The Numeracy Research in NSW Primary Schools Project 2001-2003

Joanne Mulligan
Macquarie University, Sydney
<joanne.mulligan@mq.edu.au>

Susan Busatto
NSW Department of Education & Training
<sbusatto@northsydgi-h.schools.nsw.edu.au>

This paper provides an overview of The Numeracy Research in NSW Primary Schools Project. An interview-based *Numeracy Assessment Instrument K-6* and a *Numeracy Achievement Scale* monitored students' numeracy growth using Rasch modelling. Students from Trialling schools demonstrated greater than expected numeracy growth compared with their counterparts in Reference schools. Factors found to be 'making a difference' in numeracy achievement in the 45 Case Study and the 10 Trialling schools highlighted the leadership and support of key group teachers and the principal; consistency and continuity of teaching practices and whole school planning, a focus on the language of mathematics and application of practical resources.

As a national priority, the Australian Government has implemented a Numeracy Research and Development Initiative in support of the National Literacy and Numeracy Plan (1997). Under this initiative the NSW Department of Education and Training, the Catholic Education Commission NSW, and the Association of Independent Schools of NSW participated in a three-year Numeracy Research in NSW Primary Schools Project[1] focussed on two broad research questions:

- what are the educational practices which are 'making a difference' in enabling primary school students to achieve 'outstanding' numeracy learning outcomes?
- to what extent, and in what ways, can such educational practices be successfully applied to other school contexts?

Background to the Study

The project drew upon a substantial body of national and international research literature on effective schools and effective teaching (Owens, 1998; Sammons, Hillman & Mortimore, 1995) such as the importance of strong leadership; high expectations for student achievement on the part of staff; an emphasis on basic skills; an orderly environment; frequent and systematic evaluation of students; increased time on teaching and learning tasks; shared vision and goals; and purposeful teaching.

The reform of curriculum, pedagogy and assessment initiated through the *New Basics Project* (Education Queensland) also influenced the research framework. Central to the conception and implementation of the New Basics project is the inter-relationship between the three elements of teaching and learning: curriculum organisers, productive pedagogies, and rich tasks. In particular the dimensions of productive pedagogy –intellectual quality, connectedness, supportive classroom environment, and recognition of difference are strategies which allow teachers to focus instruction and improve student outcomes. The Australian Government-funded NSW Quality Teaching Project has further developed these dimensions (Ladwig & Gore, 2003).

The NSW project also drew upon the work of Hill and Crevola (1997) who identified key elements that facilitate effective teaching: whole-school design, which included shared beliefs and understandings, monitoring and assessment, classroom teaching strategies,

professional learning teams, school and class organisation, and home/school/community partnerships.

Other international and Australian numeracy projects influenced the project design. Askew, Brown, Rhodes, Wiliam and Johnson (1997) indicated that highly effective teachers believed that almost all students can achieve in numeracy and that class discussion was an important factor in developing the "connections" that students need to assist them to work more efficiently. Further, the five-year Leverhulme Numeracy Research Programme (Brown, 2000), which aimed to develop an understanding of the causes of underachievement in numeracy, highlighted the effectiveness of teaching practice to determine the most successful approaches and to monitor the effectiveness of carefully designed interventions. Australian initiatives such as the Count Me In Too Program (NSW Department of Education & Training, 2001) and the Early Years Numeracy Research Project (Victorian Ministry of Education, 2002) provided a basis for evaluating systematic assessment data on student numeracy, and the effectiveness of professional development programs based on sound research frameworks (Wright & Gould, 2002).

Aims of the Project

This large-scale broadly focussed research project was designed to identify and describe outstanding numeracy programs, policies, processes and strategies that would support numeracy learning for all students (Stephens & Steinle, 2002). This involved the analysis of effective practices in numeracy at 45 Case Study schools and the application of some of these practices in ten Trialling schools aimed at improving their numeracy profile. One measure of this process was the development of a *Numeracy Assessment Instrument (NAI)* and a *Numeracy Achievement Scale (NAS)* designed to monitor student numeracy growth.

Design and Methodology

There were six main phases in the design of essentially a 2-year study incorporating 25 (initial) Case Study schools, 20 (main) Case Study schools, ten Trialling schools and ten Reference schools. Eight of the initial ten Trialling schools were monitored through an additional phase of the project in 2003.

1. Phase 1: 25 Case Study Schools 2001

In 2001 a sample of 25 high-performing schools in numeracy were identified from an analysis of NSW Basic Skills Test data. These schools represented students from diverse socio-economic, language backgrounds other than English (LBOTE), Aboriginal and Torres Strait Islander (ATSI)) and geographic communities (including isolated, metropolitan, rural, small and large schools). The sample comprised 70% Government, 20% Catholic and 10% Independent primary schools. The case studies were conducted by university educational researchers using field-based instruments specifically designed for the purposes of this project. The findings from these case studies provided data about effective teaching and learning practices in numeracy that informed the project in 2002 and 2003.

2. Phase 2: Development of a Numeracy Assessment Instrument (NAI) and a Numeracy Achievement Scale (NAS), 2001-2002

The *NAI* was developed and trialled in 2001 with 2832 students from Grades K-6 in 51 NSW schools. It was constructed with two forms of seven interview-based assessment schedules (Kindergarten to Year 6). Items incorporated critical aspects of Space, Number, Measurement and Data, which reflected the NSW Mathematics K-6 curriculum (Board of Studies NSW, 2000; NSW Department of Education, 1989). The *NAI* was restricted to a limited number of items (between 16 and 25 according to grade level); these were designed to elicit student's conceptual understanding of key mathematical concepts and processes. Students were asked to demonstrate their understanding with materials or by recordings; they were asked to explain their reasons or strategies used for a particular response. Data collection included samples of students' drawn and written solutions. Interviews were conducted by a team of trained officers, the Project Manager and University Researcher.

The Rasch model (Rasch, 1960/1980) was used to create a numeracy scale (*NAS)* that enabled numeracy growth of students to be measured over time. The scale was constructed to locate and map individual student's ability on a scale calibrated with tasks along a continuum showing a level of numeracy attainment measured in logits. Rasch analysis using RUMM established the integrity of items as a measure of numeracy, considering discrimination and item characteristics as well as differential item analysis for each grade. This resulted in 66 of the 242 items being discarded from the preferred set of items for assessment in 2002. Tests of internal reliability for items showed a high level of reliability (0.795); item and person fit statistics indicated that these data fitted the Rasch model. This was corroborated by QUEST analysis (Adams & Khoo, 1996).

3. Phase 3: 20 Case Study Schools, 2002

In 2002, an additional 20 primary schools were selected by representatives from each sector on the basis that these schools had outstanding practices, strategies, policies or programs that were producing outstanding outcomes in students' numeracy. Case studies were conducted by university educational researchers using field-based instruments that were used in the case studies conducted in 2001.

4. Phase 4A: Numeracy Programs in Trialling Schools, 2002 - 2003

The findings from the initial 25 Case Study schools (2001) were used to support the design of intervention programs in ten Trialling schools in 2002. These schools were identified as having school numeracy outcomes at or below the State average (as identified by Basic Skills Test data). Each of these schools selected a *numeracy focus area*, specific to its school context, through the support of Key Group teachers (two classroom teachers and the principal) who participated in a self-directed professional growth program based on a *Professional Journey* model (Alexopoulos & Robinson, 1986). This model incorporated the notion of a 'key group' to bring about change in the school as well as enhancement of teacher pedagogical knowledge in numeracy.

Phase 4B: Monitoring Numeracy Growth, 2002

In order to monitor measures numeracy growth two classes of students, matched by grade level, were assessed from each of the 20 Case Study Schools, ten Trialling Schools

and ten Reference Schools (to enable a comparative measure). This comprised a sample of 1900 students (K to Year 6) assessed through the *NAI* in Term 1 and Term 3, 2002.

5. Phase 5: Numeracy Growth Trialling Schools 2002-2003

The project was extended to 2003 to enable the project in order to determine the extent to which the changes in pedagogical and other practices initiated in the ten Trialling Schools in 2002 were sustained within each school in 2003. Eight of the ten Trialling Schools continued in 2003 where 276 students were reassessed in Term 1 and Term 3.

6. Phase 6: Development of CD ROM of effective practices –Case Study Schools

A CD Rom documenting some examples of effective classroom and school-wide practices from ten Case Study schools was developed in 2003.

Main Findings from the Research

Numeracy growth in Case Study, Trialling, and Reference Schools 2002

It was not expected that large gains in numeracy growth would be made in a short period of time (April–October, 2002). However, substantial numeracy growth (0.76 logits) was shown across all school groups (Case Study Schools, Trialling Schools and Reference Schools); but there were no significant differences found in mean numeracy growth among the three groups (0.75 logits; 0.74 logits; 0.79 logits). There were however, significant differences found in mean numeracy growth at particular year levels; an analysis of variance (MANOVA) between Trialling and Reference groups indicated a grade level effect for numeracy growth (0.000). Trialling School students showed significant numeracy growth at Year 4 and Year 6, and much less than expected growth at Year 5. Ten of the 19 cohorts from Trialling Schools demonstrated greater than expected growth when compared with their counterparts in Reference Schools. Gains in numeracy growth of students from Trialling Schools were much greater than initially anticipated because they had been performing below the state average in numeracy for a number of years. In comparison, Reference Schools were selected because BST data indicated that students were performing at or slightly above the state average.

Even though extensive professional development support was provided to the Trialling Schools in 2002, substantial growth was not seen until 2003. Further, even though teachers within a school implemented the same strategies, improvements in numeracy achievement were not equally demonstrated in the individual classes that were assessed. This was not surprising since a significant amount of time and professional development would be required before strategies can be implemented consistently and effectively by teachers across a school.

Numeracy growth in Trialling Schools: 2002-2003

The mean numeracy growth for 276 matched Trialling School students from 2002 to 2003 was very strong overall (2.10 logits); in 2003 it was greater than expected (0.83 logits), and larger than the mean numeracy growth for the same students in 2002 (0.77 logits). Although Case Study Schools and Reference Schools did not participate in 2003, the numeracy growth of the Trialling School students was higher than the mean growth (0.76 logits) shown by all school groups (Case study, Reference, and Trialling Schools).

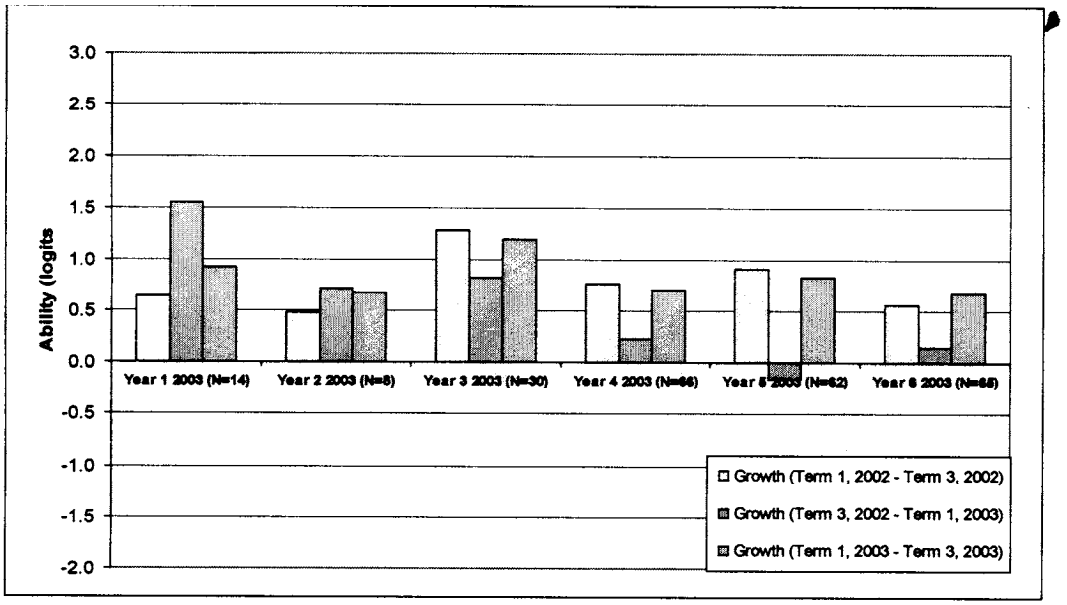

Figure 1. Mean growth (Trialling Schools) by cohort by assessment point.

Figure 1 shows mean numeracy growth of Trialling School students from 2002 to 2003 highlighting variations in growth between Term 3, 2002 and Term 1 2003. In 2003 students showed more growth at Year 3, Year 4, Year 5 and Year 6 than their counterparts in Reference Schools in 2002. The Year 3 cohort showed the greatest growth in the Term 1 to Term 3, 2003 period, and the largest growth by cohort over the entire 18-month period. Further analysis showed that numeracy growth for Year 3 boys in the 2003 sample was much higher than for boys and girls overall. This growth was much greater than the mean growth for all Trialling School boys in 2002.

School by school analysis indicated that in three of the eight Trialling Schools, numeracy growth of students exceeded that of comparable groups in both Reference Schools and Case Study Schools as measured in 2002. In two other Trialling Schools, numeracy growth of students exceeded that of comparable groups in Reference Schools.

Identification and description of factors that were 'making the difference'

The main factors which were found to be 'making the difference' were analysed within three contexts: Within the classroom; Throughout the school; and Beyond the school. This enabled Trialling schools to identify key strategies and adapt them for their local contexts, particularly in 2003.

- the use of hands-on materials to support development of numeracy concepts;
- small group work to encourage discussion and exploration of ideas;
- use of open-ended questions by both teachers and learners to establish, consolidate, extend, reinforce and reflect on concepts, skills and applications;
- discussion during lessons to enable students to engage with and understand new and established mathematical concepts;
- catering for individual needs of students through consistent and varied assessment; differentiated teaching and learning; opportunities for interaction with the teacher, the support teacher or peers;
- collaborative planning amongst teachers which provided opportunities for innovative teaching, and

- whole school commitment to numeracy with all teachers implementing policies and programs consistently in all classrooms with leadership of the principal.

Applying the strategies to other school contexts: The Trialling Schools

Trialling schools which demonstrated greater than expected growth in numeracy achievement over the 18-month period focused on either the language of mathematics, or the engagement of practical resources to support concept development in numeracy. This seems to suggest that the amount and clarity of discussion between students and teachers, and between students themselves, as well as the carefully planned use of resources are effective in improving numeracy learning.

Schools indicated that a Key Group, which was supported by the school principal, was crucial in driving the project and in supporting the ongoing change required at the school level. Long-term commitment was ensured when the professional judgments, input, experience and expertise of those involved were respected, and when the process was collaborative and positive, with outcomes that were achievable and clear. This highlights the importance of professional development across the school in order to provide consistency of teaching and learning as students move from one class to another. Continuity of teaching styles appeared to sustain and improve numeracy achievement. This continuity also allowed teachers to see that their students' attitudes towards numeracy improved, and an increased confidence was evidenced in their ability to handle mathematical concepts over the course of the two years.

Discussion

While numeracy strategies previously found to be 'making a difference' were successfully implemented to some extent in each of the ten Trialling Schools, one of the key findings of the project was the importance of each school 'owning' its numeracy plan. This required Trialling Schools to bring knowledge of their own circumstances, opportunities and constraints to what they had decided to do; and to support those directions from within their own resources and structures in their *professional journey*.

Whole school approaches were essential to ensure that all teachers had a voice in determining how successful a *professional journey* had been individually and for the staff collectively. These efforts were enhanced, for example, when teachers worked with each other to produce a resource or went out of their way to provide specific assistance to new or inexperienced teachers in the school. Teachers often saw these approaches as "working smarter not harder".

Another clear benefit of this project was to lift the profile of mathematics teaching and learning in schools, to draw attention to instances of quality teaching, and to provide for effective use of resources. In the Trialling Schools, genuine change required sustained effort and time. In several Trialling Schools, it took a second year for substantial improvements in students' numeracy to emerge more clearly. Leadership from the principal and/or the local Key Group proved that the whole school was serious about supporting all stages of the *professional journey*. Where one of the goals was to change students' attitudes towards mathematics or to improve students' capacity to express themselves mathematically, students as well as teachers were involved in monitoring this.

Limitations of the Research

The very parameters of the project precluded any substantive longitudinal design – it was established initially as a two-year project and extended for monitoring of the Trialling Schools. There was limited time (seven months) to implement the selective strategies in the ten Trialling School sites in 2002 although there was significant improvement in student numeracy growth at some year levels. The monitoring of Trialling School students was limited to a matched sample of 276 students; numeracy growth in 2003 was compared with counterparts in Case Study Schools and Reference Schools from 2002.

Development of assessment instruments that measure student achievement across a wide range of abilities and ages have limitations: the *NAI* did not significantly challenge a small minority of extremely capable students; it was developed to report numeracy achievement in general terms for all students from Kindergarten to Year 6. It was not possible to report achievement for each of the strands (Number, Space, Measurement 7 Data) for a given cohort within one year level. This was because there were a limited number of items from each strand that could be administered within the limits of the *NAS*.

The sample of 20 Case Study Schools participating in 2002 was identified by representatives from each sector as having outstanding numeracy practices in place. Unlike the 25 schools identified in 2001, these 20 Case Study Schools were not identified primarily on the basis of student achievement data. The numeracy achievement of these students was found to be similar to that of students from Trialling Schools and Reference Schools. Thus, the perception that Case Study Schools had "an outstanding program" was not supported by student achievement data in the project. Further, the 45 Case Study schools constituted only a small sample of those schools in NSW that were 'making a difference' in achieving outstanding numeracy outcomes.

The nature of the research process and dynamic school contexts meant that only a sample of the strategies identified as being outstanding could be adapted, implemented and monitored at the ten Trialling Schools. While the focus on the particular strategies being implemented at each Trialling School was maintained, it was not possible to exclude the impact of other factors in achieving project outcomes, such as the influence of individual 'quality' teachers and their pedagogical and content knowledge.

Conclusions and Implications

One significant research implication of this project would be to establish a five-year longitudinal study using student and teacher identifiers to examine the extent to which such improved numeracy outcomes can be sustained and enhanced over a longer period.

The *NAI* was developed as a unique numeracy construct based on student interview data and this supports and extends the use of other instruments; it was designed within the context of the NSW mathematics K-6 curriculum. Further research may ascertain the extent to which the *NAI* can be adapted to the mathematics K-6 curriculum for other Australian States and Territories – this would involve among other things, the trialling of additional items, and the inclusion of those new items proved to be valid in the *NAS*. Further research could determine the extent to which the findings drawn from this sample of schools could be generalised across educational systems and specific school types within and across Australia.

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