Researching Numeracy Teaching Approaches in Primary Schools

LITERATURE REVIEW

Introduction

In July 2000, the Australian Government Department of Science and Training announced funding for the Numeracy Research and Development Initiative. This important initiative, a key component of the National Literacy and Numeracy Plan is aimed at improving the numeracy outcomes for all primary school students including those who are educationally disadvantaged. There are two strands of this initiative: the Strategic Research and Development Projects strand and the National Research and Development Projects strand. Each State and Territory is undertaking a project under the first of these two strands. The *Primary Numeracy Research Project*, hereinafter referred to as the *Researching Numeracy Teaching Approaches in Primary Schools Project,* was undertaken by the Victorian Department of Education and Training, the Catholic Education Commission of Victoria and the Association of Independent Schools of Victoria.

Background

The *Researching Numeracy Teaching Approaches in Primary Schools Project* was formulated as part of a coordinated suite of projects and programs aimed at improving numeracy outcomes in Victorian schools. In particular, the *Early Numeracy Research Project: Prep–Year 2* (1999-2001), the *Middle Years Numeracy Research Project: 5–9* (1999-2000) and the *Early Years Numeracy Program* (State of Victoria, 2001).

These projects were based on the design elements of the general model of school improvement (see Figure 1 below) that emerged from the work of the *Early Years Literacy Project* (see Hill and Crévola, 1997).

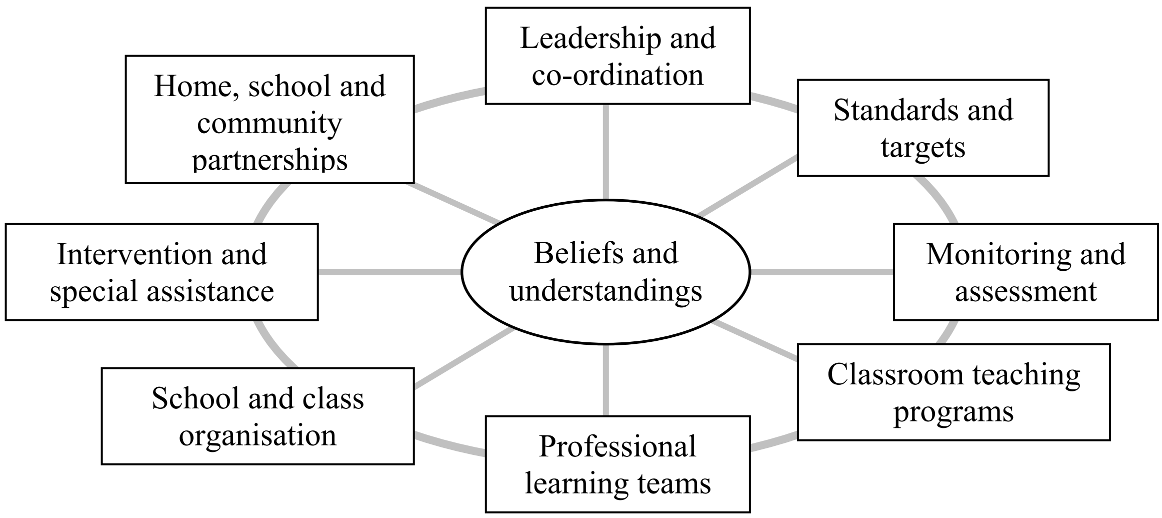

Figure 1 Design elements of a general model of whole school improvement
(Hill & Crevola, 1997)

The model is premised on the view that:

dramatic improvements are achievable within the context of a fully implemented, comprehensive program that is results-driven and involves both system- and school-wide commitment and coordination. (Crévola & Hill, 1997, p. 5)

The nine design elements are: beliefs and understandings, leadership and coordination, standards and targets, monitoring and assessment, classroom teaching programs, professional learning teams, school and class organisation, intervention and special assistance, and home, school and community partnerships. The central importance of shared beliefs and understandings is supported by many in the school improvement field (for example, Barber, 1998; Hargreaves, 1998; Fullan, 1991).

The effectiveness of the general model of whole school improvement was demonstrated by the *Early Years Literacy Project* (1996-1998) which reported significant improvements in early literacy outcomes for schools that had implemented a whole school design approach. Implicit within this was a focus on teaching strategies 'that are both structured and focused on the learning needs of all students' (Crévola & Hill, 1998, p. 14). These strategies or teaching approaches as they are referred to in the *Early Years Literacy Program* (State of Victoria, 1999) were drawn from the research literature and described in terms of the nature and amount of support provided by the teacher e.g. guided reading (Fountas & Pinnell, 1996), reciprocal teaching (Palinscar & Brown, 1984) and shared reading (Smith & Elley, 1994).

The *Early Numeracy Research Project* and the *Middle Years Numeracy Research Project* were also framed in terms of the design elements. These projects reported significant improvement in student numeracy outcomes, largely as a consequence of a greater awareness of student learning needs, but identified the need for further research and development in the area of classroom teaching programs for numeracy. In particular, the outcomes and findings of these projects raised the question of the extent to which it was possible to identify and describe a range of generic teaching approaches similar to those identified in relation to literacy teaching, that met the numeracy learning needs of all students and were effective in improving student learning outcomes.

This question informed the focus and design of the *Researching Numeracy Teaching Approaches in Primary Schools Project.* The objective of this project was to research numeracy teaching practice through the identification of effective classroom teaching approaches in mathematics for students in the early years, Prep – Year 4, and middle years, Years 5 and 6 in a range of primary schools and a special school setting, and their potential for improving student outcomes.

The following review of the literature was prepared to support the implementation of the action research component of this project and to relate the outcomes and findings to what is known about the teaching and learning of mathematics more broadly. The review will consider what is meant by numeracy and its relationship to school mathematics, key findings from related projects, how numeracy teaching approaches might be understood, influences on the implementation and effectiveness of numeracy teaching approaches, and issues in relation to investigating effective numeracy teaching practice.

What is meant by numeracy?

This section will deal with what is understood by the term 'numeracy' and its relationship to school mathematics. Numeracy is and has been a priority for all State, Territory governments and the Australian Government since the early nineties (for example, the *National Literacy and Numeracy Plan*, DEETYA, 1998). As a consequence, many views of numeracy have emerged within the Australian context over the last decade (for example, Willis, 1990; AAMT, 1997; Siemon, Virgona & Corneille, 2001). However, these views tend to have a number of features in common. Firstly, they tend to refer to why numeracy is needed for example:

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

Secondly, they variously refer to the ability to choose, use and communicate mathematical knowledge and skills relevant to context, for example, the statement prepared by the Queensland Department of Education in 1994 reported in *Numeracy = Everyone's Business* (AAMT, 1997):

> Numeracy involves abilities which include interpreting, applying and communicating mathematical information in commonly encountered situations to enable full, critical and effective participation in a wide range of life roles (p. 12)

A third feature that these views have in common is their insistence that numeracy is 'more than number'. For example:

> Numeracy is more than just being able to manipulate numbers. The content of numeracy is derived from five strands of the mathematics curriculum - space, number, measurement, chance and data, and (pattern and) algebra - as described in the National Statement and Profiles. (*Numerate Students, Numerate Adults*, Education Department of Tasmania, 1995)

This broadly encompassing view of numeracy is in marked contrast to the view adopted for the purposes of the National Numeracy Strategy in the UK. In their review of the literature related to the British Government's National Numeracy Strategy, Brown, Askew et al (1998) refer to the evolution of numeracy from its likely origins in the Crowther Report in the late fifties as 'meaning scientific literacy in a broad sense' (p. 363), to the multiplicity of meanings evident today. In particular, they refer to the tension between viewing numeracy as a social practice that incorporates a range of diverse knowledges and skills pertinent to different sociocultural pursuits, and numeracy as proficiency which positions numeracy, for example:

> … as a culturally neutral and value-free set of autonomous '*basic numerical skills'* … emphasizing mental and written calculation and knowledge of number facts such as multiplication tables (p. 363)

While it is the latter view that is embodied in the National Numeracy Strategy, the meaning of numeracy preferred by the Leverhulme Project team is:

> that relating to social practices (Baker & Street, 1993), but for the purpose of this study the definition was taken pragmatically to be that of the National Numeracy Strategy, which regards numeracy as 'proficiency' which requires a combination of understanding, skills, and confidence and includes the motivation to solve contextual problems ... In the related documents it becomes clear that in the Strategy the emphasis is on decontrextualised calculations, with a minor inclusion of traditional word problems. (Brown, Askew et al, 2003, p. 2-3)

The view of numeracy as a social practice has particular relevance to researchers and practitioners approaching the teaching and learning of numeracy from a post-structuralist perspective. For example, Klein (1999) views competence and disposition as products of social practices and discourse:

> Numeracy is not a gift but a social practice always in process; it is contextual and always constituted by, and constitutive of, learners. (p. 310).

This view of numeracy is also prevalent in the adult education field where, for example, numeracy is seen as 'critical maths', that is, 'maths which is contextualised within the maths learner's realities' (Yasakuwa, 1995, p. 38). However, within this field, and to some extent more broadly, numeracy is also seen as a subset of literacy. While it is now widely recognised that numeracy is distinct from literacy (for example, AAMT, 1997), the critical role of language and discourse in the negotiation of mathematical meaning is also widely acknowledged (for example, Pimm, 1987; Cobb & Bauersfeld, 1995, Voigt, 1995; Klein, 1999).

Zevenbergen (1996, 2000) takes the view of numeracy as a social practice one step further. She argues that the language and practices of mathematics classrooms can powerfully work to exclude some and advantage others. In a related paper, Adler (1999) suggests that drawing attention both to the language and how it is used to support mathematics teaching and learning is essential for students from different cultural and linguistic backgrounds. This is echoed by Klein (1999):

> A poststructuralist understanding of the individual constituted through discourse places the onus squarely on the uses of language and practices of school mathematics to construct students who know themselves as competent and capable numerate persons. (p. 310)

This view of numeracy connects strongly with the considerable literature on situated cognition (for example, Strässer & Zevenbergen, 1996). What this suggests is a growing awareness of the need for mathematics to connect with real world pursuits, to be meaningful and purposeful. This is reflected in Willis' (1990) call for curricula that enables learners to see that mathematics is personally relevant to them and useful in their everyday life.

A number of attempts have been made to link numeracy more overtly to school mathematics, or at least a more critical approach to the practice of 'doing' mathematics at school. For example, the Realistic Mathematics Education Project in The Netherlands (Vershaffel and De Corte, 1996) has made a concerted attempt to develop authentic mathematics problems that encourage students to 'use their common sense knowledge and experience about the real world' (p. 128) rather than approach mathematical problem solving as the search for a 'hidden' algorithm which is then solved and interpreted independently of the context or situation in which it is embedded. A similar approach is evident in a number of the reform oriented projects funded by the National Science Foundation in the United States, for example, the Connected Mathematics Project developed at Michigan State University (see Lappan, 1999).

In the United States, the term numeracy is rarely used, although there are similar concerns about the social inequities that arise if students are unable to proceed to further mathematics. In this case, the term, quantitative literacy, would appear to equate to Australian notion of numeracy.

> To define and measure quantitative literacy, we need a model that spans a wide variety of contexts … one based on a categorization of mathematical behaviours into six major aspects:
>
> - Data representations and interpretation
> - Number and operation sense
> - Measurement
> - Variables and relations
> - Geometric shapes and spatial visualization
> - Chance
>
> Quantitative literacy may be defined as the ability to interpret and apply these aspects of mathematics to fruitfully understand, predict, and control relevant factors in a variety of contexts. As here defined, quantitative literacy constitutes a significant part of the gateway to advanced mathematics. (Dossey, 1997, p.173-4)

While these views of numeracy point to generic aspects of school mathematics, they tend not convey an immediate sense of what this might mean in practice. By contrast, an understanding of literacy as reading, writing, listening and speaking, conveys an immediate sense of what schools might do to ensure students are able to participate in further schooling, work and society. An interesting and useful view of numeracy that bears some relationship to the literacy competencies is provided by the list of six universal mathematical activities identified by Bishop (1991), that is: locating, measuring, counting, designing, playing and explaining.

The fact that numeracy has become a major priority area for the Australian Government and all State and Territory governments in recent years has led some to conclude that school mathematics is somehow being diminished or devalued. To be numerate, however, would seem to involve not only a capacity for informed, critical, reflective thought that draws on whatever level of mathematical knowledge and skills an individual possesses, but also the disposition to use and appreciate all that is powerful and beautiful in mathematics. In much the same way that literacy enables us to engage with the powerful and beautiful ideas expressed in literature or art.

> Far from being some sort of minimalising threat to the sanctity of mathematics, numeracy is the most potent force for enhancing and expanding what we do in the name of school mathematics – it is about providing the *means* and the *opportunity* to engage with the very tools and ideas that make mathematics learning possible, purposeful and enjoyable. (Siemon, 2001)

Viewed in this way, numeracy, like literacy, is fundamentally about access to **the means** by which individuals can engage productively and responsibly with others as informed, critical members of various communities.

The Project on International Student Achievement (PISA) was commissioned to investigate, among other things, the general preparedness of students in a wide range of countries for their lives after school. To this end, PISA is focussed on 'reading literacy', 'mathematical literacy' and 'scientific literacy' over time. For the purposes of this project, 'mathematical literacy' is defined as:

> the capacity to identify, to understand, and to engage in mathematics and make well-founded judgements about the role that mathematics plays, as needed for an individual's current and future life as a constructive, concerned, and reflective citizen. (Lokan, 2000, p. 16)

The following view of numeracy was used to inform the design and implementation of the *Researching Numeracy Teaching Approaches in Primary Schools Project*. It goes beyond what numeracy might be needed for in the longer term, towards what numeracy might *involve* in the context of schooling.

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

Specifically, numeracy is seen to involve:

- the key underpinning mathematical knowledge identified by the *Early Numeracy Research Project* and related research
- the capacity to apply what mathematics is known in a particular context to achieve a desired purpose
- the actual processes and strategies needed to communicate what was done and why (Siemon, Virgona & Corneille, 2001).

Although the experience of Prep to Year 6 learners should be relatively seamless and advice to teachers reasonably consistent, the focus on the Early Years (Prep - 4) and the Middle Years (Years 5 and 6) in the Australian Government's Numeracy Research and Development Initiative recognises the difference between the learning needs of young children and the learning needs and dispositions of prepubescent / adolescent upper primary students (Siemon, Virgona & Corneille, 2001). The distinction is also appropriate for another reason as it marks a shift in the conceptualisation and cognitive demands of numeracy, from a focus on the essential underpinning mathematical ideas and strategies in the early years to more of an emphasis on the use and application of those ideas and strategies in an increasing variety of contexts in the middle years. The notion of generic teaching approaches is an important one in the context of effective whole school improvement. However, helping teachers structure their teaching in a more focussed and purposeful way will only be served by carefully teasing out the particular attributes of each approach as it relates to different levels of primary schooling, every student's need for different levels of teacher support at different times, and changing notions of numeracy.

Numeracy Research and Development – Key Findings

In recent years, there has been a significant increase in the number of numeracy projects funded by the Australian Government and/or the various State and Territory governments (for example, ACER, 2000). In Victoria, the then Department of Education, Employment and Training, together with the Catholic Education Commission of Victoria and the Association of Independent Schools of Victoria, commissioned a range of research projects and programs aimed at improving numeracy outcomes in Victoria. Two of these projects, the *Early Numeracy Research Project* (for example, Clarke, Gervasoni & Sullivan, 2000) and the *Middle Years Numeracy Research Project* (for example, Siemon, 2000, Siemon, Virgona & Corneille,2001 & Griffin, 2000), have provided valuable information about what should be taught when, to enhance numeracy outcomes.

For instance, a major outcome of the *Early Numeracy Research Project* was the development of a learning and assessment framework of 'growth points'. This framework was used to inform the development of the *Early Years Numeracy Interview* (State of Victoria, 2001) which has proven to be a powerful tool for assessing students' numeracy development during the first five years of schooling (Clarke, D.M., 2001). It provides teachers with in depth knowledge about their students' mathematical understandings, informs focused teaching of students and allows teachers to track their students' progress. The framework and the interview, together with interactive professional development, provided the opportunity for teachers to build their own knowledge of mathematics and the teaching of mathematics. A similar learning framework underpins the *Count Me in Too* project in New South Wales which has been implemented in the early years of schooling with gratifying results (Gould, 2000).

While classroom teaching programs were not examined to the same extent, many teachers were motivated to make changes to their classroom practice as a result of a having a better understanding of their students' learning needs and access to high quality professional development (Clarke, D.M., 2001). The project also identified a number of key characteristics of highly effective teachers of mathematics in the early years (Clarke & Clarke, 2002).

An important outcome of the *Middle Years Numeracy Research Project* was the development of an Emergent Numeracy Profile that maps students' numeracy performance against a continuum of rich descriptors that can be used to inform subsequent instruction. This project also identified that teachers working in professional learning teams supported by strong and effective leadership and coordination were associated with higher levels of student numeracy performance. While there was evidence to support the efficacy of adopting a broader range of teaching practices such as open-ended questions, investigations, manipulatives and a focus on explanations and discussion, the specifics of how teachers interacted with students to support their learning, was identified as an area for further study (Siemon, Virgona & Corneille, 2001).

In a longitudinal study of numeracy progression over time, the Leverhulme Project in the United Kingdom reported (Brown et al, 2003) that 'dips in facility sometimes occur between the end of one school year and the start of the next … children appear to learn more quickly in the early years of primary school' (p. 8) and while there was some evidence that school curricula affected item profiles, 'a major and expensive process of systematic curriculum change [referring to the implementation of the *National Numeracy Strategy*] has produced only very minor effects in attainment' (p. 13). The authors claim that these results 'highlight the complex yet weak relationship between teaching and learning' (p. 22). In addition, case studies conducted over the period of the project revealed that for many individual children their progress 'is not smooth and may include periods of stasis until new ideas are fully grasped' (p. 17).

> Thus the progress of individual children shows many variations and appears to depend on many factors, relating to the child's ability, personality and inclinations, the home circumstances, and on whether the teaching addresses their needs, especially in relation to mathematical ideas which commonly cause problems. For different children the balance of these factors is different, and may change over time for any particular child. In spite of general trends, it therefore seems to be impossible to predict the future progress of any specific child from their earlier test results. (p. 22)

Data from this project also suggest that there was no association between a number of measurable aspects of pedagogy and pupils' gains, for example, they reported that 'more whole class teaching is associated with both higher and lower gains' (Brown, 2000, p. 5), that frequency of calculator use or homework was also associated with higher and lower gains, and that the differences 'within each class is generally much larger than the differences between classes' (p. 5). Where there was some evidence of larger than expected gains or consistently high gains in case study schools, the team believed that

> this might be because teachers in those schools have a shared commitment to focusing on childrens' mathematical learning rather than on provision of pleasant classroom experiences, on providing a challenge rather than a comforting curriculum, and on having high expectations of initially lower attaining pupils. (p. 5)

They go on to say that 'these may be more important than other differences in teaching style' (p. 5). However, at that stage they were not sure that such gains would be sustained.

While there is little systematic data in relation to indigenous students, the work that has been done to date (for example, Efthymiades, Roberts & Morony, 2000; Perso, 2003) suggests that sensitivity to cultural issues, concerted attempts to build effective relationships, locate learning opportunities and assessment in the realities of every-day life, and an emphasis on conceptual rather than procedural approaches is likely to be successful. Perso (2003) directly links the development of numeracy to pedagogical practice.

> Numeracy involves fostering a disposition to use mathematics outside the mathematics classroom; and this is fostered by the pedagogies used by teachers to enhance that disposition. ... In the case of teaching Aboriginal students it is imperative that teachers build

> a rapport based on personal understanding, empathy and respect. This is true for all children, but it would seem that Aboriginal children are at a greater risk of not becoming numerate than non-Aboriginal children if this is not done, due to the importance of personal relationships in their cultures. (p. 111)

Efthymiades et al (2000) make a plea for 'investment in professional development for local indigenous staff and community members' and meaningful assessment that 'reveals what students do know, rather than what they don't' (p. 30).

Although there is considerable research pointing to the efficacy of 'reform-oriented' approaches to teaching and learning mathematics (for example, Boaler, 2002), and an impressive array of Australian research projects on numeracy (for example, ACER, 2000), very little of this has focussed on classroom communication and the teacher's role in initiating and sustaining productive interactions in relation to the teaching and learning of mathematics.

Understanding Numeracy Teaching Approaches

Origins of teaching approaches

The notion of 'numeracy teaching approaches' has its origins in the work of the *Early Literacy Research Project* (Hill & Crévola, 1997) which demonstrated the effectiveness of a small number of generic teaching strategies on the development of students' literacy. These strategies were specifically designed to support the development of students' reading and writing within the 2 hour literacy block and are differentiated on the basis of the relative levels of teacher support and student independence. For instance modelled reading and modelled writing are considered to involve high levels of teacher support and low levels of student independence. Shared reading and shared writing are used to refer to a more collaborative relationship between the teacher and the students, while guided reading and guided writing are strategies that involve low levels of teacher support and high levels of student independence.

In the *Early Years Literacy Program* (State of Victoria, 1999), these teaching strategies are referred to as teaching approaches and the relationship between them is represented in the following way.

The nature of this relationship can also be represented orthogonally as shown below.

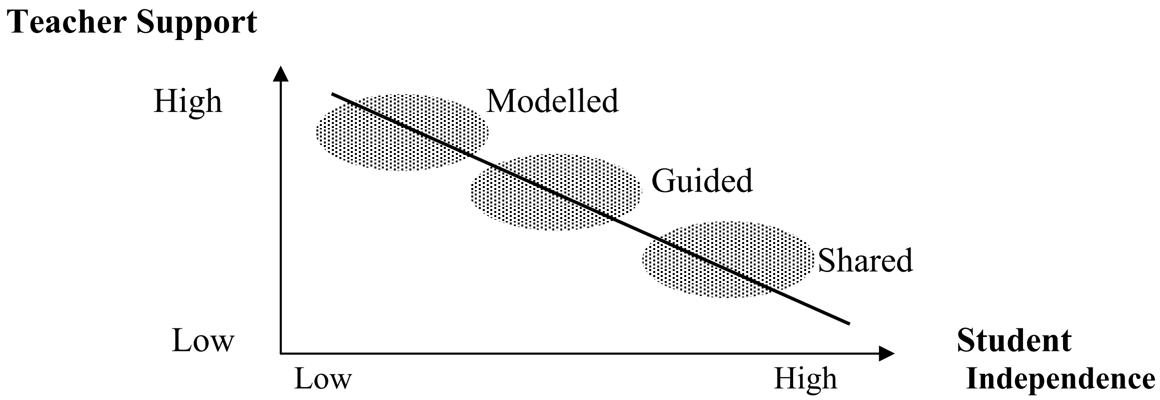

Figure 2 Representation of literacy teaching approaches

The approaches themselves can be characterised as describing different patterns of teacher behaviour as they interact with students to scaffold their reading and/or writing. The literacy research found that student improvement was maximised where these teaching approaches were focussed on the learning needs of all students (Crévola & Hill, 1998) and were used in the context of a structured classroom program involving a combination of whole class, group and individual teaching (Hill & Crévola, 1997; Hill & Russell, 1999).

Basis in theory more generally

Apart from their origins in literacy, the notion of 'numeracy teaching approaches' can be grounded in theory and research more generally. For example, it is widely recognised that teachers play a vital and significant role in students' learning (Cuttance & Stokes, 2001; Siemon, 2001); that focussed time-on-task is most consistently linked with pupil achievement (for example, Brophy & Good, 1986); and that childrens' development is enhanced through social interaction with others who have expertise (for example, Vygotsky, 1978; Wertsch et al, 1995).

More specifically, the work of Vygotsky (1978) has identified the importance of scaffolding student learning. The term scaffolding is used to describe temporary support that teachers give to students to challenge and support them to achieve beyond what they can do independently. Anghileri (2002) writes:

> metaphor of scaffolding was introduced to explore the nature of adult interactions in children's learning, in particular, the support that an adult provides in helping a child to learn how to perform a task that cannot be mastered alone (p. 49).

Clearly, the level of teacher support is relative to the particular learning needs of the students concerned. This is consistent with Vygotsky's notion of the Zone of Proximal Development (ZPD). Students who are most dependent on teacher support might be expected to be working at the margin of their Zone of Proximal Development, requiring the teacher to model, prompt, demonstrate, or coach, in order to come to new understandings and insights. Students who are least dependent on teacher support would be expected to be operating well within their Zone of Proximal Development, requiring little or no intervention or scaffolding from the teacher and accessing a range of appropriate metacognitive strategies to monitor their own learning. In this case, a different set of teacher actions might be invoked, for example, reflecting, celebrating, inviting and listening.

This notion of scaffolding as a gradual progression from embedded activity to generalisation is reflected in the literature on situated cognition. For example, Brown, Collins and Duguid (1989) propose a model which proceeds from real world activities where learners serve an apprenticeship and are coached, to work on more collaborative and problem solving activities with the more learned other, before finally attaining a position whereby they can reflect on and articulate their practice to arrive at generalisations. An important qualification of this approach is the work of Davydov (reported in Sierpinska & Lerman, 1996) which questioned the assumption that children must always proceed from the concrete to the abstract.

Current sociocultural/constructivist approaches to teaching and learning advocate an active, reflexive role for the teacher (for example, Wertsch et al, 1995; Cobb & Bauersfeld, 1995). This stance has its origins, or at least much in common, with *symbolic interactionism* (for example, Bolster, 1983), which assumes that:

> people act on the basis of the meanings events have for them; the meanings of events arises out of social interaction, and each person 'selects, checks, suspends, regroups and transforms the meanings in the light of the situation in which he is placed and the direction of his action.' In all our activities, we act on the basis of intent, observe the reaction of others to our behaviour, and act purposefully again. … Applied to the process of teaching, the assumption of reflexivity requires envisioning each classroom as a small culture created by teacher and students as they work together over a period of time. (p. 303)

This suggests that a deeper understanding about the ways in which teachers contribute to the shaping of classroom cultures and the interactions that occur within them will be relevant to any investigation of numeracy teaching approaches. Only the more general work will be considered here as the considerable work on classroom cultures in relation to the teaching and learning of mathematics is discussed in the following section.

Discourse analysis has been used to explore aspects of classroom communication for over thirty years. In particular, this has focussed on turn taking and the 'almost incessant repetition of the sequence I(nitiation) – R(esponse) – F(eedback) in teacher pupil exchanges' (Pimm, 1994, p. 138). Although there are serious limitations in this approach, for example, the tendency to ignore the content of the interaction, this type of analysis can expose imbalances in teacher pupil relationships of the type identified by Zevenbergen (2000). The I-R-F or I-R-E (E for evaluation) pattern is well recognised in the literature and leads on to a discussion of *communicative competence* or knowing when and how to participate, in particular who can say what, when and to whom (Pimm, 1987). This is a powerful notion as it suggests that teachers and pupils learn how to communicate in classrooms in very specific ways and that there is a reflexive relationship between individuals and implicit 'rules'. That is, interaction shapes and is shaped by the nature of the prevailing classroom culture and the taken-as-shared meaning within that culture (Voigt, 1995). This suggests that while teachers might adopt particular interaction pattern intentionally, such 'moves' will only be effective to the extent that the 'new language game' is appreciated and understood by students.

> Findings from each of the classroom studies reviewed … indicated that classroom communication was rule governed, and that even though the teacher established routines for pupil participation in lessons, the specific requirements for participation shifted frequently within and across lessons … For pupils to participate appropriately in any particular activity, he or she had to be engaged in actively interpreting the signals of the teacher with regard to the participation structure (who was chosen to participate and how responses were acknowledged) as well as actively tracking the development of academic content of the lesson (Morine-Dershimer, 1985, pp. 168-9)

An interesting observation from this work was that 'pupils in general were more attentive to pupil comments that were acknowledged by teacher through praise or extended questioning' (p. 169). Different patterns of attention and participation were also observed suggesting that teachers need to access/initiate a range of interaction patterns to accommodate multiple discourses.

The 'game' metaphor for classroom communication has been recognised by many authors (for example, Morine-Dershimer, 1985; Pimm, 1987; Zevenbergen, 1996). It supports a view of classroom communication as a socially situated, purposeful endeavour with different rules for different activities and different levels of participation and success.

The use of metaphors for particular patterns of interaction, such as 'modelled', 'shared' and 'guided', also has a basis in literature as being an effective way to prompt conversations about the teaching and learning process. For example, in a review of the use of metaphors in relation to classroom practice, Thomas and McRobbie (1999) conclude that metaphors can be used to describe the characteristics of teachers, learners, and learning environments; they offer a powerful means of initiating reflective processes regarding all aspects of teaching and learning, and they can be used to alter the referents that guide the practice of teachers and learners.

Relationship to mathematics education research

Current interactionist approaches to the teaching and learning of mathematics acknowledge the interdependence of teaching and learning.

> For an interactionist mathematics educator learning is not just an endeavour of the individual mind trying to adapt to an environment, nor can it be reduced to a process of enculturation into a pre-established culture. In the mathematics classroom, the individual construction of meaning takes place in interaction with the culture of the classroom while at the same time it contributes to the constitution of this culture. … In particular, students learn what counts as mathematical thinking by observing what is attended to (for example, quantitative and spatial representations) and what kind of solutions are distinguished by the teacher and other students as 'insightful', 'simple' or 'elegant'. (Sierpinska & Lerman, 1996, p. 851)

The interactionist view restores some of the earlier recognition given to the role of the teacher. Bauersfeld (1995) underscores the critical nature of the teacher's role in the education process.

> As an agent of the embedding culture, the teacher functions as a peer with a special mission and power in the classroom culture. The teacher, therefore, has to take special

> care of the richness of the classroom culture – rich in offers, challenges, alternatives, and models, including 'languaging' (p. 283)

Such a view acknowledges an active role for the teacher in shaping classroom interactions to achieve specific outcomes. This active role for the teacher has broad support and represents a change from some earlier advice to teachers from research. For example, as Lerman (1998) said, 'the metaphor of students as passive recipients of a body of knowledge is terribly limited: so too is the metaphor of students as all powerful constructors of their own knowledge' (p. 70). Wood (1998), arguing for an active role for the teacher, proposed that the individual gaps in student learning between what an individual student knows and what he/she can recognise, create space for learning 'by means of a number of 'scaffolding functions', one more knowledgeable than the learner may help to bridge such gaps, essentially by activating problem solving in the child' (p. 60). This suggests that the role of the teacher in identifying appropriate starting points, pathways, tasks and challenges is crucial in children's learning.

The case for researching the effectiveness of structured teaching approaches in Prep – Year 6 numeracy is supported by recent research which asserts that effective teaching requires teachers to take an active lead in student learning. For example, it has been widely recognised that students learn mathematics most effectively in an environment that supports the negotiation of meaning and the discussion and elaboration of strategies and solution attempts (Cobb & Bauersfeld, 1995, Clarke, 2001). Current sociocultural approaches to teaching and learning based on the work of Vygotsky also advocate an active, reflexive role for the teacher (Wertsch et al, 1995).

Cobb and McClain (1999) argued that teachers should have a clear impression of the direction that the learning of the individuals and the class will take in order to effectively scaffold student learning. They proposed that the teacher should form an 'instructional sequence (that) takes the form of a conjectured learning trajectory that culminates with the mathematical ideas that constitute our overall instructional intent' (p. 24).

The notion of teacher involvement has also been investigated in relation to mathematics teaching. Turner et al, (1998) compared high and low involvement by teachers, and reported that a 'higher press for understanding' (p. 742), that is, the determination of the teacher to keep working with students until they appreciate the connections, applications, generalisations and extensions of the particular knowledge that is their focus, was associated with greater involvement of students in their mathematics classes.

More specifically, references to something akin to teaching approaches can be found in the numeracy or mathematics related literature. For example, Rogoff's (1995) generic 'planes of sociocultural activity', which she refers to as apprenticeship, guided participation, and participatory appropriation, can be seen to loosely map on to what we might understand by modelled, shared and guided teaching approaches respectively.

Working with young adults, Rogoff (1995) describes the three generic planes of sociocultural activity in the following way.

(i) apprenticeship – involves individuals actively participating in culturally organised activity that 'has as part of its purpose the development of mature participation in the activity by less experienced people … The idea of apprenticeship necessarily focuses attention on the specific nature of the activity as well as its relation to [the] practices and institutions of the community in which it occurs' (p. 142)

(ii) guided participation – 'refers to the processes and systems of involvement between people as they communicate and coordinate efforts while participating in culturally valued activity … The 'guidance' in guided participation involves the direction offered by cultural and social values as well as social partners, the 'participation' in guided participation refers to observation, as well as hands-on involvement in an activity.' (p. 142)

(iii) participatory appropriation – 'refers to how individuals change through their involvement in one or another activity, in the process becoming prepared for subsequent involvement in related activities.' (p. 142)

The development evident across the three planes is also consistent with the model proposed by Brown, Collins and Duguid (1989) in relation to situated cognition.

The notion of reciprocal scaffolding described by Holton and Thomas (2001) and Wood's (1994) patterns of interaction also suggest it might be possible to identify a suite of defined teaching approaches specific to mathematics teaching and learning, the teacher's role and students' participation within each of these approaches.

Wood (for example, 1994, 1995, 1996, 1998 and 2002) has written extensively about patterns of interaction observed in Year 2 classrooms. In particular, she has detailed two interaction patterns which she refers to as funnelling and focussing. The funelling process is essentially a spoken cloze activity, that is, the students' only task is to 'fill in the spaces' left by the teacher. This pattern

> leaves students in a situation where they need only to generate superficial procedures rather than meaningful mathematical strategies in order to participate. (Wood, 1994, p. 155)

By contrast, the focussing pattern of interaction is

> characterised by an exchange in which the teacher's guiding questions act to focus the joint action. … the teacher's intent in questioning is to focus the attention of the student on the critical aspect of the problem – to pose a question which serves to turn the discussion back to the student leaving him/her with the responsibility for resolving the situation (p. 155)

Wood (1994) makes the point that these patterns of interaction are alternatives to the traditional I-R-E interaction (for example, Voigt, 1995) and both 'serve the teacher's central intention of trying to create learning situations which enable students to construct mathematical meaning for themselves ' (p. 159). Given the critical importance of these patterns to the research project, it is appropriate to include the following rather lengthy but very apposite excerpt from Wood's (1994) summary.

> The teacher's goal in each case is to aid students in making sense of mathematics by supporting their activity during joint problem solving through continuing an openness not only in the discourse but in the exchange. …

> The funnel pattern, then, can generally be described as an interaction in which the teacher creates a series of questions that act to continually narrow the students' possibilities until they arrive at the correct answer. In this situation, the teacher recognises that the student is unable to respond appropriately with the correct answer, and therefore attempts to offer guiding questions for the purpose of enabling the student to solve the problem. ... This form of exchange always ends with a solution to the problem at hand.
>
> The focus pattern can also be described as a situation in which the essential aspects for solving a problem are brought to the fore. Furthermore, this pattern of interaction can be described as one which the teacher's inquiries act to indicate to the child the critical features of the problem that are not yet understood. … In this particular interaction, students always have some aspect of the problem still to solve. (pp. 159-160)

In some ways there is a loose correspondence between these interaction patterns and the teaching approaches of modelled and guided mathematics respectively (Early Years Numeracy Program, 2001). However, the notion of teaching approaches would appear to be much more overarching than the very specific instances of interaction described by Wood. This suggests that it might be more useful to look at the types of interaction patterns typically engaged in by teachers as they seek to scaffold students' mathematical learning.

Holton and Thomas (2001) identify three sources of blockage in relation to students capacity to solve problems, strategic barriers, where students are unsure of which strategy to apply or how to apply it, mathematical barriers, where students require an item of mathematical knowledge that they do as yet have, and affective barriers where students are blocked for a variety of social, emotional reasons. They then discuss cognitive and metacognitive scaffolds that might be used by a 'more competent other' to support students to solve problems and overcome barriers in particular. In addition to 'conventional' scaffolding they also report that they have seen how students can scaffold themselves and other students.

> However, we have also seen how students used questioning similar to that involved in conventional scaffolding. We see this questioning as partly metacognitive in character and are inclined to call it 'self-scaffolding' when practiced by an individual and 'reciprocal scaffolding' when practiced by a group or student dyad. (p. 102)

Powerfully they note that mathematical interactions have been of the highest quality where students are placed in situations of a fairly demanding nature.

In the adult numeracy literature, the notion of excavating was introduced by Yasukawa (1995) as a means of connecting to the mathematical realities of adult numeracy learners. This notion has immediate appeal in terms of its compatibility with socioconstructivist orientations to teaching and learning and in terms of the literature on situated cognition referred to earlier. Systematically exploring what students know by questioning to make explicit what is known or to connect with students' interests and experiences clearly offers a valuable and flexible means of determining starting points for teaching.

Given the reported success of these approaches, a logical next step is to examine the extent to which the same or similar approaches might be used to support and scaffold the development of numeracy. This is important as it will contribute to the development of a much-needed, coherent and consistent way of enacting and talking about the complex practice of teaching numeracy/mathematics in a variety of settings to meet a variety of different learning needs.

Teachers also have an active role to play in the construction and negotiation of appropriate learning environments. For instance, Hiebert and Wearne (1993) demonstrated that students learn mathematics with greater understanding in classrooms in which they are allowed to explore, investigate, reason and communicate their ideas. Wood (1994) argued that 'differences in learning environments can largely be attributed to the nature of the expectations and obligations that have been negotiated' (p. 164). She also noted that interaction patterns can 'serve to constrain or enhance children's opportunity to actively construct mathematical meaning' (Wood, 1998, p. 170).

More recently, in a concerted attempt to identify the teacher's role in scaffolding mathematics learning more precisely, Anghileri (2002) has provided a useful framework of teaching strategies for scaffolding learning in mathematics based on different levels or types of communication.

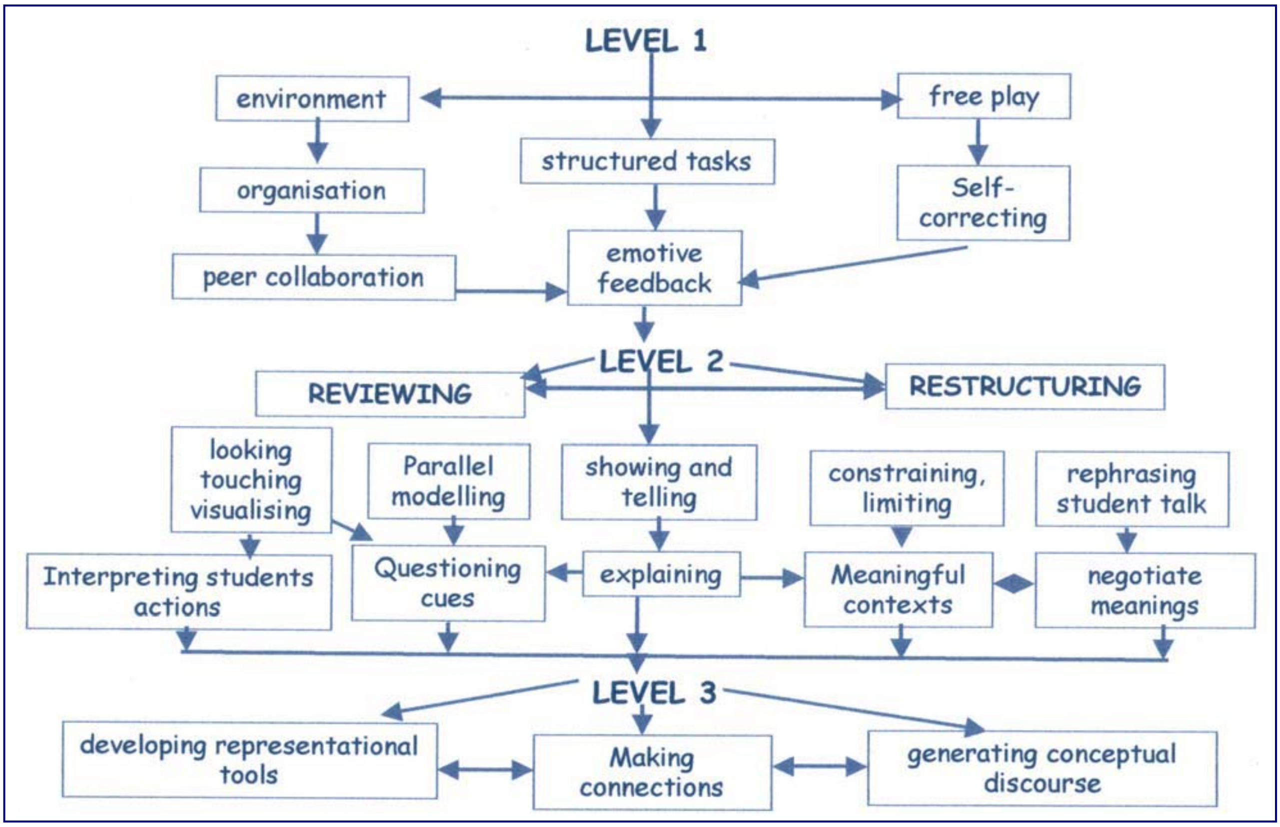

Figure 3 Teaching Strategies for Scaffolding Learning (Anghileri, 2002)

Level 1 scaffolds tend to refer to those prompts and stimuli that exist in the environment, either as a result of conscious planning or by default, that serve to support student learning in mathematics. These might take the form of a poster recording generalisations or key observations from past lessons, carefully chosen, self correcting games, engaging tasks or puzzles, materials/manipulatives, and/or mathematical tools. Peer collaboration is included in this category in recognition of the efficacy of students working together as opposed to students working alone. In this case, the teacher's immediate involvement might be low but the level of support might be described as high depending on the thought and effort expended by the teacher in deciding which displays, tasks, and materials would be made available. Level 2 scaffolds involve:

> … direct interactions between teachers and students specifically focussed on the task in hand. Such strategies vary from direct instruction – showing and telling – to more collaborative meaning making (Anghileri, 2002, p. 51).

Scaffolds at this level, according to Anghileri, include the types of interaction patterns commonly found in traditional approaches, that is, where the teacher retains control, structures conversations, elaborates, and explains. But, they also include two categories of practices that involve students more directly in the enterprise, that is, reviewing and restructuring.

> REVIEWING relates to interactions that: encourage students to look, touch and verbalise; use questions, cues and parallel modelling; interpret student actions. RESTRUCTURING involves teachers making adaptations: by constraining or limiting the tasks; by giving meaningful contexts; by sensitively rephrasing students' talks and solutions; and by negotiating solutions. (p. 53)

Level 3 scaffolds aim to make connections between students' prior knowledge and experience and the new mathematics to be learned. Developing representational tools and generating conceptual discourse are the two areas considered here. Anghileri makes the point that models, diagrams, charts, and tables 'can be used not only for recording but as tools for thinking'. By negotiating social norms and values that value conceptual (as opposed to computational) explanations 'students are likely to engage in longer, more meaningful discussions and meanings come to be shared as each individual engages in the communal act of making mathematical meaning.' (p. 56)

As previously stated, the notion of 'numeracy teaching approaches' has its origins in the work of the Victorian *Early Literacy Research Project* which demonstrated the effectiveness of a small number of generic teaching approaches on the development of children's literacy. These approaches, identified as modelled, shared and guided, were used specifically in relation to students' reading and writing. They are based on the premise that for reading and writing there is an inverse relationship between the level of teacher support and the level of student independence.

Even though there has been extensive research into issues in mathematics education, there does not appear to be research that specifically addresses the issue of a set of generic teaching approaches that teachers can use as a consistent context to talk and think about the teaching of mathematics. However, there is a growing body of knowledge gleaned from research in mathematics education to support the notion of numeracy teaching approaches. This includes recognition of the active role teachers play in supporting students to scaffold their learning through the construction and negotiation of appropriate learning environments (for example, Boaler, 2002; Cobb, Yackel & Wood, 1995; Sfard, 2001) and interaction patterns that enhance rather than constrain student learning (for example, Wood, 1998).

Given the emphasis on classroom interaction in the mathematics education literature, it was agreed that, for the purposes of the project, the notion of numeracy teaching approaches would refer to the communicative acts engaged in by teachers as they seek to scaffold students' numeracy learning in the context of Prep – Year 6 classrooms. Scaffolding in this instance refers to teachers supporting students to make conceptual connections and understand their own learning process. However, as the literacy teaching approaches also referred to 'methods and organisation' to support student learning, this suggested that some consideration in the methodology of the research project should also be given to the ways in which teachers structure and plan their numeracy teaching.

Reality bites – influences on numeracy teaching approaches

A range of influences will impact the implementation and efficacy of teaching approaches. Like any learners, teachers bring with them a complex, mutually reinforcing conglomerate of prior knowledge, experience, beliefs and values. They have preferred ways of dealing with information and will attend to different aspects of a situation as a consequence of what they know and the social context in which the event is situated. From an interactionist perspective (for example, Voigt, 1995; Cobb & Bauersfeld, 1995) meaning is created interactively in sociocultural settings and the nature of the relationship between interaction and learning is reflexive. As a consequence, anything that impacts the quality of the interaction will affect learning and vice versa.

Clearly, research on effective teachers of mathematics (for example, Askew et al, 1997; Askew, 1999a; Clarke & Clarke, 2002; Boaler, 2002) is relevant to any consideration of the factors that will impact on the implementation and efficacy of numeracy teaching approaches. To date, research that explores effective teaching practice in numeracy has tended to focus on broad teacher qualities and skills. These include the use of specific teaching skills such as the use of higher order questions, using tasks which require student thought rather than simply practice, collaborative problem solving, and encouraging students to develop and discuss their own methods and ideas (Creemers, 1997; Cobb & Bauersfield, 1995; Yackel & Cobb, 1996; Wood, 1996; Stigler & Hiebert, 1997; Askew et al 1997a).

Of the research that does begin to address effective teaching approaches in numeracy, the findings tend to provide very general advice, or advice that is so specific that it has only been applied to one narrow aspect of numeracy, for example Cognitive Guided Instruction (Carpenter & Fennema, 1992). This approach has been researched in depth with teachers and focuses on the area of number, in particular the operations of addition and subtraction set in the context of word stories. Work with teachers has shown that the strategies used in this approach were not necessarily transferred to other areas of mathematics (Fennema & Franke, 1992). However, what this research demonstrates is the critical importance of teachers' pedagogical content knowledge (Shulman, 1986).

Teacher knowledge

> Excellent teachers of mathematics have a strong knowledge base to draw on in all aspects of their professional work, including their decision-making, planning and interactions. Their knowledge base includes knowledge of students, how mathematics is learned, what

affects students' opportunities to learn mathematics and how the learning of mathematics can be enhanced. It also includes sound knowledge and appreciation of mathematics appropriate to the grade level and/or mathematics subjects they teach. (AAMT, 2002, p. 2)

There has been considerable research on the impact of teacher knowledge on the quality of classroom implementations and interaction (for example, Askew, 1997a; Clarke & Clarke, 2002; Ma, 1999). In particular, the importance of the knowledge and the intention of the teacher are now widely acknowledged. Cobb and McClain (1999), for example, argued that teachers should have a clear impression of the direction that the learning of the individuals and the class will take. They proposed that the teacher should form an 'instructional sequence (that) takes the form of a conjectured learning trajectory that culminates with the mathematical ideas that constitute our overall instructional intent' (p. 24). Likewise, the *Early Numeracy Research Project* (see Clarke et al, 2001) was based on a view that learning mathematics is about forming, linking and extending a few key ideas, with these key ideas providing the basis of planning, teaching and assessment. Teaching was seen as active, structured and explicit, while maximising the engagement of the students in carefully selected tasks and experiences. It is interesting to note that the case studies in that project identified teacher knowledge of both the content, and the processes for teaching the content, as key characteristics of effective teachers (McDonough, 2002).

Without doubt, one of the most important influences in this area is Shulman's (1986) distinction between different types of knowledge needed for teaching. That is,

Content knowledge – knowledge of the mathematics being taught, the amount and organization of the subject matter per se in the teacher's mind.

Pedagogical knowledge – knowledge of generic teaching strategies, such as questioning, grouping, planning, assessing, general factors that might impact learning; and

Pedagogical content knowledge – knowledge of the ways of representing and formulating the subject that makes it comprehensible to others, that is, knowledge of the most frequently taught topics, the most powerful models, representations, and problems that can be used to teach these topics, 'including a knowledge of what makes the learning of specific topics easy or difficult, [and] the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning of those most frequently taught topics' (Shulman, 1986, p. 9).

Ma (1999) captures the importance and interdependence of these forms of knowledge very powerfully in her comparative study of Chinese and American teachers of mathematics. Ma found that Chinese teachers were more likely to have a 'profound understanding of fundamental mathematics' (p. xxiii) than their American counterparts and that this difference parallelled the comparative difference in student achievement. This understanding included not only a deeper knowledge of subject matter but also a knowledge of how to teach it – Ma refers to this as 'teachers' subject matter knowledge' (p. 145).

Mewborn (2001) summarised and critiqued research of teacher content knowledge. She identified particular stands in that research including studies that sought to examine the relationship between teacher knowledge and student achievement, those that sought to characterise strengths and weaknesses in teachers' knowledge, those that compared the knowledge of different groups, such as primary and secondary teachers, and qualitative studies that sought to explicate relationships and to clarify the obvious complexity of the issues. Mewborn argued that, on balance it seemed that teachers' conceptions of mathematics did influence the way it is taught, but that while knowing the mathematics is important it is not the same as knowing how to teaching it. Mewborn called for research in a broader range of topics, for longitudinal research, and research into the conceptions of teachers who do have a firm understanding of the discipline.

This knowledge needs to be distinguished from formal mathematics knowledge which has been shown to be unrelated to various measures of student learning (for example, Begle, 1979) and 'not positively associated' with being a highly effective teacher of mathematics (Askew, 1999a, p. 96). In fact Ma (1999) claims that the distinguishing features of elementary mathematics is that it is a 'field of depth, breadth and thoroughness' (p. 122).

Teachers with this deep, vast, and thorough understanding do not invent connections between and among mathematical ideas, but reveal and represent them in terms of mathematical teaching and learning (p. 122).

Ma goes on to state that such teaching and learning has four interrelated properties, connectedness, multiple perspectives, basic ideas, and longitudinal coherence. However, she warns against thinking about elementary mathematics in terms of 'basic mathematics', that is, 'an arbitrary collection of facts and rules in which doing mathematics means following set procedures step-by-step to arrive at answers' (p. 123). Ma concludes her study with the observation that:

> while we want to work on improving students' mathematics education, we also need to improve their teachers' knowledge of school mathematics (p. 144)

Given the critical importance of this aspect of knowledge for teaching it is perhaps somewhat surprising that there are relatively few instruments to evaluate this type of knowledge. Most claims are made on the basis of inferences derived from classroom observations and/or interviews (for example, Fenema & Loef Franke, 1992), although a relatively recent, comparative study of teacher knowledge by Ma (1999) used interview tasks developed for the Teacher Education and Learning to Teach Project which 'were designed to probe teachers' knowledge of mathematics in the context of common things that teachers do in the course of teaching' (Ma, 1999, p. xxi).

Shulman (1986) refers to this aspect of teacher's pedagogical content knowledge quite specifically.

> Pedagogical content knowledge also includes an understanding of what makes the learning of specific topics easy or difficult: the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning of those most frequently taught topics and lessons. If those preconceptions are misconceptions, which they so often are, teachers need knowledge of the strategies most likely to be fruitful in reorganising the understanding of learners, because those learners are unlikely to appear before them as blank slates (pp. 9-10)

While the principal focus of the research project will be classroom teaching strategies and approaches, teachers' beliefs and understandings about the relationship between teaching and learning will also need to be addressed as they work to implement effective teaching approaches.

Clearly, there are methodological and ethical difficulties in researching teacher knowledge which are further mitigated in the case of mathematics teaching by lack of access to a well developed, metalanguage to talk about the teaching of mathematics. One interesting and worthwhile way of evaluating this aspect appears to be via the use of concept maps where 'expert' maps are compared to generated maps with a view to making a judgement about the level of pedagogical content knowledge demonstrated. Used for some time in science education (for example, Mitchell & Baird, 1999), Williams (1998) has shown that concept maps can be a useful device for assessing conceptual understanding in mathematics.

> Concept maps are a direct method of looking at the organisation and structure of an individual's knowledge within a particular domain and at the fluency and efficiency with which the knowledge can be used (Williams, 1998, p. 414)

Task and strategy selection

The relationship between different teaching strategies and students' understanding of mathematics is a perennial question that has proved difficult to research (for example, Brophy & Good, 1986; Boaler, 2002). While the use of open-ended questions, rich tasks, and critical discussion are widely advocated in curriculum and reform documents (for example, Curriculum and Standards Framework II; the NCTM's Principals and Standards), there has been some suggestion that these approaches may disadvantage some at the expense of others, for example, working class boys (Zevenbergen, 1999), indigenous students (Klein, 1999) and non-English speaking students (Adler, 1999). Despite this, it is evident that where teachers strive to make conceptual understanding a goal for *all* students by making open-ended approaches equitable (Boaler, 2002), advances can be made. However, as Boaler states, 'consideration of the detailed practices of teaching and learning that occur in classrooms' (p. 255) is needed. In addition, researchers

> and others will need to delve inside the general teaching approaches that have been the subject of discussion in recent years … to replace the 'pedagogies of poverty' (Haberman, 1991, p. 290), which often predominate in low income and minority communities with pedagogies of power (p. 256).

Classroom culture

There is a wealth of material on the role and function of classroom culture in relation to the constitution of meaning (for example, Nickson, 1992; Cobb & Bauersfeld, 1995; Lerman, 1998). Essentially, this literature argues for a reflexive relationship between meaning.

Voigt (1995) has taken the notion of patterns of interaction one step further to talk about 'thematic patterns (or procedures) of interaction' that he believes are more specific to the mathematics classroom and the materials and representations used to teach mathematics. This can be seen for example in direct mathematisation, where a story or a picture is interpreted as a specific calculation problem (as in the beam balances situation with a missing number on one side). Voigt uses the notion of 'themes' to argue for a reflexive relationship between interaction and learning:

> … reflexivity was defined as a property of the relationship between the context of a classroom situation, that is, the microculture, and particular meanings that are interactively constituted in the situation (Leiter, 1980). From this theoretical point of view, a mutual relationship exists between meanings and culture. The microculture makes the meanings in the particular interactions understandable, while at the same time the microculture exists in and through these very interactions. (Voigt, 1995, p. 192)

The literature (for example, Voigt, 1995, Cobb & Bauersfeld, 1995) would suggest that there is a reflexive relationship between scaffolding practices and classroom culture. Particular practices are afforded or constrained depending upon the particular socio-mathematical norms and values that exist explicitly or implicitly within the social context of the classroom and vice versa. Classroom culture is interactively constituted by the nature of the interaction patterns that commonly occur within it.

Teaching cannot be seen in isolation from learning and the students that learn:

> Teachers' emotional commitments and connections to students energized and articulated everything these teachers did: including how they taught, how they panned, and the structures in which they preferred to teach (Hargreaves, 1998, p. 573)

Brophy and Good (1986) in their extensive review of the literature relating teacher behaviour to student achievement suggest that 'more thick description and microanalysis of how lesson components are accomplished' (p. 368) is needed. However, they also suggest that teachers' intentions need to be understood to interpret the use of questions and the nature and role of teacher praise. Their conclusion amplifies the complexity of classroom teaching practice and the dangers of being too prescriptive.

> Although illustrating that instructional processes make a difference, this research also shows that complex instructional problems cannot be solved by simple prescriptions. In the past … educational change efforts were typically based on simple theoretical models and associated rhetoric calling for 'solutions' that were both overly simplified and overly rigid. The data reviewed here should make it clear that no such 'solution' can be effective because what constitutes effective instruction … varies with context. What appears to be just the right amount of demandingness … for one class might be too much for a second and not enough for a third class. Even within the same class, what constitutes effective instruction will vary according to the subject matter, group size, and the specific instructional objectives being pursue. … Even trained and experienced teachers vary widely in how they organise the classroom and present instruction. Specifically, they differ in several respects: the expectations and achievement objectives they hold for themselves, their classes, and individual students; how they select and design academic tasks; and how actively they instruct and communicate with students about academic tasks. (p. 370)

Issues in investigating numeracy teaching approaches

Identifying and describing – Implementing and evaluating

An interactionist approach to the issues involved in investigating numeracy teaching approaches or, more particularly, teachers' communicative acts, requires an ethnographic methodology incorporating systematic and detailed observations of a qualitative nature conducted over time and in consultation with those concerned.

> Such research would consist of thick, critical descriptions of what is naturally and characteristically occurring as teacher and students go about their daily business in a specific classroom. Thick, critical description is loaded with concrete detail about what participants do and say in the setting and is deliberately interpretive, identifying salient patterns of events and generating propositions that explain their interrelationships. … The achievement of such knowledge requires that the classroom be construed as a social system characterized by reciprocity among participants. (Bolster, 1983, p. 304)

According to Bolster (1983), the eventual critical descriptions are validated in two ways, 'referentially – the explanatory generalisations must be consistent with repeated patterns of events recorded in the observational data; and situationally – the explanatory framework must be consistent with the meanings teachers and students draw from and impose upon the classroom situation.' (pp. 304-305)

While classroom observations supported by a more rigorous and intensive study of teachers' practice through structured opportunities for peer observation and review might be expected to provide thick, critical descriptions of teachers' practice, their potential for improving numeracy outcomes needs to be evaluated in the context of the factors that impact classroom communication. The reason for this is the recognition that teaching approaches, like any other aspect of classroom endeavour are deeply and inherently connected to teachers beliefs and understandings (for example, Cobb & McLean, 1999; Fenema et al, 1989) and the opportunities and constraints they perceive to be operating to support or constrain their practice (for example, Clarke & Peterson, 1986). The effectiveness or otherwise of a particular teaching approach cannot be determined on the basis of student improvement data alone – what makes a particular approach work in one setting with one teacher may very well not work in a similar situation with a different teacher. How the teaching approaches are interpreted, understood and implemented will vary with teacher knowledge and experience, their past practices and perceptions about their task. As was recognised many years ago, there is no such thing as 'teacher-proof materials' (Stephens, 1982).

To this end, an interactionist model based on Clarke and Peterson (1986) and elaborated by Sullivan et al (2002), that proposes a connection between teacher beliefs and understandings, the opportunities and constraints they experience, their intentions for teaching and communication, and their actions and reflection on those actions will be used as a basis for determining what qualitative data will be collected. This model is shown in Figure 4.

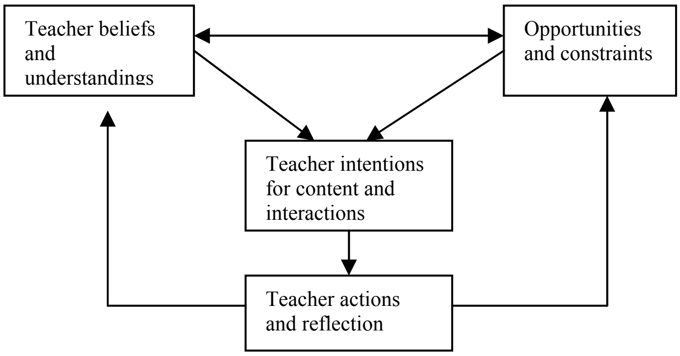

Figure 4 Interactionist model to support data collection.

To identify and describe aspects of teachers' practice requires intense, systematic study over time. One important aspect of this is structured classroom observation which:

> allows the inquirer to see the world as his subjects see it, to live in their time frames, to capture the phenomenon in and on its own terms, and to grasp the culture in its own natural, ongoing environment … to build on tacit knowledge, both his own and that of members of the group (Lincoln & Guba, 1985, p. 273)

Another powerful means of generating thick descriptions of teachers' practice is afforded by structured peer observation and review. This is exemplified by the Behind-the-screen process used widely in Reading Recovery training (Clay 1993) where a trainee Reading Recovery Tutor works with a student behind a one way mirror while up to twelve other trainee teachers observe and listen to a commentary provided by a certified trainer. The trainer labels important aspects of the teacher's practice and asks questions of the group such as 'How would you describe what was happening there?', 'What else could she have done at that point?' and 'Why did she pause?' Unsolicited observations are made from time to time by some of the trainees. While not generally used in relation to mathematics teaching, Askew, Bibby, Brown, M. (1996 and 1997) report using a similar technique which proved to be a very powerful tool to challenge teachers' beliefs and understandings about teaching and learning in numeracy.

To implement and evaluate the impact of a particular change initiative requires active commitment on behalf of teachers and schools. In the past, research has tended to be 'done on' schools and/or teachers rather than 'with' schools/teachers (for example, Ball, 2000).

The role of teachers-as-researchers is increasingly being recognised as one of the most effective forms of professional development (for example, Malone, 2000).

> If teachers are to learn about their profession in the active ways that are now known to be empowering and recommended in curriculum documents, then they will need opportunities to explore, investigate, create, reflect, and solve problems and answer research questions for themselves. Only through active engagement with problems and questions that are personally meaningful to them will they develop a rationale for action. Only through understanding their own learning through research, inquiry, investigations, and analysis will they come to understand such processes among students in their care. (Crawford & Adler, 1996, p. 1201)

Action research is a form of collective, self-reflective inquiry undertaken by participants in social situations in order to improve their understanding of their practice (Kemmis & McTaggert, 1988). Action research is collaborative, but it is only achieved through the critically examined action of individual group members.

The Eisenhower National Clearinghouse provides a website that describes action research in the following way (http://www.enc.org/professional/ideas/math/documents/0,1944,ACQ-133273-3273_18,00.shtm)

> First introduced by Kurt Lewin in the 1940s, action research has evolved into an ongoing process of systematic study in which teachers examine their own teaching and students' learning through descriptive reporting, purposeful conversation, collegial sharing, and reflection for the purpose of improving classroom practice (Miller & Pine, 1990).
>
> As in all research, effective action research projects build on available knowledge, rather than recreating it. Individuals, such as university researchers, offer expertise on the knowledge base and on research methodology to help teachers to ensure the quality of their research (Holly, 1991). In the process of conducting an action research project, teachers gain knowledge and skill in research methods applications (Lieberman, 1986; Miller & Pine, 1990; Oja & Smulyan, 1989).
>
> Sharing the results of action research can make a significant contribution to professional development. Opportunities to write about a project, to present findings to various audiences, to participate in discussions of the implications, and to develop materials that other teachers can use are just some of the ways that teachers can increase their skills and knowledge beyond what they learn from the action research itself (Loucks-Horsley et al, 1987). Assisting teachers to identify the best vehicles for sharing is an appropriate role for the professional developer. …

A key facet of implementation is that those expected to engage with the proposed change understand what is expected of them and have some chance as learners to make sense of this in terms of their prior knowledge, beliefs and experience.

> Regardless of their status or level of teaching most teachers participate in some form of teacher education designed to promote 'better teaching' however we define that term, As such teachers are learners … [they] are rational, cognising agents with all the implications that entails (Cooney, 1996, p. 101)

The opportunity to observe other teachers teach is widely recognised as one of the most valuable professional development experiences (for example, Garet et al, 2001; Jacobs & Morita, 2002). The Behind-the-screen activity as it was modified and used here clearly satisfies this and the remaining criteria identified by Garet et al (2001) for effective professional development. That is, this activity:

(i) is sustained over time (duration);

(ii) involves groups of teachers from the same school (collective participation);

(iii) is focussed on teaching-specific, mathematics content (focus);

(iv) affords opportunities to observe and be observed, plan classroom implementations and give presentations on their experience (active learning); and

(v) fosters coherence, that is, it connects with teacher and school goals and other activities and encourages professional communication among teachers.

Hiebert et al (2002) also acknowledge the 'growing consensus that professional development yields the best results when it is long term, school based, collaborative, focused on students' learning, and linked to curricula' (p. 3)

This suggests that any serious attempt to implement and evaluate whatever is identified and described by way of teachers' communicative acts will need to be supported by a long term, action research process that provides substantive and ongoing professional development and involves practitioners as partners in the enterprise. Hiebert et al (2002) argues for a new space to bridge the gap between researchers and practitioners, where:

> teachers would be able to employ the methods of replication and observation across multiple trials to produce rigorous tests of the quality and effects. Sometimes they would test practices developed by other teachers, and sometimes they would test ideas generated in the research community. Over time, the observations and replications of teachers in schools would become a common pathway through which promising ideas were tested and refined before they found their way into the nation's classrooms. And, as intentions became reality in classrooms a new kind of knowledge about improving classroom practice would emerge, a knowledge that would accumulate into a professional knowledge base for teaching and support long term continuing improvement in teaching. (p. 12)

A key issue in the implementation of any program is the extent to which the change is actively supported and sustained by the school culture and leadership.

> Changes in the culture of teaching and the culture of schools are required. Cultural change requires strong, persistent efforts because much of current practice is embedded in structures and routines and internalised in individuals, including teachers … There appear to be many people willing to work on it, but they should realize how deep a change they are getting into. (Fullan, 1991, p. 143)

As Fullan suggests, the difficulty of doing this should not be underestimated. School cultures, particularly ones which reinforce both explicitly and implicitly certain values such as achievement on traditional, largely skill based tests, exert considerable pressure on teachers, particularly on young teachers, to conform to the prevailing view and adopt practices that their training might otherwise lead them to reject.

Conclusion

Despite the evident value of teaching approaches in relation to reading and writing, there is no real evidence that knowledge gained from research on literacy practice is transferable to numeracy teaching. However, it appears that there is a growing body of knowledge gleaned from research in mathematics education to support the notion of numeracy teaching approaches. This includes recognition of the active role teachers play in supporting students to scaffold their learning through the construction and negotiation of appropriate learning environments (for example, Boaler, 2002; Cobb, Yackel & Wood, 1995; Sfard, 2001), the identification of learning needs (for example, Clarke, 2001), and interaction patterns that enhance rather than constrain student learning (for example, Wood, 1998).

Taken together with the outcomes of previous projects, such as the *Early Numeracy Research Project* and the *Middle Years Numeracy Research Project*, that pointed to the need for further research in the area of classroom teaching programs, this suggests that there is a strong basis for exploring the possibility of effective numeracy teaching approaches which can be used to support all schools in Victoria to improve student learning in mathematics.

Given the emphasis on classroom interaction in the mathematics education literature, it was agreed that, for the purposes of the project, the notion of numeracy teaching approaches would refer to the communicative acts engaged in by teachers as they seek to scaffold students' numeracy learning in the context of Prep – Year 6 classrooms. Scaffolding in this instance refers to teachers supporting students to make conceptual connections and understand their own learning process. However, as the literacy teaching approaches also referred to 'methods and organisation' to support student learning, this suggested that some consideration in the methodology of the research project should also be given to the ways in which teachers structure and plan their numeracy teaching.