COMPENDIUM

A major policy objective of the Australian Government is to ensure that all students attain sound foundations in literacy and numeracy. In 1997, all Education Ministers agreed to a National Literacy and Numeracy Plan that provides a coherent framework for achieving improvement in student literacy and numeracy outcomes. The 1999 Adelaide Declaration on National Goals for Schooling in the Twenty-First Century contains the national literacy and numeracy goal that *students should have attained the skills of numeracy and English literacy, such that every student should be numerate, able to read, write, spell and communicate at an appropriate level.*

In support of the numeracy component of the National Plan, in 2001 the Australian Government implemented the Numeracy Research and Development Initiative. This Initiative consisted of two complementary strands - a national project strand and a strategic States and Territory projects strand. *Researching Numeracy Teaching Approaches in Primary Schools* is one of ten strategic research projects undertaken by State and Territory education authorities across Australia. The purpose of these projects was to investigate a broad range of teaching and learning strategies that lead to improved numeracy outcomes.

Researching Numeracy Teaching Approaches in Primary Schools was conceptualised as a cross-sectoral project by the Victorian Department of Education & Training, the Catholic Education Commission of Victoria and the Association of Independent Schools of Victoria, and conducted in partnership with a research team from RMIT University.

Project Impact

The research is expected to influence classroom practice and impact on student numeracy outcomes in at least seven ways.

(i) The identification and elaboration of a range of interaction patterns or scaffolding practices will help teachers make more informed decisions about how to address specific learning needs and promote and sustain mathematical thinking.

(ii) Access to an emergent professional language will encourage and facilitate increased professional discussion, reflection and critical review of 'taken-for-granted' teaching practices in mathematics - a first step in improving practice.

(iii) Participation in a Behind-the-screen process or similar opportunities for peer observation and review will develop and deepen teachers' understanding of their practice, and contribute to the ongoing development of a professional language.

(iv) Recognition of the critical importance of teachers' pedagogical content knowledge will encourage professional learning teams to identify their learning needs and initiate action as appropriate (eg, mentoring, team-teaching and/or targeted professional development).

(v) Recognition of the dynamic relationship between classroom cultures and scaffolding practices will encourage teachers and professional learning teams to examine the type of classroom cultures they establish and the nature and role of

interaction in the construction of mathematical meaning.

(vi) Recognition of the complexity of classroom organisation and structure will encourage teachers to select lesson structures and groups specific to purpose. That is, according to the nature of the task(s) and scaffolding practices chosen to meet specific learning needs.

(vii) The demonstrated value of a whole school approach, supported by effective leadership and shared expectations will inform the work of professional learning teams and encourage then to engage with practice in a more open and critical way.

Addressing the Research Questions

For the purpose of addressing the research questions, teaching approaches will be taken to mean approaches to teaching (as this is understood more generally) that plan to include a range of scaffolding practices specific to the teacher's purpose. In this sense, a teaching approach represents an orientation to teaching that plans to make use of particular scaffolding practices to achieve a specific purpose related to mathematics learning.

Given the ambiguities around implementation and evaluation discussed below, it is only possible to address the research questions in terms of those findings and outcomes that suggest what is likely to lead to improved student learning outcomes in numeracy.

(i) What are the key components of teaching approaches that lead to improved learning outcomes for numeracy in the primary years of schooling?

The key components of teaching approaches viewed in this way are the scaffolding practices outlined below and the conditions and circumstances in which they are used. As components, the scaffolding practices can be selected and used appropriate to purpose, for example, to meet the identified learning needs of a particular group of students, or as the need arises in the context of the lesson. The conditions and circumstances are important as it is these that determine the extent to which the scaffolding practices will lead to improved learning outcomes for numeracy (see *ii* below).

Identification, description and elaboration of twelve scaffolding practices is the major outcome of this research (see Major Outcomes and Findings below). They describe a range of communicative acts that teachers use to support students' mathematics learning that might ultimately be removed when the learner can 'stand alone'.

(ii) If teachers implement a defined suite of numeracy teaching approaches does this result in improved learning outcomes for students?

As indicated below the conditions and circumstances that surround the use of scaffolding practices, will impact on their effectiveness. Considered overall, the findings and outcomes of the action research component of the project clearly indicate that deep pedagogical content knowledge and appropriate classroom cultures are needed to support effective scaffolding practices. In particular, it was evident that where teachers were aware of students' prior knowledge and experience and had a well-developed understanding of relevant learning trajectories in mathematics, they were more likely to choose and use appropriate mathematical learning activities. Where there was evidence of a mutually respectful learning environment in which the teacher and students were

expected to formulate, share and justify their thinking, it was more likely that the mathematical potential of the activities would be realized and interactions would be more deeply focused on the mathematics. Where these were in place, it was clear that scaffolding practices were likely to be used to greater effect and teachers were more likely to remain focused and press for understanding.

To the extent that the teaching approaches (as understood in this context) could be implemented, there was some evidence that numeracy outcomes, as valued and assessed by research schools, had improved as a result of their participation in the project, in particular the tail-end of the distribution was shorter for research schools than for reference schools.

(iii) How can these teaching approaches in numeracy best be described to support teachers to implement them effectively in their primary school classrooms to improve student learning?

Researching Numeracy Teaching Approaches in Primary Schools was aimed at researching numeracy teaching practice through the identification of effective classroom teaching approaches in mathematics for students in the early years (Prep – Year 4) and the middle years (Years 5 and 6) in a range of Victorian schools. It was also aimed at determining the potential of these approaches for improving student outcomes.

The design of the project was informed by the work of a number of research projects, for example, the *Early Literacy Project* (1996-98), the *Early Numeracy Research Project* (1999-2001), and the *Middle Years Numeracy Research Project* (1999-2000). Based on the design elements for effective school improvement (Hill & Crévola, 1997), these projects identified the need for further research in the area of classroom teaching programs.

The focus on numeracy teaching approaches was prompted by the widespread use of differentiated teaching approaches in literacy. Researching numeracy teaching approaches was seen to be important as it had the potential to contribute to the development of a coherent and consistent way of enacting and talking about the complex practice of teaching mathematics in a variety of settings, including a special school, to meet a range of different learning needs.

Support for the notion of numeracy teaching approaches was found in the mathematics education literature, for example, Wood's (1994) work on patterns of interaction and the work of Holtan and Thomas (1995) on reciprocal scaffolding. This emphasised the role of social interaction in building mathematical understanding, so the notion of numeracy teaching approaches was broadened to encompass the communicative acts teachers engage in as they support students making connections in their mathematics learning.

It is suggested that 'teaching approaches' be considered as orientations to teaching that plan to use particular scaffolding practices to achieve a particular purpose and that the scaffolding practices are best described in the way they have been presented in the final report (see section 2.4), in terms of key words, a brief description and a set of exemplars.

Methodology

Given the interest in identifying and describing numeracy teaching approaches as well as exploring their effectiveness in relation to improved student learning outcomes, the project was designed in terms of two components, an action research component and an evaluation of student outcomes component. The first component was undertaken by a team from RMIT University and was led by Associate Professor Dianne Siemon. The second component was undertaken by the Victorian Department of Education and Training on behalf of the sector partners. A Senior Project Officer was appointed by the Department to manage this component and support the work of the project generally.

The action research component involved the research team working with teachers from 16 (research) schools over approximately 18 months as they enacted their action plans and helped identify and describe a range of numeracy teaching approaches. In an effort to better understand the nature and impact of numeracy teaching approaches or communicative acts, the research team collected data on teachers' beliefs and understandings, their perceptions of opportunities and constraints, and their teaching intentions and actions, using a range of task-based activities, surveys and interviews. In addition to this, information was also derived from field notes of classroom observations, from case studies of individual teachers. An important and innovative component of the data collection was an adaptation of the one-way screen technique used in Reading Recovery training, which became known as the Behind-the-screen process, to explore teacher's communicative acts in mathematics.

To evaluate the effectiveness of the proposed numeracy teaching approaches, sample-based student interview data were collected by the Department of Education and Training at the beginning and end of the project from the research schools and a matched set of reference schools. The *Early Years Numeracy Interview* was used for students in Prep - Year 4. The *Success in Numeracy Education Assessment Interview* developed by the Catholic Education Office was used for students in Years 5 to 6.

Major Outcomes and Findings

1. The emergence of a professional language

- Although there was no clear evidence of generic teaching approaches in numeracy, there was considerable evidence to support a relatively small number of discrete interaction patterns or scaffolding practices across different teachers, Year levels, and mathematical topics.

- Twelve scaffolding practices that appear to be associated with effective mathematics teaching have been identified and described by teachers and researchers as a result of the project. The term, "scaffolding practices" is used in this report, following Anghileri (2002), to refer to those practices engaged in by teachers to support student learning that might ultimately be removed when students are able to 'stand alone' in respect of what they have learned. Each of these practices has been clearly exemplified in the Research Report. The twelve identified scaffolding practices which relate most closely to numeracy teaching and learning are:

Excavating *drawing out, digging, uncovering what is known, making it transparent*	Teacher systematically questions to find out what students know or to make the known explicit. Teacher explores children's understanding in a systematic way
Modelling *demonstrating, directing, instructing, showing, telling, funnelling, naming, labelling, explaining*	Teacher shows students what to do and/or how to do it. Teacher instructs, explains, demonstrates, tells, or offers behaviour for imitation.
Collaborating *acting as an accomplice, co-learner/problem-solver, co-conspirator, negotiating*	Teacher works interactively with students in-the-moment on a task to jointly achieve a solution. Teacher contributes ideas, tries things out, responds to suggestions of others, invites comments/opinions in what she/he is doing, accepts critique
Guiding *cueing, prompting, hinting, navigating, shepherding, encouraging, nudging*	Teacher observes, listens, monitors students as they work, asks questions designed to help them see connections, and/or articulate generalisations
Convince Me *seeking explanation, justification, evidence; proving*	Teacher actively seeks evidence, encourages students to be more specific. Teacher may act as if he/she doesn't understand what students are saying, encourages students to explain, to provide/obtain data, …
Noticing *highlighting, pointing to, attention to, drawing , valuing*	Teacher draws students attention to particular feature without telling students what to see/notice (i.e., by careful questioning, rephrasing or gestures), encourages students to question their sensory experience
Focussing *coaching, tutoring, mentoring, flagging, redirecting, revoicing, filtering*	Teacher focuses on a specific gap (i.e., a concept, skill or strategy) that students need to progress. Teacher maintains a joint collective focus and provides an opportunity for students to bridge the gap themselves
Probing *clarifying, monitoring, checking*	Teacher evaluates students understanding using a specific question/task designed to elicit a range of strategies, presses for clarification, identifies possible areas of need
Orienting *setting the scene, contextualising, reminding, alerting, recalling*	Teacher sets the scene, poses a problem, establishes a context, invokes relevant prior knowledge and experience, provides a rationale (not necessarily at the beginning of the lesson, but at the beginning of a new task/idea)
Reflecting/Reviewing *sharing, reflecting, recounting, summarising, capturing, reinforcing, reflecting, rehearsing*	Teacher orchestrates a recount of what was learnt, a sharing of ideas and strategies. This typically occurs during whole class share time at the end of a lesson where learning is made explicit, key strategies are articulated, valued and recorded

Extending *challenging, spring-boarding, linking, connecting*	Teacher sets significant challenge, uses open-ended questions to explore extent of children's understanding, facilitate generalisations, provide a context for further learning
Apprenticing *Inviting peer assistance, peer teaching, peer mentoring*	Teacher provides opportunities for more learned peers to operate in a student-as-teacher capacity, endorses student/student interaction

- The identification and elaboration of a relatively small number of scaffolding practices makes an important contribution 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, including special school settings.

- While the scaffolding practices identified here represent the beginnings of a professional language, it is important to note that this is, and should continue to be, regarded as an emergent language. This means that it needs to be treated as something that will grow and evolve over time as teachers engage with and use this language to better understand their practice. The scaffolding practices cannot be separated from the mathematics content that they communicate.

2. The value of peer observation and review

- The Behind-the-screen process, as adapted and used in the context of the project, is an effective research tool that can be used to codify key aspects of teachers' communicative practice in a way that recognizes teachers' expertise and involves them in the research and development process.

- The Behind-the-screen process as implemented here is a powerful professional learning tool that directly connects to teachers' experience, addresses fundamental aspects of teaching and learning mathematics (that is, teachers' pedagogical content knowledge), and helps build a shared language specific to the teaching of mathematics that can be used and further developed by teachers to gain a deeper understanding of their practice.

- Structured opportunities to reflect on practice, describe and justify one's teaching, observe and be observed by others, and participate in professional learning teams leads to a greater awareness of the processes involved in teaching and learning mathematics and the teacher's role in scaffolding student learning. Ultimately, it also contributes to enhanced teacher knowledge and confidence.

- Having access to a consistent language that moves closer to capturing the processes involved in teaching and learning mathematics stimulates and sustains reflective professional practice, richer staffroom discussions and productive collaborative planning.

3. The importance of knowledge for teaching (knowledge of students, knowledge of students' learning of mathematics, knowledge of mathematics)

- Professional learning that focuses on the key ideas and strategies for helping teachers anticipate likely difficulties and identify and describe student misconceptions in the major areas of mathematics is likely to be beneficial, particularly where this is grounded in open-ended questions and rich tasks.

- While teachers appear to have a relatively well developed capacity to select appropriate tasks, their knowledge of, and/or capacity to identify and describe, the key ideas and strategies for particular mathematics topics and the connections between these need further development. It was also found that though individually this applied, it would appear that a comprehensive body of knowledge exists collectively highlighting the value and importance of team work in identifying what mathematical ideas and strategies will be considered.

- There was a significant shift in what teachers perceived to be associated with effective mathematics teaching during the project. That is, from a predominant focus on activities, although these were still seen to be important, to recognition of the importance of teacher knowledge and the role of classroom culture. This suggests that school wide involvement in projects such as this can be effective in raising teachers' consciousness about key components in the teaching and learning process.

- Praise needs to be specific and warranted for it to be valued by the student. This suggests that in professional learning focussed on classroom communication, attention should also be given to ways in which teachers give feedback to students.

- There was considerable evidence to support the view that deep pedagogical content knowledge in mathematics is needed to act in-the-moment to take advantage of learning opportunities, and to initiate and sustain productive conversations with students (that is scaffolding practices) about mathematics in all settings.

4. The organisation and structure of classroom programs (lesson structure, group selection, planning and leadership)

- While the majority of lessons reported or observed contained a discernable beginning, middle and end phase, there was considerable variation within each.

- Teachers valued peer conversations and were committed to organisations that encouraged students to share their ideas, with a variety of grouping structures used across all phases of the lesson.

- Interruptions to lessons are a major problem. A determined approach is required to maximise mathematics learning opportunities without unnecessary interruption.

- Working in professional teams in which there is an expectation that teachers will talk about their practice, increases collective awareness, prompts richer discussion and greater collaboration, and helps change the culture of schools.

- Strong leadership is needed to elevate individual practice to shared practice and to make 'good' practice an object of inquiry. Effective leaders also play a powerful role in shaping the expectations and facilitating the work of professional learning teams.

5. The role of classroom culture in scaffolding mathematical learning

- The nature and importance of a teacher's relationship with students is a deeply rooted value that can enhance or constrain the operation of classroom events and practices.

- Scaffolding practices are reflexively related to 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.

- A significant number of teachers indicated that they believed the project had contributed to a shift from classrooms where the teacher led and controlled the interactions and direction of the lesson to those where students play an active and valued role in both, by making teachers more aware of their role in scaffolding mathematics learning.

- Teacher beliefs, values and goals play an important role in shaping classroom culture and thereby the roles, expectations and subsequent experience of those who participate in that culture.

6. Student Numeracy Data

- Considered overall, there was similar growth in research school students and reference school students over the time of the project. This result was not unexpected as the collection and analysis of student data was intended to identify trends in student achievement in research and reference schools. Given the relatively short time for the project, it was unlikely that any pronounced differences would occur.

- One encouraging trend was that, for some comparisons, the tail-end of the distribution was shorter for research schools than it was for reference schools. This may be because research school teachers' increased awareness of scaffolding practices encouraged more supportive interactions with the lower performing students.

Suggested actions

1. That the outcomes and findings of this research be disseminated in a manner and form that maximises the likelihood that teachers and schools will critically explore the use of scaffolding practices.

2. That consideration be given to how this emergent professional language can be supported to grow and be shared in ways that maintain some on-going coherence and consistency without rigidity.

3. In implementing some form of Behind-the-screen process, every attempt be made to ensure that key aspects of the process are retained. It should be conducted over an extended period of time, with teachers working with a small group of students

from their own classroom, with no more than 10-12 per group, including a facilitator with recognised expertise appropriate to the task.

4. Consideration be given to a core group of facilitators who understand the language and have a deep understanding of the content and processes involved in teaching and learning mathematics. These facilitators need to develop a reflexive learning culture in which teachers are encouraged to explore the language and practices involved and key observations are highlighted as part of a learning process.

5. That particular attention be given to ways in which information and communication technologies, such as the school's intranet and digital video, can be used to support a form of Behind-the-screen.

6. That careful consideration be given to ways in which teachers can be engaged in more open, reflective practice that builds and sustains a professional learning culture where practice is routinely shared and rigorously examined.

7. Working with scaffolding practices within a reflective community of practice will prompt deeper consideration of what is known collectively and it will also identify learning needs. It is therefore suggested that consideration be given to the most effective ways that a professional learning team can benefit from professional development so that the group as a whole has access to the broadest range of relevant mathematical expertise.

8. A wholistic approach to professional learning be considered to encompass the areas identified by this research, that is, teachers' understanding of scaffolding practices, student learning trajectories (or possible pathways), student misconceptions for the most commonly taught mathematical topics, and the nature and role of classroom communication and culture.

Considerations for further research

1. Further research is required to refine and elaborate the scaffolding practices identified by this project, to tease out the nature of teacher support and student independence in relation to mathematics teaching and learning, and to evaluate the efficacy of these practices over an extended period of time.

2. Further research is required to further investigate the Behind-the-screen process, particularly the role of the facilitator, and its value as a professional development tool and as an ongoing research tool that engages teachers in the process and gives them ownership of the language that is used and developed.

3. Further research is required to explore the specific ways in which access to descriptions and exemplars of scaffolding practices in mathematics teaching impacts the nature of professional conversations and practice.

4. Given the importance of teacher's knowledge for teaching and the growing importance of Professional Standards, further research is needed to build a suitable bank of instruments to assess this knowledge in ways that are valid and reliable.

The Concept Mapping and Analysis of Student Work Samples Tasks represent a good beginning but they could be developed further.

5. While being involved in the project appears to have gone some way towards raising teachers' awareness of the role of classroom culture in scaffolding student learning, further research is required to explore the relationship between scaffolding practices, classroom cultures and pedagogical content knowledge.

6. Recognition that the norms and values implicit within scaffolding practices operate to the advantage of some and the disadvantage of others leads to the need for research into the assumptions involved in the use of these practices to ensure that the learning needs of *all* students are addressed in the most appropriate way.

7. Further research is needed to identify a consistent and coherent Years 5 - 8 framework for mathematics that can be used to develop an interview to track performance over time which builds on the *Early Years Numeracy Interview*.

Conclusion

The major outcome of this research is the identification, description and elaboration of twelve scaffolding practices that appear to be effective in improving student learning outcomes. As a consequence of this work, the notion of a teaching approach was reconceptualised as an orientation to teaching that plans to make use of particular scaffolding practices to achieve a specific purpose related to mathematics learning.

The outcomes and findings clearly suggest that access to a professional language in conjunction with opportunities for sustained, collective reflection on practice powerfully impact teachers' knowledge base for teaching mathematics. While an important prompt for this was the requirement to plan for, implement and reflect on one's communicative acts, it was not until such reflections were shared, and scaffolding practices became the object of inquiry that teacher's pedagogical content knowledge was substantially shifted.

While targeted professional development in key areas can and will make a difference, ultimately, a change in how teachers see themselves and the nature of their work is needed. It is suggested that teaching needs to be seen as a social, not individual practice, that shapes and is shaped by the culture in which it is embedded. As a consequence, attempts to improve teachers' pedagogical content knowledge will need to be multi-faceted, focusing as much on the knowledge and skills of individuals, as the culture of the community in which those knowledge and skills are exercised.

In conclusion, it should be noted that participating in the Behind-the-screen process or being observed by a member of the research team was, for many teachers, a novel and challenging experience. Being asked to complete a number of unfamiliar teacher assessment tasks such as the Teacher Intentions Surveys and the Concept Mapping and Analysis of Student Work Samples Tasks, was also a challenging experience for some. The fact that the vast majority of teachers in research schools chose to participate fully in these processes is a testament to their commitment and professionalism. The team recognises the privilege and is deeply indebted to the teachers that made this work possible.