pedagogical stance. He urges that 'discovery-based software that encourages and allows ample room for exploration is more valuable in this regard' (Clements, 1999, 123).

In the United States there is a concern that 'there are still far too many young children who have little or no access to computers and the Internet' and that 'the

children on the other side of this "digital divide" don't … learn to use the tools that will be a central component of our lives for decades to come' (Ginsberg, 2001). The "digital divide" is this difference in access to technology that exists between children of different social strata.

The resolution of these, and other, issues is not simple but the following suggestions may help to clarify the issues.

Planning for pre-school numeracy

The range of numeracy skills and understandings of children prior to entering pre-school, revealed by the research reviewed in the preceding sections, clearly indicates that the effective pre-school numeracy curriculum must cater for a range of abilities, a range of interests, be more than number, address community concerns, have clear goals and 'never override the "teachable moment"' (Fleet & Clyde, 1993, 130).

Early years professionals have attempted to define what are the features of an effective numeracy program …

Early years professionals and their organizations have attempted to define what are the features of an effective numeracy program. For example, the *Effective Provision of Pre-School Education* (*EPPE*) project that commenced in 1997 in the United Kingdom is such a current endeavour. The *EPPE* project is 'part of a new emphasis on ensuring a "good start" for children' (Sylva, Sammons, Melhuish, Siraj-Blatchford, & Taggart, 1999, 1) by examining the effects on children of different pre-school provision and programs. This is a 5-year longitudinal study that is examining the development of children from different socio-economic backgrounds through their early childhood (3 to 7 years of age) years. Over 3000 children are being tracked as part of the project, but at the time of writing *EPPE* has yet to report its findings.

In the United States, the National Association for the Education of Young Children (NAEYC) has provided early childhood professionals with a list of features that should be considered for Developmentally Appropriate Programs (DAP), which in this instance equates with effectiveness (Bredekamp, 1990). In mathematics, the features of effective programs are that the 'math activities are integrated with other relevant projects, such as science and social studies. Math skills are acquired through spontaneous play, projects, and situations of daily living' (Bredekamp, 1990, 70).

There is a continuum of possible teaching behaviours …

In contrast to Bredekamp's 'math skills are acquired through spontaneous play' position cited above, McMeniman argues that 'on the contrary, teacher control and intervention where the teacher is the skilful arbiter of curricular experiences are critical to the success of students assuming responsibility for their learning' (McMeniman, 1992, 98).

However, Bredekamp has subsequently supported a form of teaching, termed interactive teaching, that is 'a continuum of possible teaching behaviors from nondirective (withholding attention, acknowledging) to directive (more intrusive), with the mediating behaviours of facilitating, supporting, and scaffolding in the middle. The point of such a continuum is that every one of these behaviours is appropriate on some occasions' and further that 'to predict children's developmental and learning needs based on some notion of normative expectations … has always been flawed' (Bredekamp, 1993, 266).

The difference between these two views makes clear that pre-school curriculum in numeracy will have many faces, and that these faces will be critical indicators of the philosophy of the pre-school, but at the same time, these philosophies (crudely polarised as learning through play and learning through structure) need to address the same fundamental curriculum issues. There are two curriculum issues in planning for numeracy in the pre-school that need further exploration here. First there is the general nature of curriculum, and second there is what we know about how children's numeracy abilities develop.

The nature of curriculum, at early childhood, or senior secondary levels, is no easy thing to pin down. For example, Brown and Cleave claim that 'there should be an emphasis on first-hand experiences, opportunities to explore materials, investigate, experiment and [to] try things as well as a chance to practice, consolidate and extend [children's] understanding' (Brown & Cleave, 1991, 42), a claim that most early childhood educators today would understand and endorse.

The nature of the early childhood curriculum has reflected the prevailing view of the child …

On the other hand, the nature of the early childhood curriculum has always reflected the prevailing view of the child. A study of the history of early childhood education shows a range of perspectives on the child that have been held over the years, from the 'natural child' of Rousseau and the 'observant' child of Pestalozzi, to Froebel, Dewey and later, the 'developing' child of Piaget and the 'socio-cultural' child of Vygotsky. In more recent years, research has revealed yet another perspective — that of the 'whole' child, a perspective that is 'permeating the field [of early childhood education]' (Williams, 1999, 22).

Cook observes, however, that 'there is little formal or widespread evidence of practitioner interest in re-assessing the appropriacy of the traditional curriculum and its associated teaching strategies' (Cook, 1996, 57), while Raines contends that 'knowing the theoretical influences on our present practices should not preclude us from examining new interpretations of the theoretical base and research that further explicate the cognitive and social interactions of learning' (Raines, 1997, 86).

Learning experiences cannot simply be introduced without finding out what the children already know …

One such new interpretation is detailed by Fleer in her description of a competency-based approach to the early years curriculum (Fleer, 1997a). The competency-based approach to early years development Fleer claims (citing Mayer) to be both 'hands-on' and 'heads-on', embracing 'constructivist principles, whereby acknowledgement is made of how children actively construct understandings for themselves' (17). This Vygotskian orientation underscores that 'learning experiences cannot simply be introduced without finding out what the children already know' (Fleer, 1997a, 17) and Fleer suggests that in 'early childhood education, it would be difficult to conceive of competence in any other way given the emerging verbal, literate and numerate group of children in our care' (Fleer, 1997, 16).

The position of Vygotsky in the latter part of last century is remarked upon by Williams in her history of the influences affecting early childhood curriculum (at least in the Unites States). She points out that 'major features of [Vygotsky's] work have become salient and are beginning to affect the theory and practice of early childhood education' (Williams, 1999, 20). These features include, notably, the social construction of knowledge that supports 'the image of the whole child and arguments for the roles of process and play in promoting development and learning [which] remains vital today' (22).

The effect of Vygotsky's work has been felt in Australia …

In Australia too the effects of Vygotsky's work have been felt. Lambert and Clyde, in their history and critique of the influences on early childhood curriculum, conclude by suggesting that 'it would seem that early childhood professionals are entering — or being dragged — into a brave new world of curriculum design in the new millennium' (Lambert & Clyde, 2000, 16). This 'brave new world', according to Lambert and Clyde, is very much founded on Vygotsky's ideas, a point with which they take issue. They suggest that 'there are many contemporary theoretical perspectives which provide better contextualized accounts of learning and development than Vygotky's' (Lambert & Clyde, 2000, 24).

In their view, a 'spherical' approach should be taken to curriculum, a perspective that takes the 'key developmental needs during these years' (3 to 5 year-old) as the basis for planning (Lambert & Clyde, 2000, 134). These spheres are the 'three key developmental aspects of exploring, creating and

communicating' (Lambert & Clyde, 2000, 134). Lambert and Clyde argue that working from this perspective implies that early childhood professionals turn their 'backs on primary and secondary curriculum approaches … [as] these are not directed towards a recognition of diversity in learners' (Lambert & Clyde, 2000, 142).

Catherwood presents the concern of curriculum balance in focus and content as 'many early childhood programs, in an effort to avoid being too directive, have presented children with … fine or gross motor skills or sensory development, but provided little opportunity for the arousal of more complex cognitive capacities' (Catherwood, 1994, 49), while 'on the other hand, the opposite approach of overdosing young children on adult-directed information has the inherent danger of weakening children's own initiative' (Catherwood, 1994, 50).

In her view, 'in order to evaluate or facilitate the cognitive competence of young children, the most fruitful starting point will always be the areas of concern and interest to them' (Catherwood, 1994, 54). Sharpe, too, argues for a reactive approach to young children's mathematical learning. She makes an 'appeal for child educators to extend the developmental milestones view of learning and development in favour of a view of learning in a more social context where children's competencies are challenged and extended' (Sharpe, 1998, 81).

Numeracy, like other cognitive skills, develops through concentration, problem-solving, creativity, imagination, exploration, investigation, understanding cause and effect, language and concept formation …

According to Smith, 'numeracy, like other cognitive skills, develops through concentration, problem-solving, creativity, imagination, exploration, investigation, understanding cause and effect, language and concept formation' (Smith, 1964, 86). However, this does not mean that numeracy develops in isolation, but rather develops together with other cognitive skills and the physical and affective skills.

As Cook asserts in regard to numeracy development, 'the evidence for a similar process [to that of literacy] occurring in support of mathematical understanding seems even more convincing in the light of the evidence [since] considered as mediational means, talk, numbers, letters, drawings and so on, are all comparable in their origin and early development' (Cook, 1996, 64). A view of curriculum that is similar is provided by Campbell who suggests that in recent curricula, in the United States at least, 'mathematics is viewed as a way of thinking about quantity, relationships and patterns through modelling, symbolism, inference, analysis, and abstraction' (Campbell, 1999, 106).

An interesting aspect of research that describes numeracy skills is that it clearly supports Carruthers' contention that 'there continues to be a dominance of seeing children's number knowledge in terms of counting errors and minute skills', a view that suggests a deficit model of children's numeracy, with a focus on the subject-matter 'rather than the child's own pattern of development' (Carruthers, 1997, 9).

Campbell suggests that 'pre-school and primary-aged children [should be] challenged to make sense of the mathematics in problem situations that arise in their direct experience, to make sense of symbolic mathematics as recordings of meaningful conceptual relationships, and to make sense of observable characteristics leading to generalizable geometric properties and mathematical patterns' (Campbell, 1999 106). This is a view that resonates well not only with the views of Carruthers, Brown, Cleave and Fleer cited above, but with many early childhood mathematics educators.

What can pre-schools do?

A number of researchers across a span of years can be seen to have a common theme in their conclusions — that of being aware of the child's current understandings.

For example, Munn's study of pre-school children's counting abilities focused on explicating the development of the purpose of counting (Munn, 1994). A clear distinction was found between the purposes that children ascribed to counting and that of adults. Munn's conclusion that 'in order to structure an environment in which children can develop meta-cognitive frameworks for literacy and numeracy activity … early years educators will require an understanding of what these activities mean to the children themselves … and also require information about how the children's understanding may be advanced' (Munn, 1994, 16).

Early years educators will require an understanding of what numeracy activities mean to the children themselves …

Fleer (Fleer, 1997, 35), in her work with key competencies, suggests that these competencies can be used as a basis for numeracy development using group projects. The examples she provides show how the development of understandings, and meaningful practice of underlying skills, can be fostered through this medium. Fleer demonstrates that this approach starts from where the children are, because the teachers work through 'actively seeking out children's views, interests, and understandings' (6), a perspective that reflects that of Munn cited above.

In England, the Early Childhood Mathematics Group advocates that while 'starting with the child' (The Early Childhood Mathematics Group, 1997, 2) is critical, so too is the role of the adult (the pre-school professional). According to the Early Childhood Mathematics Group 'positive attitudes matter', as also does 'providing a rich environment' (5). Similarly, Smith claims that the 'teacher's role is to create a link between children's ability to use informal math and the ability to understand the more formal math found in grade school' (Smith, 2001, 3). She describes a pre-school group of 3-year-olds listening to a story and then following up with literacy and numeracy activities. The numeracy activities focus on matching with socks, mittens, zoo animals, etc., ordering activities using nested measuring cups, kitchen bowls and so on, and playing games like *Where is it?* and *Where am I?*

Teachers work through actively seeking out children's views, interests, and understandings …

Smith's description of classroom practice shows how crucial is the role of the pre-school professional in the planning and implementation of these and similar activities for developing numeracy. Certainly it can be said that there is agreement among early childhood professionals that it is critical to have an understanding of what children know and understand to provide them with the most appropriate environment and program for numeracy development.

The research evidence, outlined in this section, suggests that 'appropriate' in the context of a numeracy program has two possible interpretations: the first is that of *developmentally appropriate*, in which the development referred to tends to be that of Piaget, where age is the determining factor. The second interpretation of appropriate is that of *appropriate to the individual*, a Vygotskian view, where social and cultural factors play a role.

There is agreement among early childhood professionals that it is critical to have an understanding of what children know and understand to provide them with the most appropriate environment …

The interpretation of appropriate that the professional takes will determine the pedagogy that they employ in both planning and implementing the numeracy program. However, the case of an individually appropriate pedagogy raises the issue of assessing an individual child's understanding. Informal assessment using one-to-one interviews may well be the most effective form of assessment, but time implications can be forbidding, particularly if the number of children is large. Less effective but more practical is observation, and eavesdropping, while children engage in talk, play and other activities. For these observations to provide clear evidence of children's level of development, however, the pre-school professional needs a thorough knowledge of children's likely developmental trajectories.

The dearth of suitable tools for assessing children's numeracy at the pre-school level makes critical the dissemination of early childhood research findings to the profession, and the availability of professional development, including time for reflection, even more so.

Sandpit Suggestions for the Pre-school

- Use more than number as numeracy content
- Examine home numeracy programs for a wide range of numeracy ideas
- Make a case for preparing the child for the future
- Make a case for 'one size doesn't fit all'
- Make an outline of your curriculum goals
- Make a list of your criteria for assessing your success in achieving your curriculum goals
- Consider how well your curriculum reflects the children's community
- Build your curriculum on children's interests
- Start from what the child knows and can do
- Develop children's numeracy by exploring, experimenting and investigating
- Ensure that numeracy remains more than number
- Help children use their numeracy skills to make sense of their world
- Help children make sense of their mathematical experiences
- Involve parents as partners in numeracy activities
- Value the contribution the child's cultural background makes to numeracy development
- Base numeracy plans and actions on appropriate evidence
- Use appropriate assessment techniques for gathering evidence of children's development
- Attend regular professional development activities

NUMERACY IN THE EARLY YEARS OF SCHOOL

The numeracy achievements of young children in their first years of formal schooling have been the subject of research for many years. The implications of the research findings have not changed over the years, as current researchers echo the calls of earlier years; for example, Young-Loveridge argued in 1988 that 'the findings of the [present] study have particularly serious implications if a lock-step approach to teaching mathematics is taken, with all children starting at the beginning of a programme regardless of what they already know' (Young-Loveridge, 1988, 3), a warning still relevant today.

Building on children's prior understandings is supported not only by research but also by common sense. Researchers and professionals in early childhood have revealed and documented a great deal of evidence, reviewed in previous sections, that suggests that many children are competent in a wide range of aspects of numeracy prior to formal schooling.

Evidence suggests that many pre-school children are competent in a wide range of aspects of numeracy …

The importance of this research is that it demonstrates unequivocally the need for early childhood professionals to reject the *tabula rasa* model of children and be aware that many of their children will have achieved some, or even most, of the school's numeracy curriculum, before they come to school. A major issue for early childhood professionals is how to determine the numeracy understandings of the children before planning the pre-school program.

What is early years of school numeracy?

The difference between pre-school and school is quite dramatic in terms of the aims, pedagogy, content of the numeracy program and in what is expected of the children. While some children will be able to survive this disjunction others will not, and it seems sensible for professionals working on both sides of the pre-school–school interface to communicate wherever possible. However, the school-based early childhood professional needs to consider what means there are to help them ease the pre-school–school transition for the children. In general, approaches to this transition come under the heading of school entry assessment because as the research evidence makes clear, children have a wide range of knowledge and skills in numeracy by the time they enter school. This aspect of assessment is discussed in a later section of this review.

A dramatic change in numeracy expectations occurs between pre-school and school …

While pre-schools differ in the extent of their numeracy programs, pre-school children are most likely to have had incidental numeracy experiences only, with the possible exception of rote counting activities. At school, however, children encounter a program that is part of a developmental framework extending well into their future. In every education system there is a framework describing numeracy development and expected levels of achievement. There is an expectation by parents, teachers and education systems, that children will come to understand concepts and language and develop skills that will be of use in later years of schooling and life in general. In the *Resources* section at the end of this review are links to typical framework and curriculum documents from some Australian education systems.

Evidence suggests that many children are competent in a wide range of aspects of numeracy …

The content of most Australian mathematics curricula is well represented by the National Profiles in Mathematics (Australian Education Council, 1991). In essence, the curriculum content is focused on early concepts and skills in number, and introductory notions in aspects of measurement and space. Professional resources for teachers also define the content of primary mathematics curricula in this way (see, for example, Bobis, Mulligan, Lowrie, & Taplin, 1999), while at the same time endorsing new approaches to pedagogy.

As with the pedagogy of the pre-school, Piaget's research remains a foundation for curriculum with Vygotsky emerging as a major contributor to classroom thinking. This being said, however, the most influential of recent trends is that of constructivism. This notion exists in many forms and, although not a theory as such, borrows from the theories of Piaget and Vygotsky. A brief outline of constructivism is provided by Bobis *et al*. as 'knowledge is not passively received but actively constructed'; 'students can construct new knowledge through reflection upon their physical and mental actions' and 'learning is a social process' (Bobis *et al.*, 1999. 8–9). Quite clearly the ideas of Piaget and Vygotsky are represented in these tenets.

A constructivist approach emphasises the need to know the child's current knowledge as well as the likely development of numeracy …

A constructivist approach to the classroom further emphasises the point made in earlier sections, that the effective teacher needs to know the child's current knowledge and thinking, as well as understanding the likely, or normative, developmental trajectory of numeracy learning. As Bobis *et al.* put it, 'children's informal and intuitive numerical ideas … form a very important basis for … development' and 'children begin school with a large repertoire of … strategies' (Bobis *et al.*, 1999, 134). In essence, school programs should be appropriate for the child's current state of development.

The question then arises as to what is the usual development of children's numeracy in the early years of school.

Research shows that children make great progress in terms of curriculum content during their first year at school (Suggate, Aubrey, & Pettitt, 1997), which comes as no surprise. Suggate *et al.* tested children on similar content to that found in Australian mathematics curricula, namely rote counting, counting objects, and reading, writing and ordering numbers. Tymms' *et al.'s* study of children's development during the first year of school also showed a 'massive difference to the attainment of pupils in Reading and Maths' (Tymms, Merrell, & Henderson, 1997, 117), after allowing for pupil background factors. Further, as Doig and de Lemos have demonstrated in the Australian context, this progress continues into the second and third years of school (Doig & de Lemos, 2000b). Stewart *et al.'s* study showed that 'progress was made by the majority of students and syllabus expectations were not only reached but exceeded by many of these students' (Stewart, Wright, & Gould, 1998, 562). However, as Mulligan *et al.* have described 'there is evidence that some children are unable to move from concrete to abstract thinking, or visualize mathematical situations at all' (Mulligan, Mitchelmore, Outhred, & Russell, 1997, 366).

Syllabus expectations were not only reached but exceeded by many students …

What are effective numeracy practices?

Effective practices in numeracy may be re-stated as 'what we do' (where the 'we' are classroom teachers) that is effective. The studies below describe a broad field, from teachers' practices revealed by research, to practices based on research and introduced into classrooms. The notion of there being only one effective practice is no longer tenable, and the examples of research into effectiveness outlined below show quite different approaches to a common question.

Planning to use children's prior-to-school numeracy as a starting point for further development has several implications for schools. Of these, two would appear to be crucial: the involvement of parents and the early assessment of what children know and can do. Involving parents in a non-trivial way allows the early childhood teacher to continue children's numeracy development and also enables parents to re-inforce the practices and goals of the school. As Meaney points out, 'community members have expert knowledge about their [children]' (Meaney, 2001, 4).

In her example of a strong link between home and school Meaney (Meaney, 2001) both facilitated and studied the construction of a mathematics curriculum by a community of Maori parents because she believed that 'a sharing of ideas by parents and teachers about what and how mathematics should be taught could reduce the gap between the home and school culture' (3). A less revolutionary approach to parental involvement is demonstrated by the *IMPACT* Project in the United Kingdom.

This project, *Inventing Maths for Parents And Children and Teachers* (*IMPACT*) was one of the largest projects to involve parents routinely in the learning of school mathematics by their children. The authors of *IMPACT* define the project as being 'about involving parents in the school curriculum through the "tutelage" of their children and through sustained patterns of direct contact' (Merttens & Vass, 1990, vii). *IMPACT* started in 1985 with a pilot stage, and then moved on to larger implementation. The pilot results encouraged the development and use of *IMPACT* tasks on a larger scale. Tasks were designed to have children collect evidence or ideas from home, other tasks required children and parents to solve problems together at home, and others asked parents and children to extend, at home, problems initiated at school. The impact of the project was varied; the project evaluation looked at many qualitative variables, and participants claimed that mathematics became more interesting, parents more involved with their children's abilities and development, and children's mathematical achievement developed as did their attitudes. The key point of *IMPACT* for the present discussion is that it is clearly shown that it is possible to involve parents routinely in their children's numeracy development.

Sharing ideas by parents and teachers about what and how mathematics should be taught could reduce the gap between the home and school culture …

A recent study of parental involvement practices in Scotland found that a variety of parent–school partnerships existed, but the dilemma that this variety raised was 'to what extent … should and can schools build partnerships with parents based on [the school] supporting [the parents and community] … Or should the partnership focus on how parents support the curriculum of the school?' (Tett, Caddell, Crowther, & O'Hara, 2001, 54). This is an issue that is seldom raised, Meaney being an exception in this, and certainly one that is particularly pertinent to those working with Indigenous communities.

A psychology-based approach to early numeracy is that of van Luit. Working with 5- to 7-year-old children with special needs, he employed a Gestaltist framework drawn from the work of Wertheimer for developing numeracy. van Luit claims that 'children who learn an algorithm by heart and thus without understanding the structural principles on which it is based are limited to simply following rules … [whereas] … gestalts encourage a child to shorten elaborate counting strategies' (van Luit, 2000, 29). He also claims that counting is an inadequate basis for advancing numeracy development, a claim that questions much of the current research and practice in the early years of school.

Let's look at examples and let's say exactly what it is about this practice that you'd like to see change. …

The study of teachers' practices is believed to be a critical focus for research into effective numeracy teaching and learning, despite evidence that teacher and school effects typically account for less than 10% of the variation between achievement (Creemers, 1997, cited in Brown, Askew, Baker, Denvir, & Millett, 1998). (There is some Australian evidence that this percentage is much larger than that claimed by Creemers (see Rowe, 1998). Nevertheless, calls for change in teaching practice continue, leading Stigler (American Federation of Teachers & National Centre for Educational Statistics, 1998) to declare, 'Let's look at examples and let's say exactly what it is about this [practice] that you'd like to see changed. That's how we come to understand what good teaching is'.

The search for examples of effective practice was the purpose of a major research study conducted in England, the *Effective Teachers of Numeracy*

Study (Askew, Brown, Rhodes, Johnson, & Wiliam, 1997)). In this study teacher effectiveness was classified according to average gains of pupils in specially designed tests. The results of the study may be broken into two main parts: one dealing with the classroom organisation of effective teachers, the other dealing with teachers' beliefs about teaching and mathematics. That there was no common form of classroom organization used by effective teachers was a surprising finding, particularly given the organizational focus of the (English) *National Numeracy Strategy*.

Effective teachers were found to be equally likely to use whole class, small group or individual approaches …

Effective and less effective teachers were found to be equally likely to use whole class, small group or individual approaches in organizing their mathematics lessons. On the other hand, teachers' beliefs about teaching and mathematics were a strong differentiating factor between highly effective and other teachers. Teachers in the study were interviewed about the educational orientations underlying their beliefs and attitudes to teaching, mathematics and styles of interaction with students. The results of these interviews led to the defining of three models of orientation to teaching that explained how teachers approached their teaching of numeracy.

Connectionist teachers have beliefs and practices based on valuing children's methods and understandings …

These orientations were defined as follows: *Connectionist* teachers–who have beliefs and practices based on valuing children's methods, using children's understandings, and placing emphasis on making connections within mathematics. *Transmission* teachers–who have beliefs and practices based on the central role of teaching, and a view of mathematics as a collection of discrete skills, conventions and procedures to be taught and practised. *Discovery* teachers–who have beliefs based on the central role of learning, and a view of mathematics as being developed by children, particularly through interactions with concrete materials.

The connectionist teachers were revealed as the most effective, and thus the question that arises from this study is: *How does one become a connectionist teacher?* Background information collected during the study clearly links long-term professional development courses (ten days or more) that focus on children's conceptions and strategies as the single most important correlate with connectionist teachers.

As expected, the results from the *Effective Teachers of Numeracy Study* raised many questions and the independently initiated Leverhulme Numeracy Research Programme is expected, *inter alia*, to clarify the results of the earlier study (Brown, 2000). The Leverhulme Numeracy Research Programme is a 5-year study that commenced in 1998 and the results to date confirm some of the key findings of the *Effective Teachers of Numeracy Study*. That is to say there is no correlation between the proportion of whole class teaching, use of calculators or amount of homework and class gains in numeracy scores. Higher qualifications in mathematics also appear to have no effect. On the other hand, the effect of longer-term professional development on effective numeracy teaching has not been confirmed either (Brown, 2000).

Some of the key findings of the Effective Teachers of Numeracy Study are confirmed…

The *Effective Teachers of Numeracy Study* clearly supports the conclusion in Thompson's synthesis of research on teachers' beliefs, that 'no description of mathematics teaching and learning is adequate and complete unless it includes consideration of the beliefs and intentions of teachers and students' (Thompson, 1992, 142). Teachers' beliefs about what mathematics is and how mathematics should be taught are used as part of the basis for effective practice in the *Cognitively Guided Instruction* (*CGI*) model of mathematics teaching. This model is founded on the principle that teachers' pedagogical decisions should be made on the basis of a cognitive science understanding of how children learn particular content (Carpenter & Fennema, 1988; Fennema, Carpenter, & Peterson, 1989). In the *CGI* model, the teacher's decisions are regarded as being affected by their knowledge of mathematics and children's mathematical development, and the teacher's beliefs about

each of these (Fennema et al., 1989). The *CGI* approach is similar to the one that has been used in Japanese and other Asian classrooms for nearly fifty years (Stigler & Perry, 1998).

The *CGI* approach is not restricted to a year level, and Warfield and Yttri used the *CGI* approach in Yttri's Kindergarten (the first year of school in the US) to explore the possibilities and to take up the challenges of the National Council of Teachers of Mathematics reform agenda (Warfield & Yttri, 1999). Although this was a difficult exercise the benefits to the children included that the children 'develop[ed] an appreciation for mathematics as a sense-making activity' (Warfield & Yttri, 1999, 11).

Teachers' pedagogical decisions should be made on the basis of a cognitive science understanding of how children learn

Since the early research of Fennema, Carpenter and Peterson, numeracy researchers in Australia and the United Kingdom have included teacher beliefs about what constitutes effective numeracy teaching as a core element of their research. For example, the *Victorian Early Numeracy Research Project* is attempting a detailed analysis of the characteristics of early numeracy learning and effective numeracy teaching practices and the beliefs of effective numeracy teachers.

The project is expected to be completed in the seventy project schools by 2002 (Clarke, 2000) and results to date have been encouraging. From a review of the literature the project team developed a framework of key growth points in children's numeracy learning to allow planning for teaching as well as providing a basis for identifying and describing growth in numeracy. In 1999 the project focused on counting, place value, addition and subtraction, multiplication and division, time, length and mass. Spatial aspects were added to the framework in 2000.

Teachers in the *Early Numeracy Research Project* have reported several common themes in change to their practice. These include: 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 challenge to children; having higher expectations of children; having a 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'; less emphasis on formal recording and algorithms; and allowing a variety of recording styles (Clarke, 2000, 5).

Key elements are a clear focus on concepts and thinking, an emphasis on valuing children's strategies, and encouraging children to share their strategies and solutions …

Thus the key elements emerging from these studies examining effective numeracy teaching practices are a clear focus on concepts and thinking, an emphasis on valuing children's strategies, and encouraging children to share their strategies and solutions. However, another aspect that may need addressing is put by Askew as 'while the interplay between beliefs and practices is complex, these orientations provide some insight into the mathematical and pedagogical purposes behind particular practices and may be more important than the practices themselves in determining effectiveness' (Askew, 1999, 102).

What can schools do?

Early years professionals must link their curriculum to the children in their classrooms …

The above outline of numeracy research clearly suggests that there do exist effective strategies for numeracy development for all children, with some specific strategies for special groups. It is also clear that many of these strategies are currently being used to some degree in the numeracy education of children in Australia. However, as to the question of which strategies are the more effective in the current Australian context, and for the range of children in educational settings, further examination of 'what works' is needed.

While research does show that children make great progress in terms of numeracy curriculum content during their first year at school, whether it be rote counting, counting objects or ordering numbers (Tymms, Merrell, & Henderson, 1997), the evidence of children's numeracy achievement also indicates that current curricula tend to under-estimate the abilities of many children. For example, many curricula restrict children's counting to a range that is well below their real capacity. Thus a good start to effective numeracy practice would appear to be for professionals in the early years to examine their curriculum demands with respect to the ability of the children in their classrooms.

Three strategies stand out …

However, while it is easy to agree that curriculum be re-focused on the child, the reality is that education systems, consultants, text-book authors and parents all have expectations of both teacher and child, and these expectations are not necessarily the same as those of the early years professional. Fortunately, however, in most instances these pressures are content-focused, thus leaving the way open for possible changes to pedagogical practice, and the Sandpit Suggestions at the end of this section provide a list of research-based, effective numeracy pedagogical practices, though three strategies stand out as demanding special attention.

Open questions are extremely difficult to adopt as a classroom strategy …

One of the most obvious pedagogical strategies, and one that should not be restricted to the early years of school, is that of building on the child's current knowledge base. As quoted earlier, Bobis *et al.* have suggested that 'children's informal and intuitive numerical ideas … form a very important basis for … [future] development' (Bobis *et al.*, 1999, 134) and that the school curriculum should therefore be appropriate for the child's current state of development. Again, of children entering school, Stewart *et al.* showed that 'syllabus expectations were not only reached but exceeded by many of these students' (Stewart *et al.*, 1998, 562). Any mismatches between curriculum content and children's capabilities are surely a prime cause of future difficulties in formal schooling contexts, whether the child exceeds the curriculum or *vice versa*.

A second strategy that appears obvious is to build upon both the children's natural curiosity and the rôle model provided by parents by asking 'open' questions, valuing children's answers and accepting them, although not uncritically. The notion of 'open' questions includes that there may be more than one correct answer to the question, or that there are multiple solution strategies, or indeed the question has no definite answer. Unsurprisingly, teachers find open questions extremely difficult to adopt as a classroom strategy (Doig, Groves, & Splitter, 2000), as the emphasis on valuing and accepting all children's responses, while being critical, requires the early years professional to be 'in authority but not *the* authority' (Splitter, 2000), an extremely delicate and difficult balance to maintain.

Teachers should be in authority but not the *authority*

The third strategy that is strongly supported by research is that of whole-class discussion or dialogue. The main purpose of whole-class dialogue is to allow children to share their numeracy understandings and to share their solutions and strategies to problems. Such dialogue also allows the early year's

professional to assess the understandings of children in an informal yet precise manner (Splitter & Sharpe, 1995).

Sandpit Suggestions for the Early Years of School

- Ensure that numeracy remains more than number
- Teach numeracy from where the children 'are'
- Use more open-ended questions
- Base classroom decisions on an understanding of children's numeracy development
- Find out what parents can contribute to their children's numeracy learning
- Give children the opportunity to share their numeracy strategies
- Plan lessons with a conceptual focus
- Emphasise links and connections between mathematical ideas and between classroom mathematics and real -life mathematics
- Have high expectations of children
- Give children time to explore concepts
- Help children use their numeracy skills to make sense of their world
- Assist children make sense of their mathematical experiences
- Value the contribution the child's cultural background makes to numeracy development
- Use appropriate assessment techniques for gathering evidence of children's development
- Base numeracy plans and actions on appropriate evidence
- Attend regular professional development activities

ISSUES IN EARLY YEARS NUMERACY

There are many issues that deserve the attention of early years parents and professionals. These include special provision for students with disabilities, equity for all children, the rôle of parents in their children's numeracy education, and the rôle of assessment in the early years. Following from recent Commonwealth projects into aspects of numeracy provision, this section reviews some of the other major issues relevant to effective numeracy practice in the early years.

Issues that impact on effective numeracy practices…

The issues included here are: the nature of effective pedagogy for early years numeracy; effective practices for Indigenous children; strategies for identifying children 'at risk' of not benefiting from regular numeracy provision; and effective assessment strategies for early childhood numeracy. These issues are addressed by specific numeracy programs in all States and Territories and a comprehensive review of these programs is in Doig & Underwood (2001) *A Survey of Current Australian Strategies in Numeracy*.

Effective Early Years pedagogy

An important consideration in the design of early years numeracy environments is the centre of pedagogical attention; that is, the view early childhood professionals have about the basis of their work — the theory of their craft. The three bases used as organizers in this section are that teaching and learning are either child centred, knowledge centred, or assessment centred. Each of these provides a different basis on which the early childhood professional can view their curriculum and practice.

The basis for professional practice can be child centred … or knowledge centred … or assessment centred …

Of these, the child-centred approach claims a large body of research evidence to support its contention that children use their current knowledge to construct new knowledge (Fennema & Romberg, 1999). This child-centred view of learning, loosely described as constructivism, maintains that effective instruction begins with what the learner brings to the setting. As we have seen in earlier sections, this is a view that is widely supported by early childhood research and practice. Unfortunately for early years professionals in schools there are few assessment instruments or techniques available for gaining the necessary information efficiently or easily. As with similar evidence-gathering in the pre-school, both time and the number of children are critical considerations. However, some of the more efficient instruments that exist have been developed for the Australian context. These include *Who am I?* (de Lemos & Doig, 1999a) and *I can do maths* (Doig & de Lemos, 2000a). While *Who am I?* represents an example of a good approach to school entry assessment, a wider range of early childhood numeracy assessment approaches is detailed in a later section of this review.

Effective teachers of numeracy know mathematics and this provides them with 'roadmaps' that guide their actions …

However, this constructivist point of view can be complementary to other 'centredness'. Research suggests that effective teachers do indeed know the structure of the mathematics that they teach, and this knowledge provides them with content 'roadmaps' that guide the activities that they give children, the assessments they use to gauge progress, and the questions they ask in the classroom. But knowledge of the discipline structure alone does not guide the teacher. A growing body of research provides convincing evidence that there is a nexus between what teachers know and believe about mathematics and their instructional decisions and actions (National Council of Teachers of Mathematics, 1989).

There is a link between what teachers know and believe about mathematics and their instructional decisions and actions …

In the *Effective Teachers of Numeracy Study* (Askew et al., 1997), teachers of numeracy, in the English context, were classified as being highly effective, effective or moderately effective teachers by the mean gains of their pupils in national tests. This study found that teachers' beliefs about teaching and

mathematics was a strong differentiating factor between highly effective and other teachers (these have been detailed in an earlier section of this review).

Assessment-centred practice is likely to have a diagnostic focus …

The final pedagogical centre, assessment-centred, is likely to be diagnostic in focus, and among the best known of current programs is the *Count Me In Too* program based on the research and practices of Wright (Wright, 1991a, 1994) and Steffe (Steffe, Cobb, & von Glasersfeld, 1988). The program has been implemented in all New South Wales government schools and has been adopted by schools in some other Australian States and in New Zealand. The program is an extension of the Count Me In professional development materials and is adapted from the *Mathematics Recovery Programme* (Wright, 1999). The program, recently extended to include measurement and spatial content (see, for example, Outhred, 2001), has teachers undertake professional development to learn about Steffe's counting stages.

As part of the professional development aspect of *Count Me In Too* (and its extensions) teachers view video-clips of interviews with children in which Steffe's counting stages are high-lighted and suitable follow-up teaching strategies are implemented. Armed with this knowledge, teachers explore their own children's placement within the sequence of counting stages and trial recommended classroom strategies for those requiring assistance.

A more detailed examination of assessment and diagnostic numeracy programs is to be found in *Summing Up* (Doig, 2001).

Sandpit Suggestions for Effective Pedagogy

- Describe your view of the nature of effective pedagogy for early years numeracy
- On which centre of pedagogical attention do you work? Why is this your focus?
- Review the techniques that you use for the assessment of numeracy development
- Do you agree that there is a nexus between what teachers know and believe about mathematics and their teaching decisions and actions? Why do you think this?
- What numeracy outcomes do your children's parents expect of your curriculum? How do you know?
- Rate yourself as highly effective, effective or not effective, as a provider of numeracy development. Think about why you gave yourself that rating
- Initiate a numeracy professional development activity for your colleagues

Effective practices for Indigenous children

Participation rates … about the same as for other Australian children …

The discussion paper prepared for the National Review of Education for Aboriginal and Torres Strait Islander People claimed, in 1994, 'that there appears to be little specific analysis of … what is best practice in education for Aboriginal and Torres Strait Islander people' (Yunupingu, 1994). This lack of understanding of what constitutes best practice is a serious state of affairs

when one considers that the same discussion paper records that, for children between 3 and 5 years of age, the participation rate of Indigenous children in education is about the same as for other Australian children (Yunupingu, 1994, 18).

It is eight years since the publication of the Yunupingu discussion paper and there is still much cause for concern as system-wide assessments of numeracy reveal the disparity between the achievements of children with Aboriginal and Torres Strait Islander backgrounds and the achievements of the general population of children.

The report of the 1995 to 1997 Queensland assessment program commented that the performance of Aboriginal and Torres Strait Islanders was 'more than extremely below that of the rest of the population' (Queensland School Curriculum Council, 1998, 18). In a similar vein the National Report on Schooling in Australia 1999 states that the information supplied by States and Territories indicates that 'little progress overall has been made in improving the numeracy outcomes of Indigenous students and, in many cases 'outcomes for 1999 were below those of previous years' (Buckby, 1999, 55).

While the reasons for these disparities are not always clear, more recent research provides indications of strategies that, if universally applied, may well change the situation. While most of the research reflects the number emphasis of the early childhood curriculum, it does provide insights into how effective numeracy programs could be created. Frigo and Simpson investigated the numeracy development of Indigenous children as part of the preparation for a new mathematics curriculum for New South Wales schools (Frigo & Simpson, 1999). An important aspect of this report is that it questions whether the structure of numeracy curricula reflects the numeracy development of Indigenous children. This point appears to be unnoticed by all except Willis (Willis, 2000).

The structure of numeracy curricula may not reflect the numeracy development of Indigenous children …

Bucknall has suggested a range of possibilities for improving Indigenous numeracy achievement. Among her suggestions is one that differed from most other writers at the time, and this is that 'Aboriginal students need to become aware of how and where they and their families use [Western] mathematics' (Bucknall, 1995, 24). The notion is that understanding the usefulness of numeracy and how it relates to 'real life' can motivate and support children's learning. In pre-school and the early years such awareness would be a good start to Indigenous children's numeracy development.

Teachers, and other professionals involved with the numeracy development of Indigenous children, have disseminated effective numeracy strategies — ones that have worked for them, for many years (see, for example, Knight, Hurley, & Flavel, 1993). More current strategies have been documented in the McRae report, *Explorations in improving outcomes for Indigenous students* (McRae et al., 2000). Not unexpectedly, many of the suggested strategies coincide with those suggested as effective for children more generally. Clearly, judging by the wide range of activities recorded in McRae *et al.*, the words of David Kemp, the former Commonwealth Minister for Education, Training and Youth Affairs, 'it is time to stop talking and start doing', have been taken to heart (Kemp, 1999, 16).

Many of these effective practices have been documented in the McRae report — What works? …

Programs to increase educational opportunities for Indigenous students exist in all States and Territories (see, for example, Doig & Underwood, 2001), but the achievements of Indigenous students who participate in such programs is often hidden when State-wide testing programs are the means of assessing numeracy achievement. However, the report of the survey of non-capital *Strategic Results Projects* (*SRP*), of the *Indigenous Education Strategic Initiatives Programme*, has revealed the wealth of achievement by Indigenous students. In *What works? Explorations in improving outcomes for Indigenous*

students (McRae et al., 2000) the extent of some 320 projects aimed at improving the educational opportunities for Indigenous students is laid out in great detail. These projects addressed, *inter alia*, numeracy in pre-schools, schools and the VET sector, and show what can be achieved.

Intensive professional development has improved the achievements of all children …

A different approach to numeracy for Indigenous children, and one that is teacher-focused, is the Tasmanian *Improving Numeracy for Indigenous Students in Secondary Schools* (*INISSS*) program. Its objective is to improve numeracy outcomes for all children, but particularly Indigenous children, in the middle years of schooling through a program of intensive teacher professional development (Callingham, 1999). The professional development program is based around the use of innovative tasks that pose realistic, intriguing and mathematically rich problems for children to solve. The results of this project to date show that 'the program appears to have met its goal of improving numeracy outcomes for all children, but particularly those of Aboriginal students' (Callingham, 1999, 3).

At the other end of the country, Efthymiades *et al.* (Efthymiades, Roberts, & Morony, 2000) report that the Northern Territory's small-scale research projects have confirmed what other research has suggested are the key factors to consider in relation to effective numeracy practice. These key factors include the importance of appropriate professional development programs for local Indigenous staff and community members, the need for meaningful assessment practices and materials that demonstrate what children know, rather than what they do not, and that there should be 'the development of 'tools' to assess these understandings in [the children's] first language' (Efthymiades *et al.*, 2000, 36). Gray argues similarly, but adds that we should be 'raising expectations for success' as well (Gray, 1999, 18).

The need for meaningful assessment practices and materials that demonstrate what children know …

One strategy widely advocated is that of school–community partnerships. However, what the purpose of such a partnership might be is often unclear, although this is not the case for David Kemp, the former Commonwealth Minister for Education, Training and Youth Affairs. He writes that 'stronger partnerships between Indigenous communities and their schools begin with a conversation about how to provide a school where kids feel that they have a place' (Kemp, 2001, 14). This resonates with Howard and Perry's (2001) claim that 'co-operation between the community, students and educators can help bridge the difficult social and learning experiences that many students face in the classroom' (299) and also with Gray's sentiments, above, about having high expectations of children.

Robinson and Nichol (Robinson & Nichol, 1998) describe the characteristics of traditional Aboriginal education, the one with which Aboriginal children are familiar before they come to pre-school or school. In brief, they state that in a 'traditional Aboriginal education, learning was largely oral … [with] observation, imitation and casual instruction … [and that] … learning occurred through actual participation in the life of the community' (Robinson & Nichol, 1998, 2).

The teacher who will be most successful will be one who has high expectations of Indigenous children and who understands the children …

An over-arching suggestion that is claimed to have impact on the numeracy development of Indigenous children is to base teaching, and by implication curriculum, in the 'children's own community' (Bucknall, 1995, 25). Bucknall expands on this idea at some length, providing illustrations of this approach in practice; to her, the language of the community, of the teacher and of mathematics, forms the key to children's rate of development in mathematics.

Frigo too provides broad suggestions dealing with the importance of language, the critical role of school–community links, and the necessity of materials developed for classroom use to be culturally sensitive and appropriate (Frigo, 1999, 25). The teacher's handbook that is part of the support materials for early childhood teachers in Queensland warns that 'when implementing

curriculum, care should be taken to ensure that it is comprehensive, accurate, has depth and meaning and does not trivialise … [Indigenous] … cultures and beliefs' (Queensland, 2001).

But, in the end, as Malin (2000) suggests, 'the teacher[s] who will be most successful will be those who have high expectations of Aboriginal and Torres Strait Islander students, who understand their students well, and who see themselves as learners, also open to new understandings from both their students and the parents of their students' (Malin, 1998).

Sandpit Suggestions for Indigenous Education

- Incorporate the children's local culture into numeracy in a non-trivial way
- Ensure that there is the explicit involvement of parents and other community members
- Make children aware of the mathematics in their community and daily lives
- Use children's first language to develop concepts with understanding
- Ensure that children understand 'mathematical' English
- Make extensive use of oral activities
- Use a whole-class approach as often as possible
- Use the children's interests and experiences as starting points for numeracy activities
- Let children know that you have high expectations of them
- Use practical, contextualized and meaningful activities
- Keep numeracy activities focused on the mathematics, not the context of the activity
- Use assessment techniques that show what children can do

Effective practices for children 'at risk'

As a first step, children 'at risk' need to be identified in order to ensure that appropriate programs are put in place. Identification of children 'at risk' in numeracy falls within the area of diagnostic assessment and is most often carried out on an individual basis, although States and Territories with cohort testing programs often use results on those as a further opportunity to flag potential problems. For example, the ACT uses the results from its cohort testing program to identify the lowest-achieving 20 per cent of students in Years 3, 5, 7 and 9, and New South Wales has a broad screening process, used by classroom teachers, based on the locally developed *Schedule of Early Number Assessment* (part of the *Count Me In Too* package outlined earlier) that is used for this purpose.

Other systems use assessment instruments or procedures that are specifically designed for identifying 'at risk' children on entry to school. For example, Victoria has an *Early Years Numeracy Program*, within which an option is the New Zealand developed *School Entry Assessment* (*SEA*), a series of New Zealand standardized performance tasks (Goldring, 1999; Ministry of Education, 1997). Children entering school are assessed with the *SEA* kit in their first two months at school, and within the context of the regular classroom. The numeracy task, *Check Out*, is in the form of a shopping game and is administered individually by classroom teachers, who then interpret the results in terms of their local curriculum frameworks.

In their report on children 'at risk', Louden and his colleagues (Louden et al., 2000) make the point that many people, teachers included, contend that difficulties in numeracy learning are normal. There are two consequences of this view: the first is that early identification is not seen to be important, and the second is, according to Louden *et al.*, that this encourages a belief that if literacy is well-taught then numeracy will automatically follow. Louden *et al.,* however, believe that there are key strategies, that teachers need to know and follow, for effective numeracy development.

The range and diversity of the children's competencies stand in contrast to the traditional curriculum …

Studies of 'at risk' children reveal issues with respect to specific groups of children, but also provide insights into the development of the wider group of children as well. For example, in her overview of the *Durham Project*, Aubrey (Aubrey, 1997) points out that children from lower socio-economic groups had lower scores on entry to school but made significant progress when tested at the end of their first year. However, she found that the range and diversity of children's competencies in general stood in contrast to the traditional curriculum (sorting, matching and classifying, joining and separating of sets, counting and ordering, recognizing and writing numbers 0 to 10) and goes on to suggest that the school numeracy curriculum may not support and develop the flexible use of children's existing informal strategies. Further, she argues that the social context in which materials are used in the classroom, and the type of discussion they generate, may account for the ineffectiveness of these materials in increasing children's numeracy understanding.

It is to be hoped that the release of reports such as *Mapping the Territory — Primary Students with Learning Difficulties: Literacy and Numeracy* (Louden et al., 2000) will increase awareness of the needs of children with difficulties in numeracy and lead to an increase in support in the next few years as the impact of the *National Literacy and Numeracy Plan* is felt. A significant issue may well be the development and wider use of intervention programs such as those currently being implemented in a limited way.

After the diagnostic phase, there must be a reflective phase where an interpretation of a diagnosis is the basis for action …

Following the diagnostic phase, where children 'at risk' are identified, there must be an intervention phase where interpretation of diagnoses is the basis for appropriate action at an individual level or else the diagnosis is of little benefit. A side effect of this intervention phase is that there is often change in teacher practice as awareness of children's thinking and development is made overt.

The *Year 2 Diagnostic Net* developed and used in Queensland is based upon two phases (Education Queensland, 2001). First, detailed descriptive continua of mathematical development are provided. These continua focus on number, space and measurement, and are divided into key steps that identify significant milestones in development. Hence, they are said to 'map' a child's mathematical development. Teachers in the early years are required to observe their students, and record their observations using a checklist of key indicators.

The second phase of the *Year 2 Diagnostic Net* is 'validation' where teachers use a set of validation tasks provided by the State Department of Education.

These assessment tasks are designed to provide a validation of the teacher's judgements based on observation. Children who are deemed to be 'at risk' are then provided with a suitable intervention program. As the *Year 2 Diagnostic Net* developmental continua are linked to the Queensland Year 1 to 10 mathematics syllabus and resource documents, these continua provide a basis for any program of intervention that teachers may wish to plan and implement.

Assessment tasks are designed to provide a validation of the teacher's judgements that have been based on observation …

A quite different approach to the identification of 'at risk' children is taken by *Mathematics Recovery*, a strategy that started in 1992 as a three-year collaborative research project in north-eastern New South Wales, jointly funded by the Australian Research Council, New South Wales regional government and the Catholic school system (Wright, Stanger, Cowper, & Dyson, 1996). The program, for selected first-year children, is a long-term, individualized teaching program with the aim of advancing the students' arithmetical learning to the point where they may return to the regular classroom.

The *Mathematics Recovery* program is based on the research and practices of Wright (Wright, 1991b, 1994) and Steffe (Steffe et al., 1988) and is based on a diagnostic interview protocol used by teachers with an individual child. The results of each interview are related to a learning framework (counting stages) based on children's number development research. After the initial interview, continuing assessment forms part of the teaching–learning process. Wright and his colleagues have constructed a large bank of teaching tasks for teachers to use in the follow-up program, and selections are made from this bank to ensure that the tasks used are suited to the child's identified needs (Wright, Martland, & Stafford, 2000).

Ensure that the tasks selected are suited to the child's identified needs …

A different approach to intervention is taken by *Mathematics Intervention*. This program is based partly on research into children's early arithmetical learning (see, for example, Steffe *et al.*, 1988; Wright, 1991b, 1994) and partly the research of Hunting and Doig (Gibson *et al.*, 1993; Hunting & Doig, 1992; Hunting & Doig, 1997). The initial assessment for *Mathematics Intervention* requires teachers to assess the extent of the child's mathematical knowledge by observing and interpreting the child's actions as the child works on a set task.

The *Mathematics Intervention* interview protocols allow children to talk about their mathematical strategies and form the basis of Mathematics Intervention (Doig, Pearn, & Hunting, (In press). Teachers involved with the *Mathematics Intervention* program have been offered a course in Clinical Approaches to Mathematics Assessment (Gibson *et al.*, 1993; Hunting & Doig, 1992) to develop and refine their observational and interpretative skills. The developers of *Mathematics Intervention* believe that this is a critical requirement for teachers working with students 'at risk' in mathematics.

Clinical approaches to mathematics assessment develop and refine teachers' observational and interpretative skills …

In the *Mathematics Intervention* teaching phase emphasis is placed on verbal interaction between teacher and children, and between children. Children are withdrawn from their classes and work in groups of no more than three, with a clinically-trained teacher, to assist with the development of their mathematical language skills and co-operative strategies. Evidence from the *Mathematics Intervention* program shows that it allows children to experience success with mathematics (Pearn & Merrifield, 1996).

A more detailed examination of current Australian diagnostic numeracy strategies can be found in *Summing Up* (Doig, 2001).

relation to typical expectations to identify students who need additional support. In addition, the *First Steps* literacy program has recently been expanded to include numeracy (Willis, 2000, 31).

Tasmania began its *Flying Start* program in 1997 and while literacy and other areas are also part of *Flying Start*, there is an emphasis on numeracy skills based on Wright's *Count Me In Too* materials. The Northern Territory has developed its own *Assessment in the Early Years*, a guide for teachers on strategies for identifying students at risk of not achieving at appropriate levels.

Sandpit Suggestions for Assessment

- Clarify your own reasons for assessing children's numeracy
- Find out about a range of numeracy assessment alternatives
- Review the numeracy assessment approaches used in your school
- Develop a whole school plan for numeracy assessment

practices in Australian early years numeracy education can then be correlated with children's development, and effective practices identified.

The results of *Project Good Start* will be disseminated widely so that early years professionals and parents will be informed of what is being done in developing numeracy effectively in the early years.

Project Good Start *is only one way of identifying effective practices…*

Project Good Start is one approach, and it is to be hoped that other perspectives and approaches to gathering and disseminating evidence of effective numeracy practices will be forthcoming from other early years numeracy projects.

As we set forth on the tide of the new millennium, it would appear to be an appropriate moment to look afresh at numeracy learning and development. It is hoped that this review of current research and practice is useful in stimulating productive discussion of the critical issues in numeracy for the benefit of all future young Australians.

RESOURCES

Organizations

The following list gives details of some of the organizations that could be of interest to parents and early childhood professionals. The list has been prepared from the *Australian Education Directory* (2001) published by the Australian Council for Educational Research and is reproduced with permission.

The list is arranged alphabetically and includes organizations that focus on:

- Gifted and talented children
- Indigenous children
- Mathematics
- Parents
- Research
- Rural students
- Students with special needs
- Teachers

ABORIGINAL EDUCATION COUNCIL (NSW)
132 St John's Road, Glebe NSW 2037
Tel: (02) 9660 5696
Fax: (02) 9660 5696

ABORIGINAL STUDIES ASSOCIATION INC
16 Pearson Street, Balmain NSW 2041

ASSOCIATION FOR PRE-SCHOOL EDUCATION OF DEAF CHILDREN INC
8 O'Loan Street, Yeerongpilly QLD 4104
Tel: (07) 3848 0080
Fax: (07) 3848 3553

ASSOCIATION OF PARENTS AND FRIENDS OF ACT SCHOOLS INC
Room 29, Rivett Primary School, Bangalay Crescent, Rivett ACT 2611
Tel: (02) 6287 3538
Fax: (02) 6287 3539

AUSTRALIAN COUNCIL FOR COMPUTERS IN EDUCATION
PO Box 1255, Belconnen ACT 2616
Tel: (07) 3864 3958
Fax: (07) 3812 2129

AUSTRALIAN ASSOCIATION FOR RESEARCH IN EDUCATION
PO Box 71, Coldstream VIC 3770
Tel: (03) 5964 9296
Fax: (03)5964 9586

AUSTRALIAN ASSOCIATION OF MATHEMATICS TEACHERS INC
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CANBERRA MATHEMATICAL ASSOCIATION
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CRECHE AND KINDERGARTEN ASSOCIATION OF QUEENSLAND
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EARLY CHILDHOOD DEVELOPMENT
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EARLY CHILDHOOD EDUCATION COUNCIL OF NSW
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NORTHERN TERRITORY INSTITUTE OF EDUCATIONAL RESEARCH
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PLAYGROUP ASSOCIATION OF NEW SOUTH WALES INC
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PLAYGROUP ASSOCIATION OF SOUTH AUSTRALIA INC (PLAYGROUP SA)
240 Port Road, Hindmarsh SA 5007
Tel: (08) 8346 2722
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SOCIETY FOR THE PROVISION OF EDUCATION IN RURAL AUSTRALIA
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Web-sites

The following list gives details of some of web-sites that could be of interest to parents and early childhood professionals. The list has been prepared from a brief search of the Internet and should be regarded as a starting point only.

The list is arranged alphabetically and includes web-sites that focus on:

- Gifted and talented children
- Indigenous children
- Mathematics
- Parents
- Research
- Rural students
- Students with special needs
- Teachers

Site	Web address
Australian Association of Mathematics Teachers	www.aamt.edu.au/home.html
Connections Project	connections.education.tas.gov.au/Nav/ProjectIndex.asp
Early Numeracy Research Project	www.acu.edu.au/mtlc/ENRP1.html
Early Years Numeracy	www.sofweb.vic.edu.au/eys/num/numclass.htm
Early Years Strategy	www.dete.sa.gov.au
EdNA Early Childhood	www.edna.edu.au/schools/earlychildhood/earlychild.html
Education Network Australia	www.edna.edu.au
Education Queensland: "new basics" Framework	www.education.qld.gov.au/corporate/newbasics
ERIC Clearinghouse (Early Childhood)	http://ericeece.org
First Steps Mathematics	www.eddept.wa.au
Mapping the Territory — Primary Students with Learning Difficulties	www.dest.gov.au/schools/literacy&numeracy/publications/mapping/index.htm

Site	Web address
Maths300	www.curriculum.edu.au/maths300
National Association for the Education of Young Children	www.naeyc.org
National Longitudinal Survey of Children and Youth (NLSCY)	www.hrdc-drhc.gc.ca/menu/youth_child.shtml
New South Wales K-6 'linkages' project	www.bosnsw-k6.nsw.edu.au/
North Central Regional Laboratory (NCREL)	www.ncrel.org
Northern Territory Indigenous Education	www.education.nt.gov.au/indigenous.shtml
South Australian Framework Development	www.sacsa.sa.edu.au/splash.asp
Tasmanian Department of Education	www.education.tas.gov.au/ooe/publications/Curriculum_Issues/4/
United States Department of Education (Early Childhood)	www.ed.gov/offices/OUS/PES/earl_childhood/early_childhood.html
Victorian Curriculum Standards Framework (CSF) Mark II	www.vcaa.vic.edu.au/csf/p-10/index.htm
Western Australian Curriculum Framework	www.curriculum.wa.edu.au/pages/framework/framework08.htm

All site addresses correct as at March 10th 2003.

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(Author's note: This reference list was completed early in 2002. No references after 2001have been included.)